Paper presented at ACIAR/SACCAR workshop, "New approaches to managing soil fertility and climatic constraints in dryland agriculture: some African and Australian experiences", 30 Aug. - 1 Sept 1993 Harare, Zimbabwe

Agricultural systems research in Africa and Australia: some recent developments in methodology

R.L. McCown and P.G. Cox

Agricultural Production Systems Research Unit,
PO Box 102, Toowoomba, Queensland 4350, Australia

Abstract Soil fertility depletion is a recurring, and increasingly urgent, theme both in sub-Saharan Africa and in Australia. It poses severe problems for a farming systems research approach that focuses on breaking constraints to production in a sequential and isolated fashion, and working with individual farmers. Additional approaches are required to evaluate the design of novel farming systems, and to change the attitudes and behaviour of groups.

When farming systems research (FSR) was getting started in Africa, Australian researchers moved down a different route towards the construction and use of crop models. These are now well-developed and sufficiently reliable for use in operations research. But this activity, and the decision support products it spawns, is also increasingly seen by many as problematic and deficient.

In Australia, we are beginning to recognise that FSR and modelling are components of a wider systems approach. We shall need to bring all our system skills to bear if major problems like soil fertility depletion are to be ameliorated. But the eclectic approach we are developing is, we believe, the beginning of a reproducible and transferable research methodology which could be usefully applied more widely.

Introduction

Society expects professional agricultural researchers to find out what good farming is, and to help farmers do it. But in most of Africa, and much of Australia, few farmers use the practices that researchers think necessary for efficient and sustained production. Why do we not see greater use of existing good farming methods? Is the discrepancy between good farming and much of actual farming due to a failure of researchers to appreciate sufficiently the realities which farmers face, or to our failure to help them change to something better? Is this discrepancy due to inadequate attention to technology design leading to the promotion of inappropriate technologies? Or to a failure to communicate well enough about the relative costs and benefits of alternative strategies?

In 1985, the Australian Centre for International Agricultural Research (ACIAR) hosted an international workshop on *Agricultural Systems Research for Developing Countries* (Remenyi, 1985). At this meeting, these questions were addressed in the context of both eastern and southern Africa (Norman and Collinson, 1985) and Australia (Remenyi and Coxhead, 1985). While encouraging progress was reported, deficiencies in methodology for providing answers were obvious. The aim of this paper is to consider these generic questions and some recent developments in methodology used to answer them. We take as an example the decision to invest in soil fertility improvement in situations where soils are seriously depleted but where the economics of nutrient replacement is problematic because production is so often water-limited. This situation applies in many parts of Africa and Australia.

Soil fertility in sub-Saharan Africa

Another paper at this workshop has described the serious problem of soil fertility depletion in a region of Kenya (Probert et al., this volume). In the 1970s, Ruthenberg highlighted the growing importance of the issue of soil fertility maintenance in farming systems of the African savanna zone, and predicted that soil degradation would become more general as pressure on land resources increased (Ruthenberg, 1980). Broekhuyse and Allen (1988) describe the destruction of the productive capacity of the Mossi plateau (Burkino Faso) by its inhabitants, and the social processes of over-exploitation which apply to much of the savanna zone. Lynum (1978) has described a similar process in the Machakos and Kitui Districts of Kenya. The causes of over-exploitation (high rates of rural population growth, shortage of suitable land for further expansion of cropping, and poverty which precludes replacement of soil nutrients at rates that will sustain productivity) already operate over much of Africa on scales, and to degrees, varying from worrying to catastrophic.

The problems of land degradation and low productivity are now so widespread in semi-arid Africa that it is easy to forget that this is not the natural state. Broekhuyse and Allen (1988) report that while 400 kg/ha is today considered a *good* grain sorghum yield on the Mossi Plateau, an ethnographic survey indicated that this is half the *normal* yield of former times. This decline has taken place over four generations - a rate that was perceptible within each generation, but not high enough to cause alarm.

The longer the delay before investing in soil fertility replacement, the greater the nutrient response and the higher the rate of return on the investment. Matlon (1987) refers to an FAO rule-of-thumb that adoption of fertiliser requires a 100 percent return on investment i.e. a 2:1

benefit cost ratio. He reports a value of 350 percent for sorghum in areas of Burkino Faso in the early 1980s when the rate of fertiliser use was increasing. But as population increases, fallows shorten, soil fertility declines, and poverty deepens. While the potential response to a unit of nitrogen increases under these circumstances, the financial resources needed to purchase fertiliser progressively decline. These authors rule out fertiliser as a feasible innovation because it represents such a large, and increasing, proportion of the average annual income. The only action that might break the physical resource constraint is thus precluded by poverty.

Amelioration of soil fertility decline in sub-Saharan Africa will require enormous changes in education, public policy and administration. But the confusion that exists about the nature of the problem, and the availability of technical options, is puzzling. The technical constraints on any solution are clear:

1. Nitrogen and phosphorus are the elements in most short supply.
2. Most strategies for *avoiding* the constraint actually increase the efficiency of *depletion* e.g. better-adapted plants, increased water-use efficiency.
3. Animal manure can supply the required nutrients, but there is not nearly enough manure in cropping regions to prevent further decline.
4. Chemical fertiliser needs to be supplied, but in conjunction with manure to maintain sufficient organic matter levels and prevent acidification.
5. Poor management of high input systems in industrialised countries has created specific environmental problems. But this provides no grounds for protecting the fertility-impoverished environments of the tropics and subtropics of Africa and Australia from this remote risk.
6. Grain legumes do not provide a net increase in soil nitrogen, even when P is sufficient.
7. The conditions for successful legume ley pasture systems do not exist in Africa (e.g. affordable P fertiliser for pastures, good returns in animal enterprise from investment in sown pastures). In regions with most need, population pressures are too great for this level of cropping intensity.
8. Trees in semi-arid cropping systems are a mixed blessing. Some can provide useful amounts of nitrogen (e.g. leucaena alley cropping) and others recover nutrients at depths beyond the crop root zone. But they compete so strongly for water and nutrients that they are frequently detrimental.

Farming Systems Research in Africa

Farming Systems Research (FSR) emerged as a research approach in the late 1970s and underwent much of its development and testing in Africa. At the time of the ACIAR conference in Australia, Norman and Collinson (1985) could state that "nowhere is...increasing commitment [to FSR] more obvious than in the Eastern and Southern Africa region where we work". Although Collinson's FSR schema has been re-used by numerous authors, we do so again because it depicts the approach so clearly and succinctly (Figure 1, adapted from Anderson et al., 1985). The aim is efficient use of scarce resources for research, development and extension in delivering practical benefits to farmers. To Remenyi and Coxhead (1985), the key question in FSR is: why does this farmer farm as she does? In this paper, we highlight the other side of this question: why doesn't she do certain things that would be, apparently, in her interest? In FSR, these questions about technology design are explored using a step-wise process of *on-farm diagnosis*; *planning*, using an operational research approach; targeted *component research* on research stations when required; and *on-farm testing* of promising alternatives.

We can consider the merits and limitations of FSR by looking at the *Diagnosis, Planning* stages and the *scale* aspects of this approach in relation to the issue of soil fertility decline.

Diagnosis

On-farm measurement is central to the diagnosis of soil fertility decline. But measuring the status of soil nutrients such as nitrogen (N) and phosphorus (P) is made difficult and expensive by the heterogeneity of soil fertility on smallholdings due to, for example, non-uniform return of manure. Nor, in general, has experimentation on fertiliser application rates provided a reliable basis for management. Here the heterogeneity problem is compounded by the variable and unpredictable occurrence of other constraints, e.g. water deficits, pests, diseases and weed infestations, all of which result in a reduced response to added nutrients. Conclusions about the state of soil fertility in Africa based on a synthesis of large numbers of fertiliser response trials greatly underestimate the size of the problem.

While precise problem diagnosis is not easy, and perhaps not even feasible under such conditions, it is inescapable that farming cannot continue unless nutrients removed in crops, or lost in other ways, are replaced. Yet this is almost never achieved in contemporary smallholder agriculture. The common explanation is that farmers with very low incomes cannot afford to buy inputs.

Planning

At the earlier ACIAR workshop in Australia, Norman and Collinson (1985) offered two possible ways of dealing with a constraint in the farming system: *relieve* it, or *avoid* it by exploiting flexibility in the system. They observed that "flexibility in management is enhanced when there are under-utilised resources, while increasing productivity is vital to breaking constraints". Later, Norman and Collinson state, "if one looks at the success of FSR work to date, much of it can be attributed to exploitation of flexibility rather than breaking constraints". And finally, "we submit that breaking a constraint is a much more difficult problem for both researchers and farmers than the strategy of exploiting flexibility. However, major long-term increases in productivity have to come through breaking constraints".

Seven years later, Waddington (1992) reported examples of successful on-farm experimentation by FSR teams. He observed that most examples could be regarded as "fine tuning" of existing technologies in environments with some slack in resources. Where technologies did not already exist, and in regions with great pressure on resources, little success was experienced.

An indication that Norman and Collinson (1985) had not substantially engaged the issue of soil fertility maintenance is their statement that "we believe that criteria used in developing improved strategies should reflect the felt needs of farming families, providing these are compatible with the needs of society (e.g. there is not a decline in soil fertility...)". This implies that an innovation with a negative effect on soil fertility would be exceptional. We think it is now clear that an innovation (such as a higher yielding cultivar) which exploits slackness in resources necessarily *accelerate* soil fertility depletion unless some of the increase in returns is invested in fertility inputs.

In the relatively favourable environments in which FSR has had its successes, relief of soil fertility constraints may be seen mainly as Norman and Collinson (1985) did, as necessary for "major long-term increases in productivity". However, where resources are under pressure, relief of soil fertility constraints is required to enable farming to continue to be viable as a means of sustaining low income subsistence and not degenerate into the environmentally-destructive, and ultimately self-destructive, activity of "survival farming" (Broekhuyse and Allen, 1988).

Scale

Broekhuyse and Allen (1988) distinguish the anglophone style of FSR and the francophone style, which has a more institutional, regional and long-term emphasis. They found the latter more useful when the problem was collectively-destructive behaviour at the scale of landscapes by farmers each acting in her own best (short-term) interests. Changed behaviour did not occur unless the unit undertaking change was the village rather than the individual.

The failure of FSR to deal with issues of land degradation, such as soil fertility depletion, stems partly from its focus on the welfare of individual farmers, their perspectives of their own needs, and of the choice of remedial actions within their control. While focus at this scale constitutes the strength of the FSR approach for many issues, other scales are important for the management of soil degradation.

On the Mossi Plateau, the francophone style of FSR, while casting the problem in a wider context, did not result in the breaking the soil fertility constraint. The fundamental problem is a scarcity of a costly resource which is unaffordable by most farmers. In those parts of the world where sustainable agricultural systems are well-developed, the means for preventing serious fertility depletion are well known and the cost of the necessary inputs is accepted (and acceptable). However, where circumstances force economically-rational farmers to farm in ways that are unsustainable and damaging to present and future society, there is a need for innovative policy initiatives. Soil erosion is a problem in political economy. Additional approaches are required (Biggs and Farrington, 1993).

Systems Research in Australia

FSR has not been seen as appropriate to the R&D needs of Australian farmers. Scientists have assumed they knew their needs well enough, and that farmers could readily fit new R&D products into their systems. Systems research has mainly taken the form of economic modelling, simulation modelling and decision support systems (Remenyi, 1985). But agricultural R,D&E institutions in Australia increasingly recognise the value of a richer systems approach to meet the challenges presented by the complexities, uncertainties and conflicts in modern agricultural production. People-oriented systems approaches now exist alongside the "hard" systems approaches. These have drawn heavily on Soft Systems Methodology (Checkland, 1981; Checkland and Scholes, 1990).

Another development has been to combine simulation modelling of agricultural production systems with the client-orientation of FSR (McCown, 1992). The establishment of the Agricultural Production Systems Research Unit (APSRU) by the CSIRO Division of Tropical Crops and Pastures and the Queensland Department of Primary Industries is an example of this. APSRU is a team of 17 professionals with a charter to facilitate collaboration and convergence of R,D&E effort for dryland agricultural production systems.

APSRU's primary mandate region is the subtropical grain-growing areas of eastern Australia. Although it is more variable than for the cropping regions of Africa, the climate of this region of Australia is similar to that of southern Africa. In spite of high yield variability caused by unreliable rainfall, the region developed into a major producer of both winter and summer grains and the most important source of prime hard wheat. Rain rarely allows double cropping. Rain stored during a previous clean fallow provides much of the water for most crops. Grazing of cattle or sheep is also important on most grain farms, but ley pastures are rare. In recent years, dryland cotton has become an important crop.

Total nitrogen in the pristine black cracking clay soils was originally high (> 0.3 percent on some soils). In some areas, cropping had been practised without nitrogen fertilisation for 50-80 years before crop decline became evident. R,D&E during this period focused primarily on relieving biological and physical constraints to the exploitation of the rich soil resource through new crops and cultivars, and improved water conservation and utilisation.

But it has become clear, with a dramatic decline in protein content of wheat and consequent loss in financial returns, that the "honeymoon" is over. Soil nitrogen, and particularly the economics of nitrogen supply, are amongst the most important issues in this farming system. Soil erosion, especially during summer fallows when rainfall intensities are high and decomposition rates of surface residues are high, exacerbates the problem.

Technological components

Figure 2 depicts four technological components which are widely held by professional agriculturalists to be key ingredients of profitable and sustainable cropping in this region now and increasingly in the future: opportunity cropping, conservation tillage, fertiliser and purposeful crop sequence. Each of these is important in its own right but they also interact in a complex way to influence the supply of water and N, and their use by crops.

Opportunity cropping is the strategy of planting whenever there is adequate soil water for the establishment and growth of a crop. This is a flexible response to the weak seasonality of rainfall. This strategy has been promoted as a soil conservation measure because it maximises crop cover of soil. Even though average crop yields are reduced *vis a vis* regular winter/summer cropping and fallowing, more crops are produced. The need to plant large areas quickly following a rain makes reduced or zero tillage techniques an attractive companion practice to opportunity cropping.

Conservation tillage is the strategy of reducing tillage and retaining stubble. It is an important means of increasing the efficiency of capture and retention of rainfall, as well as an effective measure for conserving soil especially during fallow. The technology is well-developed and, while costs are somewhat higher than conventional tillage, yields are often higher in dry years. In good seasons, yields may be more N-limited than with conventional tillage unless additional nitrogen is supplied.

Nitrogen fertiliser use is gradually increasing, but there are still many farmers who have never used it. This is despite abundant evidence that grain protein and/or yield is depressed by nitrogen deficiency in many seasons on their farms. Its use is seen as expensive and risky.

Legumes in rotations are increasingly being viewed as an alternative source of N for cereals. Whereas grain legumes are well-established cash crops, they do not leave much N behind. Except in the more favourable areas where lucerne is well adapted, there are major uncertainties about the technical and economic feasibility of pasture legume leys.

While these strategies are widely viewed by professional agriculturalists and some farmers as the most promising ingredients for good farming, only a few farmers appear to combine these imaginatively in the search for the "ideal" system for managing soil water and nitrogen in this difficult environment. The situation is analogous to that in Africa. A major part of APSRU's research involves asking the "why?" questions raised in our opening paragraph, and seeking answers in a number of ways.

APSRU's developing systems approach

APSRU's framework for R,D&E is shown in Figure 3. Although we have drawn heavily on Collinson's figure (Figure 1), there are significant differences between APSRU's approach and Collinson's FSR processes. We see these as enhancements that both suit the needs of our farming and institutional environments, and utilise our particular research strengths.

We view farmers as our primary clients, but we are also concerned with the decision problems faced by a range of other decision-makers (Figure 3, top) who have a stake in the performance of agricultural production systems and whose decisions influence, and are influenced by, farmers. These clients experience many of the same uncertainties as farmers, especially those concerning rainfall and prices.

Our aim is to contribute to better management and planning decisions (Figure 3, right). In order to do this, we believe that professional agriculturalists must have sufficient understanding of the context and structure of decisions (Figure 3, left). In general, farmers have evolved simpler rules for the management of key technological components that are as effective as the more complex rules generated by professional R,D&E (Cox et al., 1993a). In many cases, the farmers' rules are likely to be more effective because they recognise better the inter-dependence between the use of different components, and the open character of agricultural production systems. What we do needs to fit in with farmers' existing models or clearly demonstrate just how our way of doing things is better.

Simulation of agricultural production systems is an important ingredient of our approach (Figure 3, bottom). Other papers in this workshop provide a comprehensive account of where we are in the development of this capability. We take a utilitarian approach to modelling: we use process models when and where this provides a research advantage. As was clear from the paper by Jones et al. (this volume), we have been conducting experiments in farming systems research longer than we have been using models, but we found that experimentation has serious limitations in addressing many of the important issues.

An example is the difficulty of using experiments to assess the economics of nitrogen fertiliser where seasonal water supply is variable and unpredictable. Fertiliser response and net returns vary from strongly positive to strongly negative, and repetition for long sequences of years is needed to find an optimal strategy. Using historical weather records and models of maize and sorghum to predict grain yield under widely differing water and soil N conditions, Carberry et al. (1991) showed that the economic prospects for dryland cropping in a region of northern Australia are not sufficient to warrant further agricultural development. The provision of equivalent information experimentally would have required *400,000* plots (locations *times* years).

Recognition that simulation models can complement and add value to field experimentation in FSR has been recognised by others (Collinson, in Ruthenberg, 1980; Anderson et al., 1985; Waddington, 1992). But, practitioners of FSR have judged, with rare exception, that the cost of getting models to a stage where they could do the job reliably was prohibitive (Collinson, 1982). Like some before us (e.g. IBSNAT; Thornton, 1991), we have decided to invest in the development of this capability. This has involved identifying the best biophysical models available with which to start and then testing and modifying these to improve prediction in the semi-arid tropics and subtropical regions in which we work. While adequate prediction of crop performance is critical to the utility of these models, we also have a strong focus on the simulation of soil processes (especially water balance, erosion and nitrogen balance) as they are influenced by management. We have built a novel software environment (APSIM) for developing, testing and using crop and other component models in systems research (McCown et al., 1993). This further reduces the overheads in using models in operational research within FSR (Figure 1, centre).

We draw heavily from operational research in our systems approach (Figure 3, bottom). This involves study of the performance of farming systems primarily in terms of production efficiencies, production and price risks, and cumulative effects on the soil resource. The emphasis is on the economic consequences of alternative actions over time. This is the starting point for addressing the question of "why don't more farmers invest more in soil fertility".

Systems research on soil fertility management and restoration

We are trying to find out, in the croplands of both Australia and Africa, whether farmers who appear to be under-investing in soil enrichment understand their economics better than professional observers or whether they do not adequately appreciate the benefits of nutrient inputs and/or the penalties of continued exploitation of their soils. The answers have important implications for agricultural extension and for policy development. Achievement of this research aim is made difficult by spatial variation in circumstances between farms, and even between paddocks, which cause variation in benefits and opportunity costs. But an even greater obstacle to clarity is the variation in response to N inputs caused by unpredictable variation in seasonal rainfall.

Our approach in Australia to research on the management of soil fertility decline involves on-farm experimentation with farmers, (Figure 3, upper centre), especially on the costs and benefits of nitrogen inputs. Many farmers do experiments and even more have experiments in mind. We offer support for, and enhancements to, farmers' experiments, actual or latent. Both the content and the design of simple on-farm experiments are set by the farmers, subject to some revision after negotiation with researchers (Cox et al., 1993b). Treatments are negotiated with, and managed by, the farmers. Researchers help in planning, monitoring, interpretation of the results, and generalisation to other years and other sites. Experimental treatment areas are often simple splits of commercial paddocks. These usually involve nitrogen fertiliser rates in relation to paddock history, time of application, or crop species. Of particular interest are trends over time in responses to applied N following a legume crop or pasture, or a dry year when little or no N is used by the crop.

Although this is an attractive way of keeping research relevant to practice, there is no mystery as to why so little work of this kind has been done before. First, no matter how obvious the treatment differences, variation in water supply among seasons and the interaction between N and water supply are so great that it is difficult to attach much strategic meaning to the outcomes during an inevitably short experimental period. Second, this approach violates the assumptions of classical statistical analysis required to isolate the yield variance attributable to treatments i.e. replication and randomisation. The simulation model configured for the soil properties and initial conditions, the crop cultivar, and for each management treatment successively, and run using weather data measured during the experiment, is used to compensate for theoretical deficiencies in experimental design. To the degree that the model successfully simulates the experimental results, both experimental and uncontrolled variation are simulated by the model. If the experimental results are simulated satisfactorily, simulation of the experiment in all the years for which rainfall data are available provides a means of identifying superior management strategies.

A similar procedure provides a way to estimate the value for a decision about fertiliser use of the information in a seasonal weather forecast such as that based on the Southern Oscillation Index (SOI). This was demonstrated by McCown et al. (1991) for Response Farming in Kenya. The modelling approach provides a means of comparing management strategies in terms of long-term effects on productivity as influenced by erosion (Littleboy et al., 1992) or by changes in soil organic N (Probert et al., this volume). While these last two effects are of interest to farmers with a long-term view of the productivity of their land, the broader community also has a stake in the way in which agricultural land is used, and is paying increased attention to these issues. In Australia, farmers are increasingly conscious of this pressure.

In Africa, several lines of research stand out as having high potential benefits for the amelioration of soil fertility decline:

1. Find cost-effective ways for more efficient capture, storage and use of manure on crops, taking into account the effects on the main source of manure, the pasturelands, which are also suffering nutrient depletion.
2. Use experiments to test various FASE (Fertiliser-Augmented Soil Enrichment) strategies (McCown et al., 1992) for combining applications of chemical fertiliser with manure, crop residues and composts; and use simulation to facilitate economic comparisons of these technologies over longer sequences of highly variable years.
3. Provide a modelling framework to extrapolate the results of research on biological strategies for soil enrichment. These include: various legumes in rotations; legumes as intercrops; and trees in cropping systems.
4. Research the economics, including evaluation of the risks, of alternative soil enrichment strategies for different levels of inputs, and cost and price scenarios. Clients include farmers, R,D&E institutions and policy makers.
5. Provide inputs to analyses that contribute to formulation of improved national policies on agricultural commodities, food security and fertilisers.
6. Communicate with policy-makers that no achievements in agricultural R,D&E can negate the need for some fertiliser inputs if farming is to be sustainable. And keep this on the policy agenda.

In APSRU, we are attempting to bring the complementary approaches of FSR and computer simulation together to address the deficiencies of both. Outstanding issues include: (1) the feasibility of constructing models of farming systems that are both sufficiently realistic for operations research and which reflect the way in which farmers see the problems of managing their systems; (2) the need to combine economic and ecological perspectives; (3) the need to combine our new skills in crop modelling with more traditional economic models for operations research; (4) the need to develop and use these tools to improve communication between farmers and researchers rather than isolating them still further; and (5) to design and use tools that support intervention at different scales, ranging from individual farmers and farmer groups to local, regional and national policy.

Concluding Remarks

It is clear that there is disappointment in both national and international R,D&E organisations that FSR has not resulted in greater change in the way farming is practiced in southern Africa. But it is most important that this be interpreted as *limitations* of an approach that has provided, and will continue to provide, a valuable framework for research. In Australia, we are using a version of the FSR framework to structure our research on the management of our agricultural production systems. We see the systems approach of Figure 3 as an adaptation which retains the strengths of both the anglophone and francophone FSR schools. It will become more effective as the operational research capabilities mature and as it becomes more firmly embedded in a participatory design process.

The success of Australia's APSRU approach requires models and thinking that are up to the task. Progress in development is evident from previous papers in this workshop. The main technical deficiencies of models for assisting FSR in southern Africa (Waddington, 1992) are dealt with in APSIM (extreme N deficiency, rotations, intercropping, weed competition, and crop-livestock integration, as well as erosion). However, much work is needed to see how well these models predict over a wide range of circumstances. In Australia, networks of stakeholders in a better systems research approach are emerging to test and adapt these models and to develop innovative ways of using them to support both participatory on-farm experimentation with farmers and the management of experimental databases. Improved communication is an essential component of the approach.

Farming systems in northern Australia and much of Africa share important problems: declining soil fertility and productivity, and substantial risks associated with any private investment in soil fertility improvement. We believe that the eclectic approach we are developing is a reproducible and transferable research methodology that will be widely applicable both in Australia and Africa.

References

Anderson, J.R., Dillon, J.L. and Hardaker, J.B. (1985). Socioeconomic modelling of farming systems. In: Remenyi, J.V. (Ed.). Agricultural systems research for developing countries: proceedings of an international workshop held a Hawkesbury Agricultural College, Richmond, N.S.W., Australia, 12-15 May 1985. ACIAR Proceedings No. 11, pp. 77-88.

Biggs, S.D. and Farrington, J. (1993). FSR and the rural poor. Journal for Farming Systems Research-Extension 3 (2): 59-82.

Broekhuyse, J. Th. and Allen, A.M. (1988). Farming Systems Research on the northern Mossi Plateau. Human Organization 47 (4): 330-342.

Carberry, P.S., Cogle, A.L. and McCown, R.L. (1991). Future prospects for cropping in the semi-arid tropics of North Queensland. Final Report to the Australian Rural Industries Research and Development Corporation.

Checkland, P. (1981). Systems thinking, systems practice. Chichester: Wiley.

Checkland, P.B. and Scholes, J. (1990). Soft systems methodology in action. Chichester: Wiley.

Collinson, M.P. (1982). Farming systems research in Eastern Africa: The experience of CIMMYT and some national agricultural research services, 1976-81. MSU International Development Paper No. 3.

Cox, P.G., A.L. Garside and McCown, R.L. (1993a). Market research for decision support for dryland crop production in Central Queensland: a preliminary report. Proceedings 7th Australian Agronomy Conference, Adelaide, September 1993. pp. 332-335.

Cox, P.G., A.L. Garside and McCown, R.L. (1993b). Participatory design of an agronomic on-farm research program in Central Queensland. Proceedings 7th Australian Agronomy Conference, Adelaide, September 1993. pp. 325-327.

Jones, R.K, McCown, R.L. and Kusewa, P.K. (This volume). Linkages between Australia and Africa in agricultural research for the semi-arid tropics.

Littleboy, M., Silburn, D.M., Freebairn, D.M., Woodruff, D.R., Hammer, G.L. and Leslie, J.K. (1992). Impact of soil erosion on production in cropping systems. I. Development and validation of a simulation model. Aust. J. Soil Res. 30: 757-774.

Lynum, J.K. (1978). An analysis of population growth, technical change, and risk in peasant, semi-arid farming systems: a case study of Machakos District, Kenya. Ph.D Thesis, Stanford University, California.

Matlon, P.J. (1987). The West African semiarid tropics. In: Mellor, J.W. , Delgado, C.L. and Blackie, M.J. (Eds.). Accelerating food production in sub-Saharan Africa. Baltimore: Johns Hopkins Univ. Press. pp. 59-77.

McCown, R.L. (1991). Research in a farming systems framework. In: Squires, V. and Tow, P. . Dryland farming - a systems approach. An analysis of dryland agriculture in Australia. Sydney: Sydney University Press. Ch. 18, pp. 241-249.

McCown, R.L., Freebairn, D.M. and Hammer, G.L. (1992). A framework for research on improved management of agricultural production systems. Proceedings 6th Australian Agronomy Conference, Armidale, February 10-14, 1992. pp. 214-221.

McCown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D. and Huth, N.I. (1993). APSIM: An agricultural production system simulation model for operational research. Proc. International Congress on Modelling and Simulation, Modelling Change in Environmental and Socioeconomic Systems. Univ. Western Australia, Perth, 6-10 December 1993.

McCown, R.L., Keating, B.A., Probert, M.E. and Jones, R.K. (1992). Strategies for sustainable crop production in semi-arid Africa. Outlook on Agriculture 21: 21-31.

McCown, R.L., Wafula, B.M., Mohammed, L., Ryan, J.G. and Hargreaves, J.N.G. (1991). Assessing the value of a seasonal rainfall predictor to agronomic decisions: the case of response farming in Kenya. In: Muchow, R.C. and Bellamy, J.A. (Eds.). Climatic risk in crop production: models and management for the semiarid tropics and subtropics. Wallingford: CAB. pp. 383-409.

Norman, D. and Collinson, M. (1985). Farming Systems Research in theory and practice. In: Remenyi, J.V. (Ed.). Agricultural systems research for developing countries: proceedings of an international workshop held a Hawkesbury Agricultural College, Richmond, N.S.W., Australia, 12-15 May 1985. ACIAR Proceedings No. 11., pp. 16-30.

Probert M.E., Keating , B.A., Siambi, M.N., and Okalebo, J.R. (This volume). Management of soil fertility.

Remenyi, J.V. (1985). In: Remenyi, J.V. (Ed.). Agricultural systems research for developing countries: proceedings of an international workshop held a Hawkesbury Agricultural College, Richmond, N.S.W., Australia, 12-15 May 1985. ACIAR Proceedings No. 11.

Remenyi, J.V. and Coxhead, I. (1985). Farming systems research in Australia: results of a survey. In: Remenyi, J.V. (Ed.). Agricultural systems research for developing countries: proceedings of an international workshop held a Hawkesbury Agricultural College, Richmond, N.S.W., Australia, 12-15 May 1985. ACIAR Proceedings No. 11, pp. 96-107.

Ruthenberg, H. (1980). Farming systems in the tropics. 3rd Edition. Oxford: Clarendon Press.

Thornton, P.(1991). Application of crop simulation models in agricultural research and development in the tropics and subtropics. International Fertilizer Development Center Paper 15: 23pp.

Waddington, S.R. (1992). The future for on-farm crop experimentation in southern Africa. Paper presented at the CIMMYT FSR Networkshop on Impacts of On-farm Research, Harare, Zimbabwe, 23-26 June 1992.

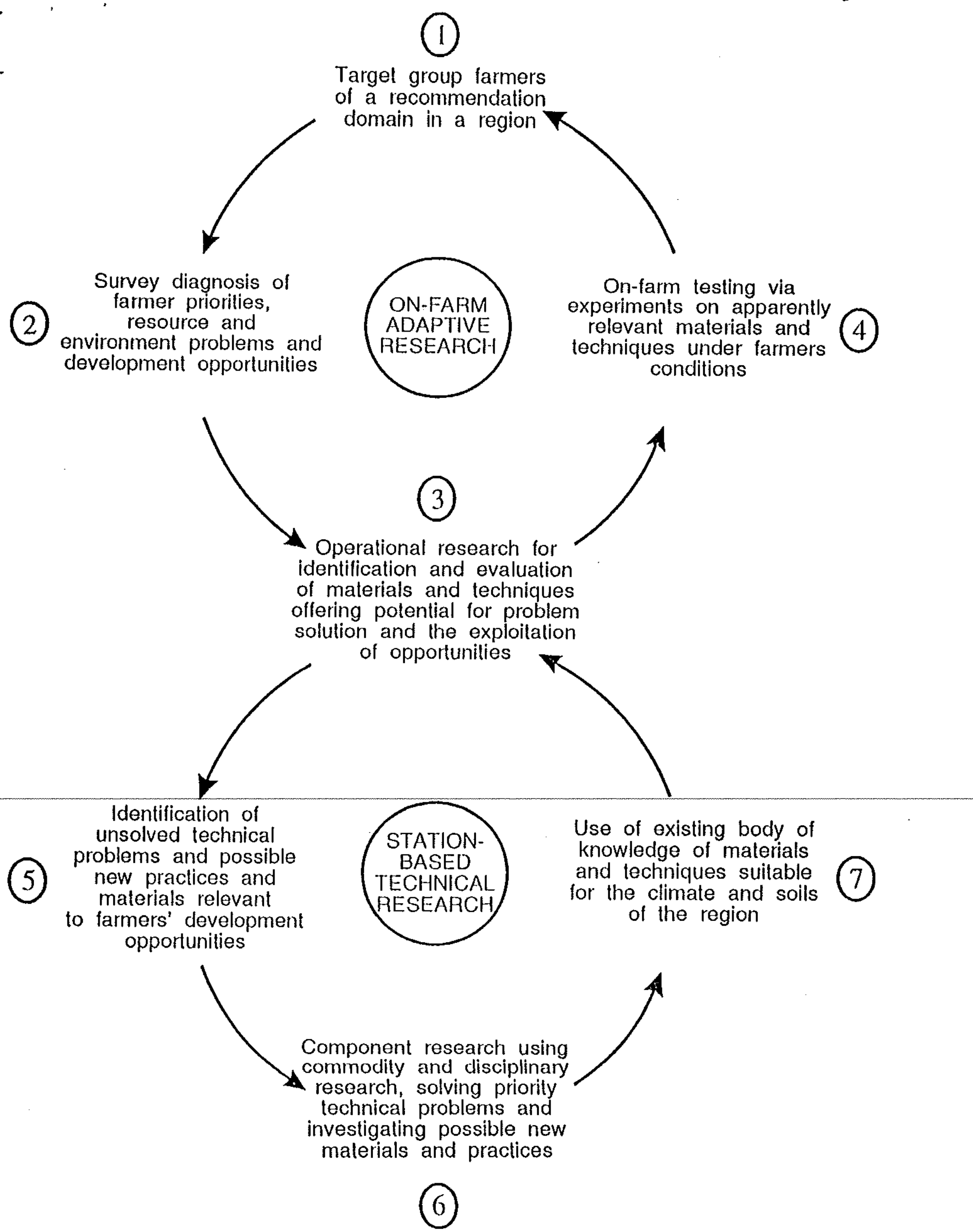
Figure Legends

Figure 1. Schematic of Farming Systems Research methodology (Collinson 1982, modified by Anderson et al. 1985).

Figure 2. Technological components that contribute to improved strategies for managing scarce soil water and nitrogen supplies in subtropical eastern Australia.

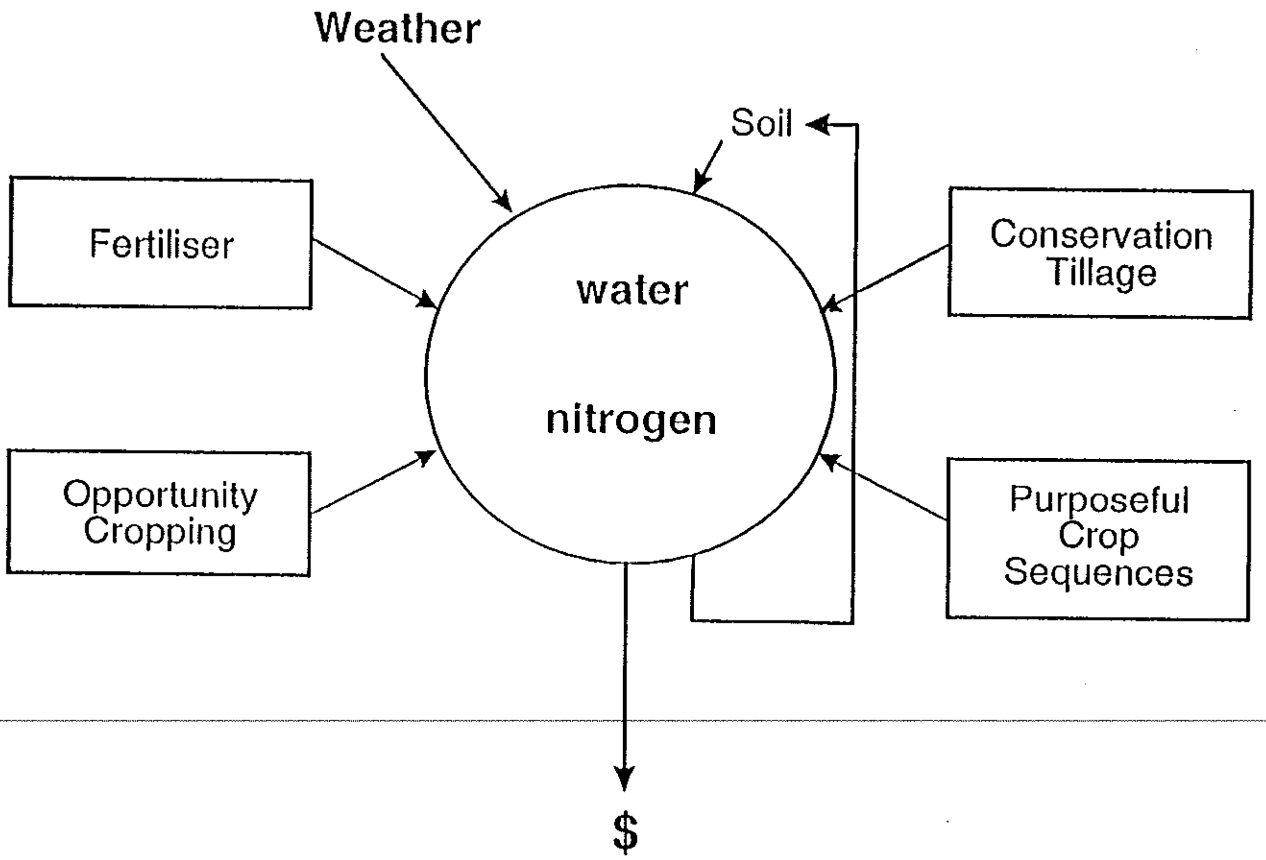
Figure 3. APSRU's framework for client-oriented R,D&E aimed at improving management of production and associated processes in an agricultural system.

Fig 1

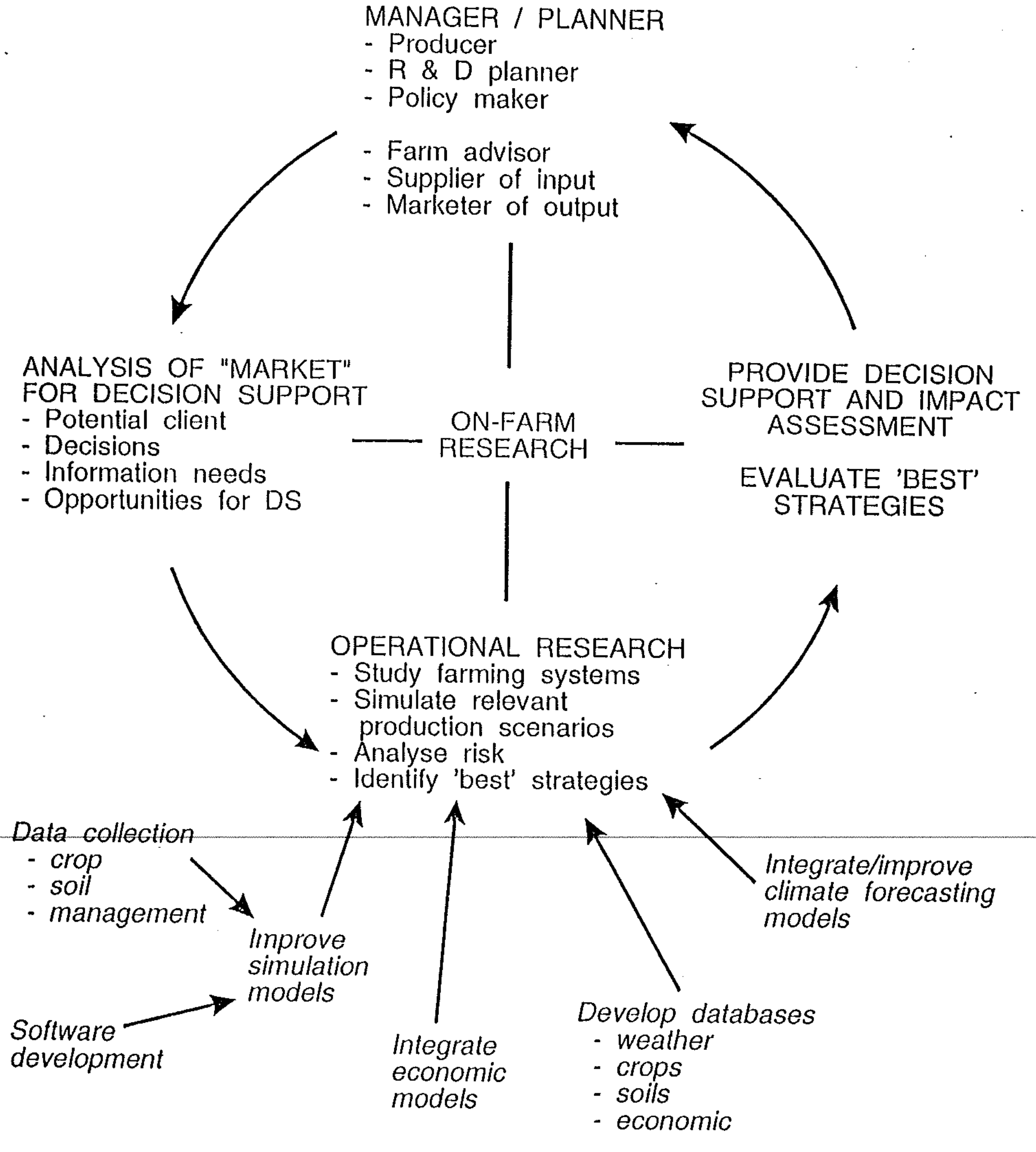


1
Target group farmers of a recommendation domain in a region
2
Survey diagnosis of farmer priorities, resource and environment problems and development opportunities
ON-FARM ADAPTIVE RESEARCH
On-farm testing via experiments on apparently relevant materials and techniques under farmers conditions
4
3
Operational research for identification and evaluation of materials and techniques offering potential for problem solution and the exploitation of opportunities
Identification of unsolved technical problems and possible new practices and materials relevant to farmers' development opportunities
5
STATION-BASED TECHNICAL RESEARCH
Use of existing body of knowledge of materials and techniques suitable for the climate and soils of the region
7
Component research using commodity and disciplinary research, solving priority technical problems and investigating possible new materials and practices
6

Fig 2


Weather
Soil
Fertiliser
water
nitrogen
Conservation Tillage
Opportunity Cropping
Purposeful Crop Sequences
$

Fig



MANAGER / PLANNER
- Producer
- R & D planner
- Policy maker
- Farm advisor
- Supplier of input
- Marketer of output
ANALYSIS OF "MARKET" FOR DECISION SUPPORT
- Potential client
- Decisions
- Information needs
- Opportunities for DS
ON-FARM RESEARCH
PROVIDE DECISION SUPPORT AND IMPACT ASSESSMENT
EVALUATE 'BEST' STRATEGIES
OPERATIONAL RESEARCH
- Study farming systems
- Simulate relevant production scenarios
- Analyse risk
- Identify 'best' strategies
Data collection
- crop
- soil
- management
Improve simulation models
Software development
Integrate economic models
Develop databases
- weather
- crops
- soils
- economic
Integrate/improve climate forecasting models