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# Convergence of sciences: the management of agricultural research for small-scale farmers in Benin and Ghana

**D. Hounkonnou[1], D.K. Kossou[2], T.W. Kuyper[3], C. Leeuwis[4], P. Richards[5], N.G. Röling[4,*], O. Sakyi-Dawson[6] and A. Van Huis[7]**

[1] Connecting Development Partners (CDP) International, Cotonou, Benin
[2] Faculty of Agricultural Sciences, University of Abomey-Calavi, Cotonou, Benin
[3] Soil Quality Group, Wageningen University, Wageningen, The Netherlands
[4] Communication and Innovation Studies Group, Wageningen University, Wageningen, The Netherlands
[5] Technology and Agrarian Development Group, Wageningen University, Wageningen, The Netherlands
[6] Department of Agricultural Extension, Faculty of Agriculture, University of Ghana, Legon, Ghana
[7] Laboratory of Entomology, Wageningen University, Wageningen, The Netherlands
* Corresponding author (e-mail: n.roling@inter.nl.net)

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## Abstract

The Convergence of Sciences programme (CoS) addresses the sub-optimal impact of science on the livelihoods of resource-poor farmers in West Africa, particularly in Benin and Ghana where it operates. CoS aims to develop insights into the *pathways* through which investment in science and technology can improve rural lives. To this end, CoS features participatory experimental and action research by eight PhD students, who each develop technologies and institutional arrangements with groups of farmers. The ninth PhD student carries out comparative 'research on agricultural research'. The current article deals with a higher aggregation level than the individual project: the management of the programme as a whole. How did CoS try to zero in on the small windows of opportunity West African farmers face? How did it manage the ensuing issues of trans-disciplinarity, and of interaction among students, (social and natural science) supervisors, and other key stakeholders? How does it face up to the issues that arise with respect to scaling up? One of the most interesting aspects of CoS is that it not only deals with technical innovation *within* the constraining institutional and policy framework conditions, but also experiments with incipient ideas about how to *stretch* them.

*Additional keywords*: democratization of science, pathways of science, social space for learning, pre-analytical choices, research on research

## Introduction

The article addresses the conditions that need to be created at the management level if research programmes are to make design choices that ensure relevance for small-scale farmers, and that adhere to such criteria as inclusiveness, participation, and democratization of science. The article focuses on West Africa as a context for agricultural research that makes special demands on the practice of agricultural science, and analyses the first two years of the Wageningen University Interdisciplinary Research and Education Fund (INREF) research programme entitled 'Convergence of Sciences: inclusive innovation technology processes for integrated soil and crop management' (CoS) that operates in Benin, Ghana and the Netherlands.

CoS takes off from the observation that West African farmers derive sub-optimal benefit from formal agricultural science. One important reason emphasized in the CoS proposal that was inspired by such publications such as Chambers & Jiggins (1987a, b), is the conventional, often tacit, linear perspective on science. Scientists discover or reveal objectively true knowledge, applied scientists transform it into the best technical means to increase productivity and resource efficiency, extension delivers these technical means to the 'ultimate users'; and the farmers adopt and diffuse the 'innovations'. Judged against the assumed goal of productivity, African agriculture is called 'stagnant' (Anon., 2004), notwithstanding the dynamism and innovation that are observed by anyone who looks at it carefully (Hounkonnou, 2001). In other words, formal agricultural research and African farmers fail to meet, and investing more money in agricultural research without exploring the ways by which the interface between farmers and research can be improved only promises more-of-the-same and continued lack of impact. This article attempts to address *the management of the alternative pathways* that enable science to help improve the livelihoods of small-scale West African farmers.

This focus is highly salient. The Consultative Group on International Agricultural Research (CGIAR), universities, national research organizations and governments that seek to develop alternatives to the linear model of research planning, design and implementation, need to think through the implications for management of embracing more participatory and interactive approaches (Chema *et al.*, 2003). The recent IAC Report (Anon., 2004), the reports of the UN Millennium Project (Anon., 2005a) and of the Commission for Africa (Anon., 2005b) have called for greater investment in agricultural research for poverty alleviation, especially in Africa. But the pathways by which agricultural science is expected to make a contribution are left implicit.

CoS works on the principle that innovation is the emergent property of the interaction among different stakeholders in agricultural development. Depending on the situation, stakeholders can be village women engaged in a local experiment, but they can also comprise researchers, farmers, (agri)businessmen and local government agents. The configuration of stakeholders that interacts in a 'theatre of innovation' (Engel & Salomon, 1997) is not given and depends on the situation. In fact, efforts to enhance agricultural development must identify and build promising configurations of actors that can gel into theatres of innovation.

In CoS, eight PhD students engage in experiments with farmers on integrated pest

and weed management, soil quality, or crop diversity. They focus on both experimental content and the design of agricultural research for development relevance. The ninth PhD student carries out comparative 'research on research' in order to formulate an interactive framework for agricultural science. However, the present article aims at another scale level than that of the individual student projects. It deals with the CoS programme as a whole so as to analyse its first two years focusing on the *management of the co-creation process* by which the programme is learning its way forward.

At the time of writing, CoS still has about 2 years to go. So a final verdict cannot be given. For this reason, the article focuses on a number of highlights that seem useful for research management, with special reference to the priority that is currently being given to making agricultural research work for reaching the Millennium Development Goals (UN Millennium Project, 2005). In doing so, the article departs from the assumption that current emphasis on heavy funding of science and technology as a route to African 'Enlightenment' [the word used in a special report on 'Reinventing Africa': 'Foundations for a Prosperous Future' in *New Scientist* (2 July, 2005: 8, Vol. 187/2506)] lacks a sound consideration of the pathways by which science and technology (S&T) are supposed to impact poverty in Africa. The grand technologies that are proposed (e.g., in Anon., 2004) offer little insight into how they can fit the very small windows of opportunity that African small-holders actually have.

## Designing the interface between the Convergence of Sciences programme and small-scale African farmers

### Assumed conditions under which CoS must make an impact

In order to effectively engage small farmers, research managers must invest in understanding the context within which research can make a contribution. Farmers are free to say 'no' to any research output. In that sense, it can do no harm to consider farmers as consumers and a research programme as a firm intent on selling its wares. Scientists who assume that they are the experts to whom farmers must listen will simply fail, a scenario that is enacted across Africa many times every year. An example is the impasse with respect to soil fertility. Formal research insists on the use of certain green manures (even when their use forces farmers to forego one or more other crops, as with *Mucuna*) and mineral fertilizers (even when farmers cannot afford to) as the only way out. Farmers persistently refuse to apply them or to continue to use them when the artificial conditions surrounding their introduction have disappeared.

CoS makes the following assumptions about the context in which it must make an impact:

1. Very small windows of opportunity for most farmers. These windows require deliberate attention to making pre-analytical choices about the design of the research;
2. A strong local innovative dynamic among small farmers keen to improve their conditions (except where repeated frustration has led to ritualism or fatalism);
3. A large store of indigenous experimental results, i.e., a large potential for capturing farmers' best practices;

4. Very high pressure on natural resources and ecological services (land, soil fertility, water, (agro-)biodiversity), leading to non-sustainable land use;
5. Very limited and heavily contested markets for selling surplus. Most others are also farmers and the small but growing urban demand increasingly is usurped by imports;
6. Virtual absence of farmer political clout;
7. Governments and most other actors preying on farmers for revenue;
8. A virtually total lack of institutional and policy support for agriculture.

Two examples from the CoS experience suffice. US rice farmers are subsidized for up to 70% of their production costs (Velthuis, 2005). Ghana is one of the countries where the cheap rice is dumped and its commercial rice production has virtually stopped. A Ghanaian minister of agriculture who protested was transferred; the political establishment benefits from the low food prices in urban areas where the important electorate is. Meanwhile, imported rice is rapidly becoming a preferred food that substitutes home-grown foods. Farm development is pre-empted and Ghana's farmers are disqualified from contributing to global food security.

In Benin, cotton has been a major cash crop for years. For many farmers it not only is their main source of a monetary income but also the only way they can access fertilizers for their maize. The cotton industry is in turmoil. The EC and the US dump subsidized cotton on the world market, which reduces cotton prices in Benin directly (Anon., 2003). The onslaught of cheap Chinese cotton has severely affected the industry. Benin has to do everything to improve its competitive position on the world market. But what happens in practice? The enforced privatization of the cotton industry seems hardly to have reduced the number of officials, ginners, pesticide salesmen and extension people that 'eat' from cotton. Recently, the pesticide companies in Benin have refused to make available the pesticides required for a new and effective system of crop protection that would reduce farmers' pesticide costs by half, on the grounds that it would undercut their profits.

These examples make clear that technical research that focuses on producing innovations to enhance agricultural productivity can only play a role that is necessary but not sufficient. But that was not so clear when CoS began.

The observations on the West African context are not new (e.g. Janvry & Dithier, 1985; Jiggins *et al.*, 1996; Fabré & Kleene, 2004). What is perhaps interesting is CoS' struggle to take the context into account. One issue that we shall come back to is whether an agricultural research programme can actually improve the context, or whether it has to accept to work within it and try to add the collective intelligence of millions of small farmers who have to live by the results.

## Co-ordination mechanisms and the pathways of science

The mechanisms for co-ordinating human behaviour (e.g. Powell, 1994) are widely agreed to comprise hierarchy, market and a third one that is variably described as networking, co-construction of knowledge, or social learning. Each co-ordination mechanism suggests pathways by which agricultural science can be expected to be effective in society.

### *Hierarchy*

Scientific results are translated into (price) policies, regulations, or concrete measures such as investment in irrigation schemes (Cochrane, 1958; Röling, 2002). The mechanism is based on centralized power and control that can make things happen. Scientists seek to influence that power. This type of scientific impact assumes an effective government and an ability to implement laws and regulations. In West Africa these conditions are only beginning to emerge. Yet the impact of policy should not be under-estimated. The examples of rice in Ghana and cotton in Benin given above show this very clearly. With some exceptions, such as the recent measures in Ghana to improve prices for cocoa farmers, policy in West Africa has generally worked to the detriment of farm development. Assuming that agricultural research can be effective through policy impact has led to disappointment, as has been experienced by the Wageningen model builders time and again (H. Breman, personal communication).

### *Market 1*

Scientific results are translated into products or patents (e.g. genetically modified organisms, pesticides). For this approach to work organizations must be able to provide affordable access to the products and institutions must be in place to prevent adultery of products, substitution and the like. Neither of these conditions is being met in most West African countries.

### *Market 2*

The best-known pathway of agricultural research impact is the 'agricultural treadmill' (Cochrane, 1958; Röling, 2002). Farmers are price takers. Extension services and other 'delivery mechanisms' feed scientific results into the store of agricultural practices that allow farmers to be competitive on the market. Technologies that allow farmers to be more efficient are adopted by progressive farmers and diffuse in farmer communities (Rogers, 1995). This process drives down farm prices, which in turn propels diffusion and, eventually, forces 'laggards' to leave farming; their resources are taken up by the progressive farmers. This process assumes that large numbers of farmers in similar circumstances produce the same commodities for a single market, and that effective delivery mechanisms are in place [i.e., the conditions in the Midwestern US where diffusion was observed for the first time in 1943 (Ryan & Gross, 1943)]. By and large these conditions do not exist in West Africa. Extension services have been abolished and the diversity of African farming systems prevents the emergence of homogeneous recommendation domains for which the uniform technologies and multiplier effects can be produced that give investment in agricultural research a high internal rate of return (Evenson *et al.*, 1943). Hence the treadmill does not operate in West Africa except perhaps for some specific sectors. Meanwhile, West African farmers bear the brunt of the global treadmill because they have to compete with farmers in countries that have benefited from years of public investment in reducing production costs (Bairoch, 1997).

### *Market 3*

A related market mechanism is induced innovation (Hayami & Ruttan, 1971). Farmers

perceive changes in relative factor prices and see a chance to improve their incomes. Science impacts this process, e.g. through advances in mechanization, more efficient fertilizer production, or new varieties. In West Africa, many examples can be found of science impact on crop varieties used by farmers. But spontaneously induced innovation is more spectacular. An example is the rapid and autonomous diffusion of cassava throughout West Africa during the last century in response to increasing land pressure and other factors. The highly dynamic and innovative, though not necessarily sustainable nature of West African farming can largely be explained through such spontaneously induced innovation. Farmers try to adapt their farming systems to the exhaustion of soil organic matter and reduced water-holding capacity as soils become overused, they develop technologies to deal with the emergence of weeds when fallow periods decrease (Vissoh *et al.*, 2004), they migrate to Nigeria because farm prices are better there.

The conclusion from the analysis of the first two co-ordination mechanisms must be that the main pathways through which agricultural research is usually seen to have its beneficial effect do not operate at all or only defectively in West Africa. *There simply is no agreed approach to make agricultural science work effectively for small-scale farmers in West Africa.* That is the challenge CoS sought to tackle.

## Emergent CoS strategy: the third co-ordination mechanism

CoS has focused on the third co-ordination mechanism, co-construction of knowledge, networking and social learning in nested platforms of stakeholders at multiple scales in support of cognitive convergence and concerted action (Röling, 2002; Jiggins, 2005). In this it taps the rich traditions of farming systems research (e.g. Collinson, 2000), participatory approaches (e.g. Reijntjes *et al.*, 1992), farmer field schools (e.g. Röling & Van De Fliert, 1998), and other forms of 'interactive agricultural science' (Röling, 1996). In this sense, what CoS attempts is not new at all. What is perhaps new is the effort to systematically address the lessons from these traditions at a research programme level and to draw implications for management.

CoS embraces the third co-ordination mechanism by assuming that innovation is the emergent property of a soft system, i.e., of a human activity system that features multiple stakeholders in a 'theatre of innovation' whose initially divergent perspectives, knowledge and purposes begin to converge as a result of conflict, shared learning and active co-construction of knowledge, so as to allow collective or distributed agency and concerted action. Note that CoS does not assume that the third co-ordination mechanism *replaces* the other two. It rather takes as its point of departure that the third co-ordination mechanism has been neglected and needs to be developed in order to create an optimal *'mix'* of co-ordination mechanisms. Research by Sherwood (e.g. 2004) in Latin America has clearly demonstrated that successful alternatives at the farmer field school or village level are not sufficient to ensure change. Lack of policy and institutional support at higher levels, or active corruption can destroy the effect of successful 'bottom-up' activities. Market and policy provide framework conditions within which the third co-ordination mechanism can be used to its advantage. Perhaps, and intriguingly, the third mechanism (sometimes) can be used to

change the framework conditions. When CoS started we had little idea of how to go about building a programme based on these ideas. We could, of course, as said, draw on the rich international experience with participatory approaches such as Participatory Rural Appraisal, Participatory Learning and Action, Participatory Technology Development, farmer research groups, and farmer field schools, at the farm and village level.

In these approaches, farmers are key stakeholders in the outcomes of science who must actively participate in generating these outcomes, be it by identifying the problems that require research, by specifying the context, by helping to determine 'what works' in that context, and, more often than not, by generating the original breakthroughs that allow science to move on. A typical example is the hybridization of *Oryza sativa* and *Oryza glaberrima* in the fields of Sierra Leonean farmers at a time when official science still believed that to be impossible (Jusu, 1999). The Africa Rice Center (WARDA) has used that break-through to develop New Rice for Africa (NERICA).

## Zooming in on small windows of opportunity

### Pre-analytical choices

In designing its research process, CoS explicitly tried to pay attention to pre-analytical choices (Nederlof *et al.*, 2004; Röling *et al.*, 2004). Pre-analytical choices can compromise the ability of research to take into account the context and needs of farmers. Paying explicit attention to them can be seen as an important condition for zooming in on small windows of opportunity. Giampietro (2003; Röling *et al.*, 2004) defines pre-analytical choice as the 'choice of relevant goals, variables, and explanatory dynamics for the selection of an explanatory model'. We suggest to call pre-analytical all those choices that are made before serious (participatory) technology development starts and thus would include most of the choices normally made in a research proposal. An example is Mandelbrot's claim that it is not possible to define the length of the coastline of Britain without first defining the scale of the map that is to be used for the calculation. The more detailed the map, the longer will be the same segment of coast. In other words, the pre-analytical choice of the scale will have a major impact on the outcome of the study. Yet the choice of scale is arbitrary. This means that stakeholders' intent on knowing the length of Britain's coastline must agree on the meaning of the concept 'length of coast line' and on the scale of the map they will use. Non-equivalent perceptions need to be negotiated because 'different observers can make different pre-analytical choices about how they define 'a segment of coast', which will make them work with different identities for the system to be investigated' (Giampietro, 2003). De Janvry & Dethier (1985) speak of '*ex-ante analysis and participatory research*': "It is evident that very little information and analysis goes into the definition of research priorities. The result is that the socially more vocal and powerful sectors unduly dominate the course of technological change. Needed to counteract this tendency is a greater collaboration between natural and social scientists, and a greater

participation of research beneficiaries (and affected sectors) in the definition of research priorities".

Making pre-analytical choices is a necessary aspect of all research. There is no way researchers can avoid them. One has to ask for funds on the basis of proposals that are not informed by deep understanding of the situation in which, and the beneficiaries for whom, one will carry out the research. Researchers choose a specialization according to their interests, talents and opportunities. The choices made by a research institute are determined by its mandate and its donors. Hence a considerable number of unavoidable choices is made before the research really starts.

Such choices *ex ante* reduce one's degrees of freedom to determine research priorities, objectives, problem, scale, variables and beneficiaries. They draw attention to the need to make explicit especially the *irrevocable* choices. For example, agricultural research projects usually assume as a matter of course that the objective of research is to increase the productivity of a given crop. But many West African farmers face conditions under which increasing productivity is irrational from an economic point of view because they cannot sell a surplus. In all, it is imperative to negotiate the pre-analytical choices with the intended beneficiaries of the research and other stakeholders, especially when windows of opportunity are small. It is of interest to analyse how CoS managed this process.

## Pre-analytic choices before CoS started

CoS is a large programme that includes many disciplines but leaves out significant other ones (such as animal husbandry and economics), that works in an area where farmers have little clout, and that is science-driven if only because of its nine PhD researchers devoted to their doctorates. Such conditions can be expected to motivate the kind of choices that do not foster the inclusiveness, client orientation, pro-poor participatory technology development and so on, that are CoS' *raison d'être*. It behoves us to examine in detail what choices we made before our CoS fieldwork had started.

These choices included:

1. Science (done differently) matters for African farmers;
2. This science needs to include both social and natural science;
3. This science needs to include both 'southern ' and 'northern' scientists;
4. Each individual investigation needs both the social and natural sciences;
5. Problems that have often been mentioned with respect to farming in Africa are genuine problems (weeds, pests, soil fertility, etc.);
6. Pest problems can be tackled by entomologists (and therefore virologists are not included in the project); soil fertility problems by soil biologists (and therefore soil chemists or inorganic-fertilizer scientists are not involved), and social issues by anthropologists and communication and innovation scientists (and therefore economics and developmental sociologists are not involved);
7. It is possible to understand local problems by taking a local view (the *a priori* choice to leave out political science);
8. Farmers are considered as a homogeneous group with regard to issues such as migration and land tenure;

9. An individual scientist with a background in one domain and some knowledge in the other, supported by scientists from north and south and from social and natural sciences, can usefully tackle the issue under investigation;
10. Problems in the domain of the social sciences are social also in the sense that their solution depends on collective learning and experimentation.

To this list we can add the choices made with respect to crops and related domains (Table 1) that were negotiated among CoS partners *before* any fieldwork was done. (Later on, partly as a result of the technography, work on maize and cassava was included particularly in relation to soil fertility. In Benin, genetic diversity management in yam was included.)

An evaluation of these choices will have to wait until the end of 2006 when CoS will be completed. Now we only can draw a few conclusions. Farmers who actively participate in the CoS individual research projects have an overriding motivation to improve their lives. Although they were keen to participate in experimental projects, they often harboured mixed feelings towards such projects and confess to be 'tired of learning' because constraining external conditions, especially with respect to markets, are not addressed. Thus the implicit choice for agronomic field experiments, even if social science issues are also addressed, implies that we initially opted to help farmers adapt to the small windows of opportunity without doing anything to enlarge them. Efforts to affect the constraining conditions themselves took on increasing importance as CoS evolved. We shall come back to this issue later. A second point, in hindsight, is that a programme such as CoS should start with a formulation phase during which stakeholders and others are consulted so that pre-analytical choice making can systematically be addressed.

## COS procedures for creating an effective interface with farmer realities

CoS included research phases that allowed making important choices before the eight experimental studies started and before the students' research proposals had been

Table 1. The Convergence of Sciences programme. Choices of crops, agro-ecological zones (AEZ) and research topics in Benin and Ghana. (Adapted after Röling *et al.*, 2004)

| Type of crop | Benin | | | Ghana | | |
|---|---|---|---|---|---|---|
| | Crop | AEZ | Topic | Crop | AEZ | Topic |
| Orphan, traditional or grassroot crops | Sorghum, yam | Savannah zone | Plant genetic diversity, weeds | Sorghum | Savannah zone | Plant genetic diversity |
| Private interest crops | Cowpea, cassava | Transition zone | Plant genetic diversity, weeds Soil fertility | Cowpea, cassava | Transition zone | Soil fertility Plant genetic diversity |
| Cash or public crops | Cotton | Savannah zone | Integrated pest management | Cocoa | Forest zone | Integrated pest management |

hewn in stone. The experimental work itself included farmers as key experimenters, and regular consultation with rural communities and other stakeholders, so as to ensure that technologies were appropriate to the conditions and needs of farmers.

CoS used two approaches to making explicit pre-analytic choices: technographic and diagnostic studies. We shall not discuss these in great detail here since they are the subject of another NJAS special issue (Röling *et al.*, 2004).

The *technographic studies* were done at the prompting of Richards (2001). The efforts to carry out technographies in CoS have since led to further development of this approach. The CoS technographies explored the innovation landscape for the six major crops that the CoS consortium had chosen (Table 1) and were carried out by mixed teams of Beninese and Ghanaian PhD supervisors. The studies looked at the technological histories, markets, institutions, framework conditions, configurations of stakeholders, and contextual factors at a higher scale level than the diagnostic studies.

The technographies had a few important outcomes. Farmers, both in Benin and Ghana, were observed to use cassava as a major strategy for restoring soil fertility, an idea that some scientists would consider surprising. As a result, the two soil fertility studies have included cassava in the experiments. Although it is not the place here to dwell on agronomic research in CoS, the cassava example demonstrates myopia in soil fertility scientists. Because cassava is seen as the last plant that can grow on depleted soils before fallowing, it has been assumed to be responsible for the depletion. Meanwhile, soil scientists have often not seen the inter-connections between cropping strategies and soil fertility strategies (extensive cassava cropping or *jachère de manioc* in French is as much a cropping and land use strategy as a strategy to restore soil fertility), and the possible roles of soil organisms (there could be a carry over effect of Mycorrhizal fungi on subsequent maize production).

In fact, the inclusion of soil fertility as a subject was itself based on the conclusion of the technographic studies that soil fertility was a domain for which innovations were required. Also as a result of the technographic studies, weed management was justified as a focus of research in Benin. As it turned out, both the technographies and the diagnostic studies justified many of the pre-analytic choices made earlier.

But the technographies also left something to be desired. It turned out to be quite difficult to really look at the innovation landscape at a macro level with an unprejudiced eye. In the case of cocoa, for example, the options for innovation identified closely resembled those that one of the authors of this article remembers from writing an extension handbook in Nigeria in 1966. The focus on crops pre-empted some of the more exciting avenues that Richards had in mind when he suggested the technography as a starting point for CoS, such as looking at local marketing networks, urban food systems, and other ways of identifying promising theatres of innovation. Also, the CoS emphasis on innovation proved to lead to quite a narrow focus on technical issues instead of also on institutional and organizational ones. From the CoS experience it is clear that much more training, guidance and experimentation are required at the beginning of a technography effort than could be provided in CoS. Also, the technography should be included in the formulation phase when the research is negotiated with the stakeholders.

Each of the eight PhD students carried out a *diagnostic study* (DS) as a compulsory

part of their research project before the start of the experimental work. Previous experiences and research traditions had an important influence on the nature of the diagnostic studies. In Benin, CoS can be seen as a sequel to a successful research project featuring integrated pest management farmer field schools in cowpea (*Vigna unguiculata*). To a considerable extent, the people involved in CoS are the same as the members of this previous project. The earlier project had an important implication for the way the diagnostic studies in Benin were carried out. Unlike in Ghana, where the researchers quickly zoomed in on a few specific villages and groups of farmers with whom they negotiated the experimental work, in Benin, each of the students first did an 'exploration' involving many villages and areas, only later to engage in an 'in-depth' diagnosis together with local people in a few villages. At first, the term 'diagnostic study' was used in Benin only for the 'exploration'. This led to some confusion before we had discovered that we were dealing with different practices (Nederlof *et al.*, 2004). Nevertheless, the DS proved important for the students. They specified, verified or elaborated their research problems, identified a farmer experimental research group that would be the partner in their research, established protocols for research with the farmers, and, in a number of cases, explored the links between this research group and the rural community. Furthermore, the diagnostic phase allowed the students to identify other stakeholders who needed to be involved in the research.

On the whole, the DS proved to be an important mechanism for interaction and solidarity with CoS and contributed to the sense of achievement among its members, both students and supervisors. The main reason was the publication of the DS in a special issue of NJAS (Röling *et al.*, 2004). The supervisors were co-authors of the articles. The whole process of drafting, re-writing, discussing and rounding off this special issue, and the success it proved to be in the end, had an important impact on the CoS team. In hindsight, the special issue proved to be an important management tool.

## The role of the diagnostic study in the total research challenge

Tekelenburg (2002) suggests that a research programme must answer *all* of the following fundamental questions if it is to achieve 'development' outcomes:

1. *What are the useful abiotic and biotic relationships that can be constructed*? This question requires fundamental research, for example, for understanding the life cycle of a new pest.
2. *What can technically make a difference*? This question requires applied experimentation and conventional agricultural research, grounded in international science. What pheromones can be used to lure insect pests into traps? What natural enemies can be used to control the pest? The general question is: what are the best available technical means for given (i.e., assumed) human problems? Most agricultural research falls into this category.
3. *What can work in the context*? Answering this question requires an analysis of the context in which small farmers live. This is usually achieved by paying attention to the agro-ecological zone. But equally important is the analysis of the market, input provision, transport availability, and risk of theft. It is, for example, no use to carry

out research on maize productivity in Kenya if maize can be imported 20% cheaper than it can be produced with the best local technology (C. Ndiritu, personal communication). Meanwhile subsistence farmers still need to cope with *Striga* in maize. We suggest that this question is best answered by a technography.

4. *What can work in the farming system*? Here farmers' labour availability, gender differences, knowledge, access to land and other resources, land tenure and market opportunities determine the range of appropriate options that fit the local system. At this point, one has to leave a disciplinary or sectoral perspective altogether and focus on how the outcomes of the research fit into the local system. Will it work within that system? It is the fundamental question of the farming systems approach and for diagnostic studies.
5. *What will be acceptable*? What systems do farmers want and need, given their explicit enthusiasms, alternatives, cultural inclinations, experience, livelihood strategies and superior insight into local conditions and constraints? To answer this question, and avoid invoking farmers' veto power, one has to leave behind any pretence that the scientist alone can determine what is best. The question cannot be answered without engaging farmers as co-researchers and without empowering them to have clout over the research process.
6. *How can the outcomes be scaled up*? Most research projects can be considered expensive, small-scale, pilot efforts that become socially effective only if the experiments are replicated at a societal scale, for example in factories or at markets. Scaling up is not only a question of doing more of the same, i.e., through the diffusion of a given technology among farmers, but especially a question of change in institutional relationships in marketing chains, consumption patterns, education, government budgets, etc. Most successful pilot projects in Africa that artificially create conducive framework conditions collapse as soon as the special conditions are removed. We shall come back to this issue later. In CoS it was a bit of an afterthought, in hindsight replicability should be ensured already in the formulation phase.

## Have the diagnostic studies increased CoS relevance?

At this point, we can only point to the tentative conclusions of a comparative study of the eight DS (Nederlof *et al.*, 2004).

1. The DS have established communities of practice of farmers, researchers and other stakeholders, including academic supervisors, scientists from national research institutes, local administrators and local chiefs, who are engaged in learning from a concrete experimental activity. The outcome of research will emerge from the interaction within this community and is not the end-of-pipe product of a linear science-driven process.
2. The DS have given farmers a say in the design and conduct of agricultural research. This has allowed them to bend its outcomes in the direction of producing innovations that work in their circumstances and that satisfy their needs and priorities. The DS have, therefore, led to negotiations with farmers about the type of research to be conducted.
3. The DS have led to deliberate choices with respect to the selection of sites, farmers

and, in a number of cases, to the inclusion of additional experiments than envisioned at first, in one case even to a complete revision of the original research proposal.

4. The DS created the conditions for negotiation that sometimes led to adaptation of the research to farmers' knowledge, and sometimes to convincing farmers. In a number of cases, the DS confirmed the original choices made by the researcher.
5. The DS played a crucial role in all research projects in establishing the importance of the context for the relevance of the project. However, as the context is continuously subject to change, a researcher cannot afford to consider the diagnostic phase closed.

## Partnership building

### Inter- and trans-disciplinarity

Trans-disciplinarity combines stakeholder participation with inter-disciplinarity (Tress *et al.*, 2003). Convergence in CoS means both, inter-disciplinarity, especially between social and natural sciences, and science as a multi-stakeholder process. In this process-driven science, social and natural science disciplines work together to create new knowledge, modes of thinking, and theory. A typical example of the integration of life, earth and social sciences is the work of one student who not only experiments with farmers on low external input agronomic practices for sustainable cocoa production, but also has mobilized a district consortium to deal with the common practice of doctoring weighing scales by Licensed Buying Agencies (E.N.A. Dormon, personal communication. Upon hearing this story, the DG of an international development agency in West Africa burst into laughter and admitted that this practice had paid for his school fees.) In other words, CoS student researchers not only experiment with farmers to develop technologies, they also seek to intervene in social arrangements to create human activity systems that improve the conditions small-scale farmers face. Other examples include the negotiation of agreements between landlords and immigrants about sustainable soil management, and the development of an organic cocoa chain. In our opinion this is one of the exciting aspects of CoS. We are dealing not only with an integration of life, earth and social sciences for understanding, but also for action. And CoS' first steps on this path suggest that it might be possible experimentally to tackle the restricting and rapacious framework conditions farmers face and to improve farmers' countervailing power.

### Establishing the international partnership

CoS was conceived in the Netherlands by a consortium of chair groups at Wageningen University. It was evident at the start that potential links in West Africa would need to be established before the final application for funding could be submitted. These activities all happened under time pressure. The programme document had to be submitted one week after the return of a two-week identification and formulation mission to

Benin and Ghana by three members of the CoS team. In hindsight, this procedure could be considered madness. International research programmes seem to need a long and funded formulation phase during which partnerships are built and the formulation of the research proposal becomes a team-building activity.

A complicating factor was that Benin and Ghana differ in the structure of their agricultural research systems (as a consequence of different colonial histories). In addition, as was mentioned earlier, Wageningen entomologists had collaborated over several years in a project on integrated pest management (IPM) in cowpea. So setting up a liaison group of Beninese scientists was comparatively easy. Trust and mutual expectations had been established in the past.

Collaboration with Ghana was much less self-evident. The mission therefore needed to establish a framework through which Ghanaian scientists could participate in the project, provided they had sufficient interest. The network in Ghana needed to be built up from the start. Exploring entry points through universities and other research institutions, governments, the FAO regional office, and other was a major issue. The recent democratization in Ghana helped to create a receptive atmosphere for the proposed CoS programme. Within political and institutional circles in Ghana there was increasing dissatisfaction with the rather marginal role science had played in developing the agricultural sector. For example, the Cocoa Research Institute of Ghana (CRIG) published the fact that only 3.3% of the technologies it had developed had been taken up by farmers (Ayenor *et al.*, 2004). Several key persons in Ghana were well disposed towards the approach. This helped in building up a core group (similar to the one in Benin) in a reasonably short period. But it would have been preferable to have more time to identify partners and to properly formulate the project together with Ghanaian scientists.

## PhD students and inter-disciplinarity

CoS chose to reach its objectives through the recruitment of PhD students because they were expected to be highly motivated, eager to publish, to contribute to university scientific output, and to be relatively cheap. CoS has not been disappointed in these expectations. Because CoS goals could only be achieved through an interdisciplinary effort, it recruited four students with a natural science and five with a social science background. The initial idea was that they could work in tandem in the field, one of them focusing on socio-economic aspects and the other on technological innovation. However, eventually the choice was to go for 'polyvalent' students being able to handle both disciplines. During the six months of preparation in Wageningen, polyvalence was pursued by giving the natural scientists training in subjects such as '*Methods and techniques in social scientific research*', and social scientists in subjects such as '*Ecological aspects of agricultural systems*'.

Back in Benin and Ghana the students carried out research with farmer groups focusing on the following themes: crop diversity in sorghum, cowpea and yam; integrated pest management in cocoa and cotton; weed control in maize and sorghum, and improvement of soil fertility in various cropping systems (cassava, cowpea, pigeon pea, seed melon (*egusi*) and maize). The validity and appropriateness of these themes

was verified in the diagnostic studies. As said, the students concentrated not only on technological improvements, but also on socio-economic, cultural and institutional innovations. This requires interdisciplinary research, and each student is supervised by both natural and social scientists, from both their own country and from the Netherlands. This means quite heavy supervision and demands a capacity for deft 'supervisor management' on the part of the students. They have all become masters at this game.

## Investment in interaction

The close collaboration among the Beninese, Ghanaian and Dutch partners is stimulated through explicit investment in their interaction. CoS deliberately creates 'social spaces for learning at multiple scales' (Jiggins, 2005). Table 2 lists the various 'social spaces for learning' used in CoS. This interaction requires considerable travel, including tedious and sometimes anxious journeys across Togo, which lies between Ghana and Benin.

Table 2 only contains face-to-face meetings. Not included are the numerous reports that are produced, the website, and the intensive contact between students and super-

Table 2. Convergence of Sciences programme's social spaces for learning.

| Meeting | No. of persons involved | Location | Times per year |
|---|---|---|---|
| Co-ordination Committee [1] | 5 | Cotonou and Accra | 2 |
| Scientific Co-ordination Committee | 3 | Wageningen | 5–6 |
| Inter-country meeting of all supervisors | ca. 20 | Accra or Cotonou | 1 |
| All PhD students | 9 | Accra, Cotonou or field | 2 |
| International seminar of all CoS members & invited speakers | 40–50 | Accra or Cotonou | 1 |
| Country team | ca. 10 | Benin and Ghana | Varies |
| Students with Dutch supervisors | 3 | Capital cities or field research sites | 1 |
| Students with local supervisors | 2–3 | Research sites/capital cities | Varies |
| Students with farmers and other stakeholders | Varies | Research sites | Varies |
| Country team with steering committees | ca. 20 | Accra or Cotonou | 2 |

[1] Comprising the international co-ordinator (A. Van Huis), the two national co-ordinators (D.K. Kossou in Benin and O. Sakyi-Dawson in Ghana), and two scientific co-ordinators (D. Hounkonnou and N.G. Röling).

visors via e-mail. The table assumes the situation when students did fieldwork in their respective countries, and not their initial and final periods in Wageningen.

In both Benin and Ghana a steering committee was composed to advise the programme. These committees comprise important national stakeholders, such as the heads of agricultural research establishments, vice chancellors, rectors and deans of universities, and national agencies, who can be considered important for the integration and scaling up of the lessons of CoS.

In all, a tremendous amount of effort and resources are invested in interaction among CoS members. Investing in interaction at multiple scales and in multiple modalities is considered an essential management tool to ensure that a common perspective and synergy emerge, and that the project is considered a worthwhile endeavour that is more than a source of funds. The following section provides a case study of such interaction, in this case a workshop to support convergence on the CoS philosophy.

## Converging on a programme philosophy

When CoS started, things were not clear at all, and consensus about what CoS really was about had to be co-constructed from scratch. The CoS programme involves scientists with widely diverging backgrounds in terms of nationality, discipline, cultural values, institutional embedding and working experience. While each of them has reasons to be part of CoS, all of them have different views on what may be special, important and worthwhile about the programme. So we cannot do full justice to all when trying to say something about '*the*' programme philosophy. Although it is necessary to respect the diverse and often implicit 'individual philosophies', one does at different points in time need some explicit common starting points in order to effectively work together. Another issue is that such an explicit 'common philosophy' of the programme is – and must be – evolving.

### Process of maintaining and re-inventing the common philosophy

As can be noted from previous sections, the initiators of the programme already had made many choices based on their convictions, opportunity grasping and theoretical orientations. This served the purpose of producing a coherent programme document that was eligible for funding by the various prospective donors. This document can be seen as the first version of our common philosophy. While it proved a sufficiently common basis to orient the programme's activities during the first year, unease and discontent started to develop when the diagnostic studies had been completed and the PhD students were about to enter their third year. There was widespread concern that there was not – or no longer – sufficient clarity about the overall philosophy of the CoS programme, in particular about what this meant for the content and design of the PhD dissertations. Both students and supervisors started to become frustrated and confused. In addition, a mid-term review commented that CoS had made insufficiently clear how its philosophy differed from 'conventional' participatory approaches. Some

of the co-operating scientists began to wonder about the added value of the great deal of additional effort that was invested in student supervision.

In view of the above, it was considered necessary during an encounter of PhD students and delegations from Ghana, Benin and the Netherlands to collectively (re-)establish our common ambitions and philosophy, and decided that we needed to do this without focusing too much on existing documents. To this end, a meta-plan session was organized during a workshop in Accra. Everybody was able to write down what he or she considered to be the core ambitions and ideas underlying the project, and indicate simultaneously what made the project special *vis-à-vis* other approaches. Eventually, five clusters were identified that can be seen as a next explicit version of a common philosophy.

## Outcomes of the 'project philosophy' workshop

The eventual objective identified for CoS was to contribute to '*improved livelihoods and poverty alleviation among farmers*'. The five clusters represent the key approaches required for achieving this objective:

1. *Taking science seriously.* The project starts from the idea that science played a sub-optimal role in development processes, including both participatory technology development efforts and farmer field schools. Amongst other things this is because scientists have been unwilling or unable to engage in interactive forms of research, but also because many 'participatory' projects assume incorrectly that 'indigenous knowledge' is sufficient. The CoS projects feels that both social and natural scientists can contribute considerably to improving technology development efforts, provided that the two strands of science co-operate and '*converge*' effectively; hence the effort to involve university scientists from various disciplines and countries in societal technology development trajectories.
2. *Democratization of science by interaction.* It was felt that – in order to make an effective contribution – 'convergence' was not only needed between natural and social scientists, but also between societal stakeholders (including farmers) and scientists. Such convergence of farmers' and scientists' knowledge and experience could be achieved by intensive and sustained interaction between them. Of key importance here is that societal stakeholders influence scientists' research agendas (and *vice versa*) and also that farmers gain more confidence in their own knowledge and capacities.
3. *Enlarging social and technical space as elements of innovation.* It was argued that effective innovations consist not only of new technical devices, methods and practices, but also of new social arrangements and practices (e.g. adapted land-tenure contracts, new marketing channels, novel ways of mobilizing labour, see also Leeuwis & Van Den Ban, 2004). An important difference between the CoS approach and conventional approaches is that we aspire to work on both aspects, rather than on 'technical' technology alone. As a consequence we are not just interested in 'appropriate technology' but also in 'changing what is appropriate'. This requires that we work towards the development of new social relations, partnerships, etc.; not only at the 'local' level, but also across hierarchical levels and scales

(Giller *et al.*, 2003). The space for innovation is often constrained by 'outside' factors.

4. *Developing a better research process to enhance innovative performance and change.* Methodology development was identified as a key ambition of the CoS project. In order to develop new methodology we want not only to experiment with new modes of working, but also to study, evaluate and reflect critically on what we are doing. The workshop suggested several special emphases in the sphere of methodology development:
   a. Forms of interaction that improve joint understanding and collective agenda setting among farmers and scientists, contributing to the *'democratization of science'.*
   b. *Creating space for mutual learning and analysis.* It was emphasized that it was important to create and study 'learning environments' (including tools and methods) that allowed farmers to better understand scientists' perspectives (and *vice versa*) as a basis for joint analysis and design of innovations. South-south co-operation was also mentioned as an aspect of such a learning environment.
   c. *Demonstrate a successful 'natural and social science' encounter.* Research process development also involves the development of better approaches for fostering co-operation between natural scientists and social scientists.
   d. *Developing learning tools relevant for scaling up.* Based on the learning experiences we want to develop tools and approaches that can be used for the scaling up of relevant innovations. Depending on the complexity and 'knowledge intensity' of the innovations, such tools may either be geared to 'discovery learning' or more conventional forms of 'extension'. Learning tools may relate to the technical and/or social aspects of innovations, and may be geared to various audiences, including audiences at higher hierarchical levels.
5. *Critical reflection on science institutions.* An important ambition of this programme is to reflect critically – based on our experiences in CoS – on whether science institutions (including the three universities involved) are conducive to fostering 'Convergence of Sciences'. We expect to identify a range of factors and conditions that may impede or stimulate scientists to work according to the philosophy adopted in CoS.

The outcomes of the workshop are still similar to ideas outlined in the original project document, but the language, phrasing and emphasis clearly differed in several respects.

## The significance of the workshop

After the exercise on the project's philosophy, the workshop continued with a second round of group discussions that centred on the concrete implications of the philosophy for the content and set-up of the dissertations. This re-established common starting points as well as joint ownership over the project, and thereby the participants regained a sense of direction for future activities. So the workshop can be seen as a critical incident. However, the significance is bound to its specific time and space context. In an ongoing and complex programme such as CoS, problems present themselves continuously as the project unfolds, both at the level of individual PhD studies

and the programme as a whole. It is certain, therefore, that new challenges will have to be met in the future, and overcoming these may well require a next effort to re-establish, change and/or add to 'the' common philosophy. In order to overcome challenges and direct action, the philosophy must be actively discussed, maintained, internalized, translated and re-negotiated from time to time. This requires active attention and facilitation on the side of the programme management. A large international conference about CoS in October 2005 played an important role in this respect, but came too late to be reported upon in the present article.

## Institutional change and scaling up

One of the key issues for CoS has been the impact of the project on the research and academic institutions involved: the University of Abomey-Calavi (UAC) in Cotonou, the University of Ghana (UoG) in Legon, and Wageningen University (WU) in the Netherlands.

### Universities and interactive science

The universities lack an organization to work according to interdisciplinary or trans-disciplinary lines. The discipline-based system remains the organizational form of science, even if nature sets no frontiers. According to Brewer (in Tress *et al.*, 2002) "The world has problems, the university has departments". So the challenge for universities is to institutionalize interdisciplinary training programmes, and to allow, facilitate, fund and stimulate interactive research. Courses tackling these issues in agriculture do not exist and need to be elaborated, using experiences gained in the current CoS programme, a challenge to be taken up. Often the questions proved very practical.

How to register a student engaged in interdisciplinary or trans-disciplinary research? At WU the graduate schools involved (one dealing with social sciences, and the other with natural sciences) have no rules. The students were registered in the graduate school that related to their original discipline. However, some 'social science students' focused more on natural sciences than on social sciences, and *vice versa*, so this is not a satisfactory situation. Registration in both graduate schools proved to be possible, but this only meant that students were informed about the events in one graduate school while the responsibility remained with the original school. In the UoG registration proved to be difficult because natural and social sciences are hosted at different faculties. Again there was no satisfactory solution to host the CoS students. Also, to meet the requirements of some faculties, students sometimes needed to pass exams in extra subjects that had little relevance to their work. Therefore, discussions in this university started about setting up an interfaculty dealing with integrated studies or interactivity in research and education. It shows that interactive research becomes a lever to change institutional patterns.

The disciplinary organization of universities could be considered as an impediment to interdisciplinary research. At WU, for example, CoS deals with three different

administratively separated expertise groups: the social, the plant and the environmental sciences. Also the graduate schools are organized according to disciplines. This means that interdisciplinary research will only happen through the personal interest of researchers or through outside stimuli such as research opportunities created by funding bodies, either within or outside the university. WU made a special effort to stimulate interdisciplinary research. At the start of the millennium, its Executive Board decided to continue working in developing countries with as main objective interdisciplinary and comparative research focused on development and education. The Interdisciplinary Research and Education Fund (INREF) was launched and CoS was one of the selected programmes. But one pilot project does not mean that the university as a whole is able to work in an interdisciplinary manner. In fact, incentive systems increasingly drive departments into keeping their students to themselves and discouraging them from buying education or supervision from other departments. In that sense, we feel that so far CoS has not had any influence in WU, even though at project level supervisors from different backgrounds have entered into exciting discussions and have learned to appreciate each others' viewpoints. Within WU there is no one who can answer the phone on that issue.

## Inter-university PhD degrees

In the programme, north-south collaboration is apparent in workshops, inter-country meetings, joint supervision, joint publications, the joint organization of a large international conference, and the joint effort to interest other donors to finance similar projects. Research, academic and extension organizations in Benin and Ghana closely follow the programme as a potentially new model for agricultural innovation processes. Discussions dealing with creating institutional space for beta-gamma interactive research and training have started at a high level in both African universities.

But the problems are especially evident at the very practical level. For example, how to organize their co-operation and collaboration in PhD training? How to arrange officially the PhD? Would it be a UAC, a UoG or a WU degree, or would it be possible to arrange for a degree recognized by more than one university? To play safe, students were registered at both the northern and the southern universities, while solutions were being negotiated. Procedures, regulations and maybe institutional pride have proved too strong for the deliberate efforts of CoS to make inroads. WU does not have arrangements for joint PhD degrees with other universities. CoS tried to stretch the limits of the regulations, which resulted in permission to organize the WU PhD defence outside the Dutch borders. This is quite a rare event in the history of WU. The mixed composition of the supervisory team and the PhD academic forum against the objections of which PhD students must defend their work may probably incite the southern universities to endorse the delivered diploma. This is the limit of what seems possible at the moment.

## Scaling up

CoS has developed protocols supportive of the inter- and trans-disciplinary interaction

among PhD researchers, farmers and supervisory teams so as to establish effective learning communities. At the time of writing, it remains for CoS to complete the documentation of the approach and the results achieved, to develop university curricula based on its achievements, and to ensure continuity for the farmer research groups that have been established.

Scaling up from these achievements involves different processes. In the first place, one can expect diffusion ('scaling out') of concrete results to other farmers, for example through the development of modules for farmer field school (FFS) curricula by CoS researchers. However, the experience with FFS is that complex messages such as IPM do not diffuse easily from FFS participants to others.

In the second place, scaling up CoS achievements means that national agricultural research stations, international agricultural research centres, and other public and private agricultural research and development and academic organizations incorporate the CoS philosophy and approach into their technology development practices, into their organizational and managerial routines, and into their capacity-building practices. This does not mean that all fundamental and applied scientists should be working with farmers, but it does mean that technographic and diagnostic studies, as well as experimental work with farmers, would become routine aspects of research projects and institutional strategies.

In the third place, scaling up means that national and international development agencies begin to take institutional framework conditions seriously, e.g. by ensuring fair trading practices, controlling revenue extraction from small farmers, creating effective marketing chains, and increasing the competitive position of national agricultural industries in the world market. The CoS experience (e.g. with cocoa marketing and land tenure arrangements) shows that much can be done. It is not just a question of governance, but very much also one of building coalitions around opportunities for improvement, driven by farmers with political clout. Scaling up would imply building capacity for facilitation of such processes.

Finally, scaling up implies improving the marketing opportunities for African food farmers, beginning with creating compromises between the long-term need to give African farmers a protected space within which to develop, and the short-term interest of urban politicians and their voters in cheap imported food. CoS has run into this problem, but there seems to be no way by which scaling up from CoS could solve that problem.

## Conclusions

Although at the time of writing, CoS still had two years to go, this overview article has hopefully shown that CoS has made contributions where it counts.

In the first place, although we have not reported on them here, the individual student projects are beginning to yield concrete technical results in such fields as sustainable cocoa and cotton production, weed management, genetic diversity management in sorghum, cowpea and yam, and in soil fertility management. Farmers accept the technologies produced in terms of their effectiveness, appropriateness and compat-

ibility, i.e., they are effective within the conditions faced by small-scale farmers.

In the second place, CoS has developed, tested and published (Röling *et al.*, 2004) protocols for zooming in on farmers' small windows of opportunity and for establishing effective interfaces between scientists and farmers that allow research to make a contribution. So CoS seems to be succeeding in its main objective: to design pathways by which agricultural science can have an impact on livelihoods of small-scale farmers *within* the conditions that farmers face.

In the third place, CoS PhD researchers have begun to tackle the framework conditions. At first CoS focused mainly on technical innovation. But as CoS progressed, the researchers began to tackle institutional issues that constrain agricultural development, such as ineffective commodity chains, cheating by produce buyers, and land tenure arrangements. This (action) research is to some extent able to *enlarge* the windows of opportunity.

But our results also show that this is not enough. Farmers face market conditions that prevent them from developing their farms. They are not able to contribute to national food security and the long-term – i.e., taking into account climate change – ability of West African countries to combat hunger and poverty. Tackling this issue will require more than the facile narratives that are currently popular when it comes to the 'how' of reaching the millennium development goals (MDGs) in Africa. These narratives tend to be about funding 'centres of excellence for S&T' and 'harnessing the power of knowledge and innovation', about market liberalization, and even about ending export subsidies by the US and the EU. But they do not address the key question: how can protected spaces be created that allow the energy, intelligence and experimental creativity of Africa's small farmers to be enlisted to achieve MDGs, ensure global food security for a troubled planet, and, as cynics would argue, prevent a mass exodus of impoverished rural Africans? CoS cannot answer that question, but we feel it has helped specifying the issue that needs to be addressed.

We draw some lessons from the CoS experience for the UN Millennium Development effort with respect to the management and funding of agricultural research that at least targets farmers' small windows of opportunity.

1. Finance multi-disciplinary teams (including social scientists) around concrete PhD research projects. Stimulate joint publication of the results and facilitate that process vigorously in terms of time management, supervision, and editorial assistance.
2. Invest in formulation missions that use tools such as technography, rapid appraisal of agricultural knowledge systems (RAAKS; Engel & Salomon, 1997) and diagnostic studies, to ensure pre-analytic choices that allow identification and mobilization of effective stakeholder coalitions in promising theatres of innovation, as well the concrete research projects mentioned under 1.
3. Step out of the narrow confines of expert science focusing on agricultural productivity, irrespective of framework conditions, and emphasize justice, fairness, gender equity and environmental sustainability and especially market access as dependent variables of the research effort.
4. Create effective spaces for learning at multiple scales and invest heavily in frequent and intensive interaction in these spaces. Ensure facilitation of learning processes

during these interactions. In other words, it is management of *processes* rather than management for *output*.

5. Make sure that both, peer scientists *and* small-scale farmers can exert effective judgement over the outcomes of the research.

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