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Agricultural research in the face of diversity, local knowledge and the participation imperative: theoretical considerations

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Abstract

In the light of the challenges to formal agricultural research posed by renewed interest in diversity, local knowledge and end-user participation, this paper attempts to provide the beginnings of a theoretical underpinning for the response to repeated calls for greater farmer participation in agricultural research. Two views are explored. First that there is a degree of substitutability between formal and farmers' experiments, with the latter being important in adapting technology to particular local circumstances. Second that there is a potential for synergy from closer integration of formal and farmers' experiments. Empirical data from Africa is used to explore this synergy hypothesis and it is concluded that there is reason to be sceptical of claims for potential synergy. Thus, to make most efficient use of limited formal research resources, as a general rule partially specified technologies should be released to farmers for final specification at as early a stage as possible. Within this general rule, the basic characteristics of the technologies being developed must guide the timing, type and level of farmer participation.

Keywords: Agricultural research; Farmers' experiments; Synergy; Participation

1. Introduction

It is now more than a decade since Biggs contrasted what he termed the 'central source' and 'multiple source' models of innovation within the agriculture sector

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(Biggs, 1990). The paper used the device of a simple dualism to contrast the two models. Accordingly, the 'central source' model was described in terms of a single, central source of knowledge generation, innovation or new technology (essentially a state supported research system). Going along with this was a view of farmers as passive recipients of information or technology. The logic of this model led to hierarchical systems of research and extension, where communication and information flow was linear and unidirectional, from the researchers (the centre) to the farmers (the periphery) via extension. In contrast, the 'multiple source' model was depicted as more dynamic, with multiple, interacting sources of knowledge generation and innovation, including the state funded system, universities, the private sector, development organisations and farmers themselves. This model was built on a view of farmers as active innovators and experimenters, and it was therefore logical that communication and information flow should be multi-directional.

While most of the ideas in the paper had been around for some years (e.g. Biggs and Clay, 1981), Biggs brought them together in an accessible and compelling argument, leading to the conclusion that if policy makers and researchers were to succeed in bringing the tangible benefits of research to poor producers in the developing world, they needed to reject the 'central source' and embrace a 'multiple source' model. Such a move, while positively impacting on the efficiency and outcomes of research, would also have significant implications for the organisation and management of agricultural research, and for the researchers themselves.

Of course the story is never quite as simple as it is wont to appear through such dualisms. For example, there can be little doubt that the main theoretical underpinnings of the agricultural extension component associated with the 'central source' model can be found in diffusion of innovations theory (Rogers, 1983). This body of theory has dominated research and teaching in agricultural extension and communication for over 50 years. It is interesting to note, therefore, that diffusion of innovations theory explicitly recognises 're-invention' as a process of change or modification of an innovation *by a user* during adoption and implementation. Associated with this is the notion of 'trialability', which describes the degree to which an innovation is amenable to experimentation *by a user*. Thus the proposition that formal agricultural research and extension saw farmers only as passive recipients of information and technology is difficult to sustain.

Somewhat more broadly, there are many well researched and widely acknowledged examples of the innovative prowess of small scale producers in the developing world. The establishment and development of the cocoa industry in Ghana provides compelling evidence of technical and institutional innovation (Hill, 1965) and many similar illustrations can be identified. It is nevertheless true that the recognition of these historic achievements has often not been adequately reflected in the design and operation of agricultural research and extension programmes.

In any event, and even if the distinction between the 'central source' and 'multiple source' models was stylised and overdrawn, Biggs developed a compelling case for a broader conception of processes of innovation within agriculture. In many essential ways this broader conception mirrors much of the thinking, driven largely by Niels Röling and his colleagues at Wageningen, around the concept of an 'agricultural knowledge and information system' (AKIS; Röling, 1985). Both Biggs and the AKIS literature highlight local knowledge and local processes of innovation, with the implication that bringing these local processes into closer contact with formal research should be beneficial. It is in this context that we can begin to understand the explosion of interest in farmer participation in formal agricultural research during the late 1980s.[1]

But it is one thing to call for more integration of local and formal innovation processes through greater participation, and quite another to determine the most effective ways of doing it. How can or should all the parts of the multiple source model (formal research, farmers experiments, participation, extension, etc.) fit together most effectively? To date, this has been approached largely as an organisational or managerial problem, with a distinct emphasis on the identification and dissemination of 'successful' examples and 'best practice' (e.g. Van Veldhuizen et al., 1997). The relationship between formal and farmers' research has not been adequately theorised, and consequently, while researchers are under pressure both to increase the impact of their work and to make it more participative, there is little if any basis on which to systematically determine appropriate forms and levels of end-user participation.

In this paper, we begin to sketch out a theoretical basis for operational decisions regarding appropriate forms and levels of farmer participation within formal agricultural research. In the next section, new concepts are introduced which are incorporated into two alternative models of farmer–researcher interaction. Data from field studies of farmers' experiments in Africa are then used to explore these models. Next, two key characteristics of technology are described and their implications for farmer participation in formal research evaluated via a simple typology of agricultural technologies. The final section draws conclusions and implications for research policy and management.

2. Theorising end-user participation within agricultural research

The call for increased farmer participation in agricultural research is rooted in a view that poor producers farming in less well endowed areas have failed to benefit from public investments in agricultural research. The challenge posed by these areas—for research and for development policy more generally—goes beyond

[1] It is not correct to assume that the only motive for increasing farmer participation in agricultural research was to increase its effectiveness. We previously made a distinction between what we termed 'research-driven' and 'development-driven' farmer participatory research activities (Okali et al., 1994). Research-driven farmer participatory research aims primarily to improve the effectiveness of formal agricultural research. While the ultimate goal may be a positive impact on the livelihoods of poor farmers, this goal is approached through the development of new or improved agricultural technology. On the other hand, development-driven farmer participatory research activities are often associated with projects, community organisation efforts and group-based approaches. Farmer participatory research is seen to contribute to the wider objective of empowerment through the transfer of research skills, increased self-reliance and the idea that local people can be in a stronger position vis-à-vis formal research and extension institutions.

poor and variable rainfall, difficult topography and infertile soils, encompassing a host of other conditions such as low levels of irrigation, poor transportation infrastructure and limited access to markets, agricultural extension and the like. The result is that they are characterised by high levels of diversity, of both natural resources and livelihoods. This diversity means that it is unlikely that an individual new innovation, such as a crop variety, will be suitable for a large number of users or a high proportion of the cultivated land area. The standard models of agricultural research are not well suited to such situations of diversity, where innovations need to be tailored to the needs of relatively small groups of potential users. The argument is that greater farmer participation in the identification of problems to be researched, the choice of possible solutions, the design and implementation of trials, the identification of indicators of success, etc. will increase the practical value of research outputs to producers in these diverse, poorly endowed areas.

Drawing on both the multiple sources of innovation model and the new enthusiasm for 'local knowledge', the argument can be further developed as follows. Farmers have an intimate knowledge of their local environment, conditions, problems, priorities and criteria for evaluation, and actively engage in experimentation as part of their farming routine. This knowledge, experience and experimentation is normally out of the reach of 'outsiders'. At the same time, the results of formal agricultural research are often inaccessible and sometimes inappropriate for poor farmers. However, by using farmers' experiments as the keystone of a new, collegial relationship between farmers and researchers, significant extra benefits will accrue to both the farmers and the formal research system. We have previously called this the 'synergy hypothesis' (Sumberg and Okali, 1997).

Before assembling the concepts which will be required for a theoretical treatment of this proposition, five points need to be addressed. The first is that we are concerned only with 'research-driven' farmer participation in agricultural research; in other words, where the primary interest is in making research more effective. Here we are not concerned with 'development-driven' farmer participation or with the notion that participation in and of itself can be an empowering experience. Second, experience in the industrial sector has shown that end-user participation is not always synonymous with successful product development, indeed 'different studies have found relationships between user involvement and project outcome that range from positive to neutral to negative' (Leonard-Barton, 1995, p. 94). The trick is surely to know when, or in what situations, end-user participation is most likely to be beneficial. The third point is that there are many possible types and levels of participation, from one-off 'participation' in a questionnaire survey to, for example, long-term 'participation' as a farmer-selector in a participatory plant breeding programme. Again, since there are costs associated with participation, the challenge for a researcher is to identify the type and level of participation that are most appropriate in a particular situation. Fourth, we can now take as given the notion that many (most) people engaged in agriculture investigate the relative value of different methods, varieties, etc.: they 'do experiments' (Sumberg and Okali, 1997). In addition, some farmers are more actively engaged in innovation processes, in developing new or making major modification to existing techniques or technologies. Finally, we are primarily concerned here with what we term the adaptive end of the spectrum of agronomic research, focused on questions such as which crop variety, spacing, planting date, fertiliser application rate, etc.? Given the current international division of labour within agricultural research most researchers within national research systems, particularly within Africa, focus on questions such as these.

2.1. Concepts

2.1.1. Partial substitutability of formal and farmers' research

At one level the process of technology development can be seen as a funnel, where the wider, open end represents the stage when a technology is simply a broadly defined idea. In the process of development this 'notional technology' is progressively defined and refined so that it arrives at the end of the process, at the small end of the funnel, as 'fully specified' technology. In principle, the fully specified technology is ready to be used. In a situation of high diversity among end-users, there may, however, be some advantage to halting the formal development process before the end point of full specification. In this case, individual end-users are responsible for the final specification, essentially customising the technology to suit their particular conditions: in industry this kind of end-user customisation is known as the 'production engineering' stage. The point is that if farmers 'do experiments' and can thereby adapt (at least some) technologies to their individual needs and circumstances, then to some extent formal and farmers' technology development activities may be seen as partial substitutes for each other. Given that the availability of formal research effort is highly constrained, particularly in relation to the diversity highlighted earlier, it makes sense to hand over a technology to end-users for final specification as early as possible (Reece and Sumberg, in press). However, it is clear that the substitutability of formal and farmers' research is only partial as farmers cannot do everything the researchers do, and vice versa. The limitations of this partial substitutability have important implications in relation to different kinds of technologies, and this will be explored later.

2.1.2. Synergy

The idea of partial substitutability of research effort does not fully capture the proposition that extra benefits can be gained by bringing end-users more centrally into the research process. As indicated earlier, these extra benefits have been discussed in terms of a synergy between formal and farmers' research. Synergy has been defined as 'increased effectiveness, achievement, etc., produced as a result of combined action or co-operation' (Oxford English Dictionary, 1997), and is more commonly understood in the sense of 'a whole being greater than the sum of its parts'. In the next section we will use the idea of increased effectiveness or achievement to formalise the synergy hypothesis relating to the integration of formal and farmers' research.

2.1.3. Heterophily

Communication is a major theme within diffusion of innovations theory, as diffusion is dependent on the successful movement of information (Rogers, 1983). According to the theory, one key criterion for good communication is a degree of similarity (in terms of beliefs, education, social status, and the like) between the two interacting parties. This similarity was termed homophily. The opposite of homophily is heterophily (the degree to which two or more individuals who interact are different in certain attributes), and again, the idea is that too great a degree of heterophily makes communication and understanding between individuals difficult. On the other hand, one can imagine that a certain degree of heterophily, or difference between two interacting parties, might be the basis of a positive and desirable 'creative dissidence', the result of which might also be described in terms of synergy.

2.2. Alternative hypotheses

We can now use these concepts to formalise two alternative models or hypotheses in relation to the benefits of closer integration of formal and farmers' research. For the sake of clarity these models can depicted as:

H_1. A simple additive model: $RGN = R + F$

H_2. A synergistic model: $RGN = R + F + (R^*F)$
where, RGN = research generated knowledge; R = knowledge generated through formal research; and F = knowledge generated through farmers' research.

The simple additive model is built around the notion of the partial substitutability of formal and farmers' research as discussed earlier. Thus, particularly in relation to the fine tuning of a partially specified technology to meet local conditions, farmers' research can, to some degree, replace formal research. The assumption is that whether done by researchers, by farmers, or by both parties working together, this process of final specification will be essentially the same in terms of objective, method and the like. There is no expectation of creative dissidence or synergy, and the total 'research generated knowledge' is reflected in the sum of formal and farmers' research effort.

In contrast, the synergistic model posits an additional term due to the interaction of farmers' and formal research, which increases the research generated knowledge beyond the simple sum of the constituent parts. This interaction term represents the synergy effect, the extra benefit from bringing the two constituent parts together. The synergistic model raises two questions: first, under what conditions should it be expected to operate; and second, is the interaction term likely to be large enough to worry about?

The concepts of homophily and heterophily were introduced above in relation to the degree of similarity or difference between individuals as a key factor mediating effective communication. By extension, it is reasonable to expect that the degree of similarity or difference between research paradigms, objectives and methods will, to a large degree, determine the effectiveness of a particular research collaboration. For example, with very high levels of homophily between research collaborators, communication and mutual understanding will be good, but little that is new or challenging will be brought to the collaboration. In other words, the expected result of the collaboration will be more research, but the nature of this collaborative work will be essentially the same as that done by the partners when working individually. In the case where there is a very high degree of heterophily between research paradigms, objectives and methods, there would simply be no basis at all for collaboration. On the other hand, it is in those situations where there is an intermediate level of heterophily that the productive potential of research collaboration increases significantly. Here there is sufficient shared understanding to work together, but enough difference in approach to result in some creative dissidence. This stylised relationship between level of heterophily and potential synergy is shown in Table 1.

This formulation provides a basis to evaluate the synergy hypothesis. If high levels of either homophily or heterophily between formal and farmers' research are found, the synergy hypothesis can be rejected. On the other hand, if an intermediate level of heterophily is found, if formal and farmers research share some common elements and diverge around others, the synergy hypothesis will stand. Either conclusion will have important implications when considering appropriate types and levels of farmer participation in research.

2.3. Empirical findings

Sumberg and Okali (1997) studied farmers experiments in Kenya, Zimbabwe and Ghana, analysing 154 farmer-reported experiments in terms of topic, origin, method, source of idea or technology, and outcome. A representative selection of these farmer-reported experiments is shown in Table 2. Experiments were reported by all socio-economic groups; there were no clear associations between socio-economic characteristics such as gender, age, level of education, marital status or primary occupation, and either the propensity to report or the type of experiments reported. In terms of their subject focus, the examples of farmer-reported experiments had much in common with the experiments which form the backbone of formal, adaptive agronomic research: they revolved around a relatively limited array of standard and very practical agronomic concerns such as crop variety choice, fertiliser and pesticide rates and times of application, and inter- and intra-row spacing (Table 3). Thus, like

Table 1
Hypothesised relationship between heterophily and potential synergy

Degree of heterophily	Potential for synergy
Low	Low
Intermediate	High
High	Low

Table 2
Some examples of farmer-reported experiments

Site	Example
Ghana	In July 1994 she planted about 1/8th of an acre of water melon for the first time. She had seen the water melon growing on Kojo Yeboah's farm but he was not there at the time. She collected seeds from people she saw eating water melon. She does not know about fertiliser application and guessed about planting distance and date. Her crop did not do well and as a result she sought advice from a friend whose father also grows water melon. The friend advised her to apply fertiliser two weeks after planting, but it was already too late. Although her first attempt was a failure, she intends to try again and will also try to extend the area. She has not visited any other farms to see water melon being grown.
Ghana	'This is an experiment farm'. He treated a couple of rows with a liquid starter fertiliser that he made himself from granular fertiliser. He applied the liquid three days after transplanting; the adjacent rows received regular granular starter only three days ago. There is a dramatic difference in the growth and colour. He says the idea came from his own head—he will pluck the first flowers from the more vigorous plants so all the fruits mature at the same time.
Zimbabwe	Last year she made ridges with a hoe and planted sorghum on them. It was her first time to use ridges, and the first time to plant sorghum with a hoe: she would normally plant following the plough. The crop was healthy and the harvest good. The only problem was that the field was too small! This year, because of the poor early rains, she plans to extend the same ridges.
Kenya	He used to plant bananas by digging only a small hole, but he noted that plants did not do very well. He remembered that during earlier periods of ethnic conflict people dug large holes in which to hide. Later, when these holes eventually filled with leaves and garbage, some people planted bananas in them and they did very well. So he dug a large (4 feet in diameter) hole and filled it with loam soil and manure, then planted bananas. They are doing well.

Source: Sumberg and Okali (1997, p. 88).

much formal, adaptive research the farmer-reported experiments tended to seek incremental improvements by testing minor modifications to an established combination of agronomic practices. The vast majority of farmers' experiments were proactive (i.e. they did not happen by accident), and 40% used side-by-side comparison or some other kind of 'control' treatment.[2] These controls usually took the form of a small 'experimental plot' within a field that was farmed in the usual manner; alternatively, fields were split with the 'experimental treatment' applied only to one part.

[2] There are three reasons why we believe this to be a conservative estimate of the use of the principle of a 'control' within the farmer-reported experiments. First, because of a lack of specific information to the contrary, a number of the examples which involved trying a new variety were classified as not using a control. It seems likely, however, that in most cases new varieties would be grown near other plots of the same crop that would act as a control. Second, it is not obvious how the testing of new crops, which accounted for 15% of all examples, could easily include provision for a control or comparison. When the new crop examples are eliminated, examples with an obvious control increase to 45% of the total. Third, and perhaps most significantly, it was clear that some farmers used an internalised 'historical control' based on their accumulated understanding of the past performance of a particular field or crop, and the major factors affecting that performance such as rainfall.

Table 3
Some characteristics of farmer-reported experiments from Kenya, Zimbabwe and Ghana

Characteristic	Frequency (%)
*Topic (*n*=154)*	
Land preparation/seeding method	20
New crop variety	18
New crop	15
Spacing/density	14
Fertiliser/soil fertility	8
Other	25
*Origin (*n*=149)*	
Proactive	85
Reactive	15
*Method (*n*=120)*	
Without control	61
With control	39
*Outcome (*n*=154)*	
Minor modification/fine tuning	83
Major modification	7
Something novel	10

Source: adapted from Sumberg and Okali (1997).

Thus, the image of farmers' experimentation that emerged from these data was of a planned and relatively systematic activity yielding minor modifications to existing practice. By-and-large farmers seemed to be using their experiments to make an existing production system or practice marginally better by seeking adaptations to local conditions; few farmers reported regularly using experiments to develop or explore novel ideas or techniques. The experiments they do and the manner in which they are done illustrate again the importance to individual farmers of customising or fine tuning techniques and production systems to suit their individual circumstances. This is essentially the same picture that emerges from other studies of farmers' experiments (e.g. Johnson, 1972; Richards, 1986; Van Veldhuizen et al., 1997), with experimentation being a normal part of, if not inherent to, small-scale farming.

Based on the similarities between the farmer-reported experiments and key aspects of formal, adaptive agronomic research, is it reasonable to conclude that there is considerable homophily between the two. This leads to scepticism in relation to the synergy hypothesis: in other words, if formal and farmers' research are more closely integrated the potential for synergy is likely to be limited. On the other hand, the finding of considerable levels of similarity between formal and farmers' experiments significantly strengthens the case for their partial substitutability, and thus the role that farmers could or should play in the final stages of technology adaptation.

This conclusion is open to attack on three fronts. First, because it is based on a limited empirical base. In fact, there is now a considerable body of literature describing farmers' experiments from many regions of the world (e.g. Van Veldhuizen et al., 1997), and it is our contention that the picture of farmers' experiments that emerges from this literature is essentially the same as that from our own field studies. The second objection is that the analysis has not taken any account of the 'cosmovision' or worldview of local people. Specifically, Millar (1993) and others have argued that it is reasonable to expect that a local farmer's worldview will be different from that of a trained researcher, and will be intimately tied to his/her epistemology (and thus his/her understanding and interpretation of an 'experiment'). It is certainly true that there are many different worldviews, and these may have important epistemological implications. On the other hand, neither farmers nor agricultural researchers focused on technology development are concerned primarily with either testing or contributing to theory, or determining the specific ecological, physiological or biochemical mechanisms governing the outcomes of their experiments (i.e. the Why? question). Rather, both groups are interested essentially in (1) improving specific combinations of existing techniques, and (2) expanding the catalogue of available techniques. To accomplish this both farmers and agricultural researchers focus on the same rather limited number of leverage points, which are themselves determined by the very nature of crop production.

The third potential objection is that the apparent similarities between formal and farmers' experiments may simply reflect the loss of indigenous research traditions and approaches, and thus the impoverishment of local culture and knowledge systems, in the face of western, positivist science (e.g. Van der Ploeg, 1990, 1993; Mooney, 1993; Amanor, 1994). This is an extremely difficult attack to parry as there is little evidence of the characteristics of these indigenous research traditions and approaches. Is the observation that farmers' experiments commonly use variations of the side-by-side comparison (perhaps repeated over several seasons) evidence of the erosion of indigenous research traditions? Perhaps, but then it is difficult to conceive of other approaches or methods that would be of more value to contemporary farmers who, while being small-scale and relatively poor, are likely to purchase some inputs, market some of their produce, and exercise choice in terms of the technologies used.

2.4. Further concepts

With or without the synergy hypothesis, the call for greater participation in formal agricultural research has usually taken the undifferentiated form, 'more is better'. There has been little consideration of the implications of a research focus on different kinds of technology for the type or level of farmer participation. This is understandable in as much as some calls for greater participation were rooted in the empowerment agenda, where the political benefits of participation are foremost. However, when increased research efficacy is the justification for farmer participation, a more subtle approach is warranted. So, what effect should a research focus on different kinds of agricultural technology have on the type and level of farmer participation? Here we draw on three concepts developed by Reece and Sumberg (in press)—environmental range, solution space and farming system precision—which define key characteristics of technologies and the contexts within which they are used.

2.4.1. Environmental range

The environmental range of a technology refers to the set of bio-physical conditions (rainfall, temperature, soil type, etc.) under which the technology will give satisfactory results. Thus, the environmental ranges of different technologies can be small or large depending on the degree of variation in these bio-physical conditions which will still allow the technologies to give satisfactory results. In focusing on yield stability as a desirable trait for new varieties, plant breeders working on some crops have explicitly acknowledged the importance of a large environmental range.

2.4.2. Solution space

The notion of environmental range is not sufficient to describe the flexibility or adaptability of a technology as it makes no mention of the role of management. This management element is captured with the concept of solution space, which is defined as the 'area' around an optimal set of operator-influenced conditions within which a technology will still yield satisfactory results. A solution space, then, is all combinations of values of critical management variables (e.g. for crop varieties, variables such as planting date, spacing, fertiliser application, etc.) that deliver positive results when a particular technology is used within a given environment. Different technologies will have solution spaces of different size, with the size of a solution space reflecting the technology's ability to deliver positive (if sub-maximal) results as the operator-influenced conditions move further and further from the optimal set. In other words, a large solution space technology is more forgiving of sub-optimal management than one with a small solution space.

2.4.3. Farming system precision

If solution space is a property of a technology, then the level of management generally achieved is a property of a farming system. Specifically, farming systems are characterised by the degree of precision with which farmers are able to implement their decisions or plans, which in turn is a product of their ability to exert effective control over key resources such as land and labour. Systems where farmers exercise relatively little control can be seen as low precision systems, and those where they exercise more control are high precision systems. It seems likely that farming systems dominated by poor, small-scale producers, or in areas with relatively poor natural resource endowments, will be low precision.

Using these concepts and the notion of progressive technology specification as outlined earlier, leads to the following propositions: (1) the environmental range and solution space of a technology are likely to decrease as the technology becomes increasingly more highly specified; (2) as the environmental range and solution space of a technology decrease, the number of potential users declines, and (3) technologies with relatively large solution spaces will be better suited to low precision farming systems (i.e. the rural poor) because there is a lower risk of failure if optimal management cannot be provided. The challenge now is to use these concepts to move from such general propositions to a more detailed analysis that could help point to appropriate types and levels of farmer participation in formal research.

Table 4
Example agricultural technologies for the humid zone of West Africa

Example technology	Level of specification required before 'release' to users	Likely environmental range of fully specified technology	Likely solution space oftechnology fully specified
Vaccine against livestock disease	High	Large	Small
Gari (cassava) processing machinery	High	Intermediate–large	Large
Pesticide or herbicide	High	Intermediate–large	Small
Hybrid maize variety	High	Small–intermediate	Small–intermediate
Open-pollinated maize variety	Intermediate	Large	Large
Integrated agroforestry system	Low–intermediate	Small	Intermediate
Use of legumes as green manure	Low–intermediate	Small–intermediate	Small
Community mgt. of local forest resources	Low	Small	Large–intermediate

2.5. Technology implications for participation

A number of example agricultural technologies for the humid zone of West Africa are listed and categorised in Table 4. From the table three broad technology types are apparent. The first includes a livestock vaccine, a pesticide–herbicide and hybrid maize, and constitute what are essentially commercial or 'mass market' technologies. Because they embody relatively sophisticated technology, and some have public health implications, they must be highly specified before release to potential users, and they are likely to have a small solution space; but in order to be viable, they must have a large environmental range. The second type (including integrated agroforestry, community management of forest resources, and legume green manure) constitute 'systems technologies' which, because of their site specificity and socio-technical complexity, cannot be very highly specified before being given to users. In their fully specified, user-defined forms, technologies in this group are likely to have a small environmental range but an intermediate–large solution space. The third technology type includes what might be called 'defensive technologies' such as the open pollinated maize variety. These technologies are essentially about own-consumption and risk reduction: they are likely to have both large environmental ranges and large solution spaces.

Research on the 'commercial', relatively sophisticated technologies appears to offer relatively limited scope for farmer participation. These technologies generally address problems that are both widespread and well known. Potential end-users may have some role in assessing alternative forms of the technology prior to full specification, but as these technologies are fully specified at the time of their release, farmers are essentially faced with a yes/no adoption decision. This is not to say that even highly specified technologies might not be used in ways unintended by the researchers, but that the logic of these more sophisticated technologies leaves relatively little room for end-user specification. On the other hand, the 'systems' technologies appear to provide considerable scope for end-user input; indeed experience indicates that without it, they are unlikely to be widely used. For these technologies, which by their nature may require complex links with other activities, resources and institutions, farmers must play a role in problem identification, assessment of alternative forms early in the specification process, and end-user adaptation. Finally, the 'defensive' technologies are likely to revolve around fairly well known, staple crops. Farmers' inputs in relation to priority areas for research will likely be important, and there should be considerable scope for end-user adaptation. These implications for farmer participation are summarised in Table 5.

3. Conclusions and implications for research policy

Our objective has been to provide the beginnings of a theoretical basis for determining types and levels of farmer participation in formal agricultural research. This is particularly important as the challenge of diversity, the synergy hypothesis and the proposition that 'more participation is always better' have put formal agricultural research on the defensive. Given the already weakened state of many research systems in the developing world, we suggest that such pressure is likely only to have a negative impact on the ability of these systems to serve the agricultural sector. In effect, thinking about farmer participation in agricultural research has been confused by those who have seen participation in research, almost independent of any eventual research outputs, as primarily a route to the empowerment of local populations. Such an approach can only be wasteful and disappointing.

There is to date little empirical evidence to support the assumption that bringing formal and farmers' research closer together will result in synergy and thus yield significant additional benefits for producers. Rather, farmers' research is probably best seen as a partial substitute for the adaptive end of the formal research spectrum, having particular value in the final specification—or adaptation—of technologies to the diversity of local conditions. On the other hand, if farmers are seen as consumers

Table 5
Implications of technology types for farmer participation in the formal research process

Technology type	Implications for farmer participation
Commercial, 'high' technology	Limited role in problem identification Possible role in assessing alternative forms prior to full specification Yes/no adoption decision; no scope for end-user adaptation
Systems	Important role in problem identification Important role in assessing alternative forms early in specification process Significant scope for end-user adaptation
Defensive	Important role in identification of priority areas Significant scope for end-user adaptation

[3] Reece, D., Sumberg, J., Pommier, L., Using market segmentation to increase the impact of agricultural technology development: methodological considerations. Unpublished manuscript, School of Development Studies, University of East Anglia, Norwich, UK.

of agricultural technology, then farmer participation must be conceived more broadly than simply in terms of farmers' experiments. Here agricultural research has much to gain from the experience of product development and marketing in the developed world.[3] One immediate lesson is that there is no magic or universal formula for successful product development, just as there is no single best approach to end-user involvement in the development process. We have suggested that some of the basic characteristics of the technologies being developed should guide the timing, type and level of farmer participation, but ultimately, the judgement (and the responsibility) must rest with the researcher(s). Strategic participation of farmers in agricultural research is certainly essential for an effective and efficient formal research system. The need is not for less research, nor for research that is less 'rigorous', but rather for more and higher quality research.

Available empirical evidence points to the fact that farmers commonly test, evaluate, validate, adapt and reinvent technologies, and that they do this in ways that have some significant commonalties with the methods utilised by researchers engaged in adaptive agronomic work. While it has been suggested that training farmers in more formal research methods would make their experiments more effective (Bunch, 1989, 1991; Gubbels, 1993), we know of no evidence to support this assertion. The need is not necessarily to improve the methods that farmers use to experiment, but to increase the supply of 'raw material', or partially specified technologies, which they can incorporate into their ongoing farming and experimental activities. Given the financial and human resource constraints faced by many research and extension systems in the developing world, and the diversity which characterises the bio-physical environments, farming systems and livelihoods of the rural poor, the responsibility for making new technologies work must certainly rest with the farmers themselves.

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