Decision support for grassland systems in developing countries

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Key points

1. Information flows in complex systems are often themselves highly complex, and decision support approaches based on linear input-output processes may have only limited impact.
2. How decisions are made, and how they can be appropriately supported, is often incompletely understood, in part because of inadequate understanding of the objectives and attitudes of all the decision makers involved.
3. Much of the developing world faces daunting problems in the coming 30 years, and appropriate information could play a critical role in dealing with these.
4. System complexity, household variability, and institutional intricacies have to be embraced rather than avoided, and so decision support might best be orientated towards identifying 'hotspot' areas of the highly disadvantaged and targeting appropriate activities in pursuit of the Millennium Development Goals.
5. Effective decision support could be served by more coordinated efforts to develop and maintain key baseline databases in developing countries, and by innovative, participatory approaches to the processing, adaptation and use of information.

Keywords: models, information, decision-making, intervention mapping, policy

Introduction

Human population in the developing world is expected to increase to 7.6 billion people by 2050, from its current level of 4.7 billion. In sub-Saharan Africa, the numbers of people will more than double to 1.5 billion (FAO, 2004). This is one element in the increase in consumption of animal products projected to 2020, the others being higher incomes, increased urbanisation, and changing dietary preferences (Delgado *et al*., 1999). Livestock production already accounts for about 40% of global agricultural production, and this figure is increasing (FAO, 2002). By 2020, developing countries will be producing some 60% of the global meat supply and 52% of the milk (Steinfeld, 2001). Given the importance of livestock to the diets and incomes of the rural poor (Thomas & Rangnekar, 2004), understanding how livestock fit into these systems, and how these systems may evolve in the future, are issues of critical importance. Clearly, there may be significant opportunities for resource-poor smallholders to benefit from this likely increase in demand for livestock products. At the same time, there may be substantial environmental, social and public health risks for smallholders; some have called attention to possible environmental problems (Barrett, 2001; Gerber *et al*., 2004), and Slingenbergh *et al*. (2002) note that severe imbalances may occur in global livestock development; the promotion of commercial and industrial systems, coupled with stringent sanitary regulations, tends to exclude household-based livestock production systems, in which many poor families are engaged. The concentration of livestock production in urban and peri-urban areas also has direct consequences on public health. If benefits are to accrue to the rural and urban poor, through plentiful supplies of livestock products for consumers and increased production marketing opportunities for producers, then many things have to happen.

Food safety issues will have to be addressed, as will potential deleterious impacts on the environment. Policies will be needed that can remove critical market distortions, and promote institutional change in property rights in commercialising smallholder areas (Delgado *et al.*, 2001). In all this, the implications may be enormous, but their local impacts are difficult to foresee. The situation is complicated by the fact that predicted increases in demand for livestock products over the next few decades will occur in concert with climate change and other drivers of change. These drivers will undoubtedly lead to the intensification of agricultural systems in many places (Staal *et al.*, 2001). Working out the implications of increased demand for livestock products for poverty in developing countries will demand a taxing research agenda.

Given the dynamism of the situation in developing countries, no great foresight is needed to predict an increasing importance in the role of information to help decision makers at all levels in the agricultural sector make appropriate decisions, from international trade policy makers to community organisations and livestock farmers, in the quest for sustainable development. In this paper, a short background section highlights the changing nature of information needs and decision support, and touches on the current status of decision support in developing countries. Some recent examples of decision support tools are then described in the areas of research planning and targeting, policymaking, and livestock management. The final section lists some areas that need attention in the future. 'Decision support' is taken here to refer to a process, involving digital methods at some stage, designed to generate or interpret information to assist decision-making. 'Grassland systems' are also interpreted widely, to include pastoral, agro-pastoral, and mixed crop-livestock (grassland-based) systems. The focus of the paper is on the poor; of the 1.3 billion people globally who live on less than $1 per day, some 600 million of these people keep livestock (Thornton *et al.*, 2002).

Decision support: background and status

McCown, (2002a) traces the history of Decision Support Systems (DSSs) back to the early days of operations research in the late 1940s. The special issue of the journal in which that paper appears is devoted to case studies of DSSs, and McCown (2002b) attempts to explain the fairly dismal record of computer-based DSSs in actually impacting on farmers' lives. He is not alone; Matthews *et al.* (2002) similarly attempt to explain the poor record of crop-soil models outside of the research domain. There are various reasons, but many arise from an inadequate understanding of the context and nature of decision-making. In trying to understand the scope of the issue of information provision in general (of which decision support can be seen as a part), and how it is changing, it is useful to consider the process of innovation itself. A traditional view is that Advanced Research Institutes (ARIs) do upstream research that produces outputs that are then taken on by National Agricultural Research Systems (NARSs) and adapted in some way, to produce something that can then be passed on to the extension services, who then disseminate the innovation to grateful farmers. This simple, linear model has been the norm in the mindsets of many people associated with agricultural research and development for a long time. In many ways, this is not surprising; after all, the Green Revolution can be described as a triumph of this 'Transfer of Technology' approach (Douthwaite *et al.*, 2004). A more modern approach to the innovation process is shown in Figure 1, built around Integrated Natural Resource Management (INRM - Campbell & Hagmann, 2003). Here, the process is anything but linear. Sayer & Campbell (2001) identify three key elements for implementing INRM: management needs to be adaptive; it must move further along the research-management continuum; and the approach must provide for, and be based upon, negotiation among all stakeholders.

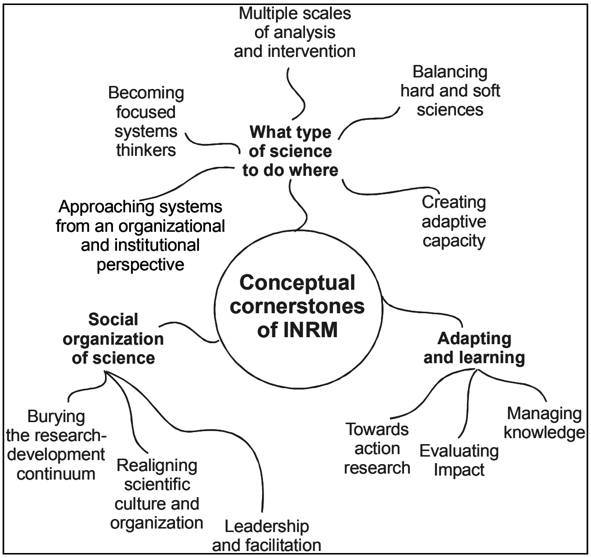

Figure 1 The conceptual pillars of INRM (Campbell & Hagmann, 2003)

It follows that there are key requirements for process facilitation and institutional adaptability if INRM is to be implemented effectively. Decision support tools are seen as being critical to the success of INRM approaches, however van Noordwijk *et al*. (2003), see these more as 'negotiation support systems', in the sense that in complex INRM situations, there are bound to be conflicts between different stakeholders with very different outlooks and objectives. Negotiating resolutions to such conflicts then becomes a key part of the process of INRM research. In any event, however innovation is seen as occurring, there may be niches for decision support at all stages of the process, and the notion of 'a decision maker' has to be expanded to include all stakeholders, not simply the farmer and other direct users of natural resources. The apparently increasing complexity of effective innovation systems has important ramifications for the design and implementation of effective decision support tools; the world is an increasingly complicated place.

Various 'domains' of decision support are shown in Table 1, together with the type of questions that each domain is concerned with, and the tools and information that may be appropriate for helping to answer such questions (NB. Table 1 is by no means exhaustive). 'Decision support' tools may be applied in all domains, involving a wide range of combination of the tools shown in Table 1. For most of these tools, there are numerous recent examples in developing countries, associated with advances in technical power or spatial coverage.

Table 1 Decision support domains, questions to be answered, and tools and information that could be used to address them

Domain	Examples of relevant questions to be answered	Relevant tools	Information sources
Research	Are there adequate frameworks for describing well-understood processes, and can these be easily applied? Do replicable methods and tools for investigating phenomena exist, and can they be easily applied?	Models (conceptual, theoretical, mathematical, etc)	Field data Agricultural statistics
Impact assessment & research planning	What has worked in the past, where, and why? Given limited resources, what should we work on in the future, and where, to maximise research impact? What constitutes a coherent portfolio of research activities that fully addresses an institute's goals?	Models GIS analysis Information systems	Poverty maps Technology intervention maps Agricultural statistics Spatial data layers
Policy formulation	What are the effects of existing policies on different beneficiary groups? What would be the impact of changing institutional and market environments on existing policy outcomes? What would be the impact of policy changes on different groups of beneficiaries?	Policy analysis & sector models Knowledge banks Toolkits Information systems	Agricultural statistics Household surveys
Management & conflict resolution	Which crop and livestock management options are most appropriate for particular conditions, now and in the future? When, where and what type of action should be taken against a crop or livestock disease? Can income be maximised while minimising nutrient losses and maximising capital asset values in livestock?	Models GIS analysis Expert opinion Participatory modelling approaches Integrated assessment	Field data Household surveys Agricultural statistics

For example; Benson (1998) produced maps of spatially- and temporally-variable nitrogen fertilizer recommendations for resource-poor, maize-based crop-livestock systems in Malawi; Thornton *et al*. (2004) provided an assessment of the value of de-stocking decisions in semi-arid grazing lands in southern Africa in response to medium-range weather forecasts of drought; Burnsilver *et al*. (2004) studied the key interactions between livestock, wildlife and pastoralists in Kajiado, Kenya, to help gauge the likely ecological impacts of subdivision of group ranches; and LPP (2004) is one in a series of CD-ROM-based knowledge banks on resource-poor livestock keepers and the animals they keep, in the context of development and sustainable livelihoods, to be used as an information source for informing policy debate.

While the development continues apace of tools and databases that should form strong foundations for different DSSs, the evidence for their use and for them impacting in the four domains shown in Table 1 is more patchy. In the domains of research and impact assessment and research planning, the use of tools and databases is becoming more widespread. For policy formulation and management, however, there is generally less evidence of use and impact. As McCown, (2000b) noted, there may be many reasons for this, but in addition to the increasing complexity of the innovation process associated with research for development, other plausible reasons include the enormous variability in resource endowments and household objectives (making it very difficult to generalise, particularly in the management and conflict resolution domain), and the complexity of information flows between the various stakeholders in any situation. Given a complex and dynamic decision-making context, and the seemingly ever-present problems associated with reliable data acquisition in many developing countries (Minae *et al*., 2003), it is perhaps not surprising that DSSs have yet to demonstrate substantial impact in some domains. The next section presents examples of recent and on-going work in the domains of impact assessment and research planning (PRIMAS), policy formulation (EXTRAPOLATE), and livestock management (Talking Pictures), that show how some of these difficult problems might be partially addressed.

Examples of DSS

Decision support for research planning and targeting: PRIMAS

PRIMAS (Poverty Reduction Intervention Mapping in Agricultural Systems) is a CD-ROM-based tool that is designed to generate an integrated series of maps on the location of resource-poor livestock keepers and associated natural resource, climatological, communication and marketing data layers for different systems. From an understanding of the problems and needs of resource-poor livestock keepers, there may be several technology options appropriate for the production systems under study. Each of these options may be expected to go someway to solving a perceived problem, or opening up new opportunities for livestock keepers. The PRIMAS tool enables options to be filtered by attempting to match the characteristics of particular options with the characteristics of particular target groups in the landscape (as far as this can be done sensibly in terms of spatial data). A prototype has been developed for Kenya, and this is being refined and its coverage extended. This involves the collation of a great deal of spatial information related to climate, weather, soils, forages and forage availability, roads, markets, cities and towns, predominant livestock species, human and animal population densities, and pest and disease risk. PRIMAS includes a small database of interventions for pastoral and dairy systems. These are summarised according to a common format that describes the intervention, who was responsible for developing it, and where it has been (or is being) applied. PRIMAS allows the user to browse all the available data layers, using a ‘map explorer’. The user can carry out a set of overlays, which are basically simple intersections of different spatial data layers. The user can also do simple weighted overlays, where scores or weights can be assigned to the probability of a particular value being associated with a particular spatial variable. Weighting may be useful in assessing variables such as the degree of market integration for target groups, where it decreases with distance from markets and all-weather roads, for example.

PRIMAS uses third-party software, and so can be used and distributed free of any royalty payments. In addition, the user can add interventions and spatial data layers to the system. As an example, consider the distribution of *Pennisetum purpureum* (Napier grass). To map this distribution in PRIMAS, some description of the areas in Kenya where it thrives is needed. Using the information in KARI (1992), *P. purpureum* intervention was described in terms of three constraints: altitudes between 1500 and 2000 m above sea level; rainfall in excess of 750 mm per year, and soil pH greater than 4 (domains may be determined in much more sophisticated ways based on multivariate analysis using discriminant analysis or logistic regression analysis). Figure 2 shows the results in PRIMAS of running (overlaying or intersecting) these three constraint layers.

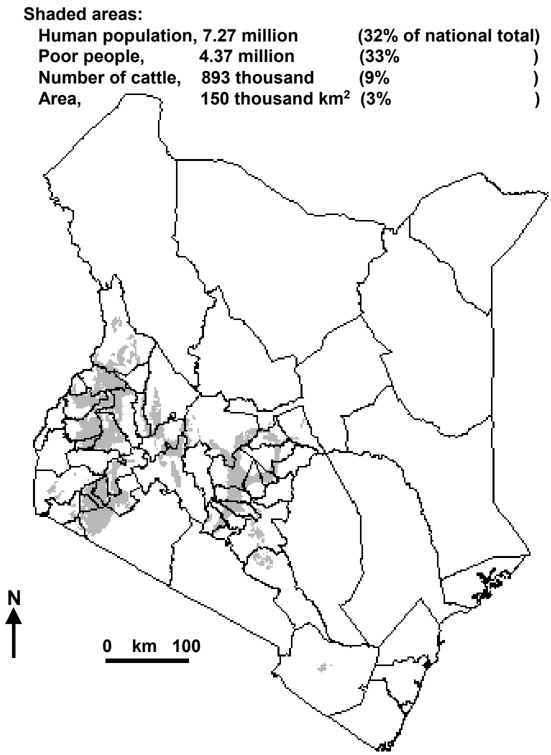

Figure 2 Kenya and district boundaries, shaded areas showing a domain for *Pennisetum purpureum* (Napier grass)

The shaded areas are those that satisfy the constraints relating to altitude, soil pH and annual rainfall, together with tabular output that summarises the area of the domain, the human population, the livestock population, and the number of resource-poor livestock keepers (Thornton *et al*., 2002). In this example, the *P. purpureum* domain contains about 33% of Kenya's human population, but less than 3% of the land area of the country. The prototype of PRIMAS is being tested in a project to assess options, from the point of view of farmers' objectives and attitudes, to improve household well-being. An output of this work is to take the experiences gained from study sites in western, central and coastal Kenya, and extrapolate their relevance to East Africa as a whole. A process of up-scaling is underway, whereby potential domains are identified that are similar to the study sites in terms of agro-ecology, distance to markets, population densities, and farming systems. Field visits are made to randomly selected sites within these domains, to 'ground-truth' the domain identification and, if possible, assess the relevance and potential of involving farmers in trying some of the interventions tested earlier in the project at the original study sites. PRIMAS is being used to identify domains related to the key technology interventions being tested within the project, including methods of manure and cattle urine management, and the growing of small areas of vegetables for the local market (Waithaka *et al*., 2005).

Decision support for policy: EXTRAPOLATE

EXTRAPOLATE (EX-ante Tool for RAnking POLicy AlTErnatives) arose out of the need for a decision support tool to assess the impact, both visually and numerically/verbally, of different policy measures. It is a tool that can serve as a filter (in a similar way to PRIMAS) to sift through (in an *ex-ante* fashion) a range of policy measures, to identify those that could be applied in a specific situation to achieve particular outcomes that further policy objectives of specific decision makers. It was envisaged that this would be the first step in assessing potential impact before looking at a situation in more detail. The framework (Figure 3) is circular, and an analysis might start by identifying the opportunity (number 1 in Figure 3), such as the existence of a rapidly expanding market for eggs around a large town. Who are the potential beneficiaries of this expansion (number 2)? Potentially the peri-urban and rural farmers in the vicinity. Who is currently benefiting from this expansion (number 3)? Only a limited number of these peri-urban and rural farmers. What are the constraints to more farmers benefiting from this expanding market (number 4)? There may be several: for example, many farmers have limited physical access to feeds and markets; commercial producers have a competitive edge; many farmers lack the required husbandry skills; and there are poultry diseases that are constraining smallholder producers. Several policies can be envisaged that might have an impact both on the constraints that currently prevent smallholders from taking more advantage of the expanding egg market, and on other opportunities for increasing incomes (number 5). For example, policies that influence rural infrastructure (roads for access, etc), policies that favour commercial producers at the expense of smallholder producers, and existing sanitation rules. If policies are changed, what are the possible impacts on the constraints, and what are the trade-offs involved (number 6)? For example, commercial producers may suffer; it may result in lower food standards; it may increase peri-urban pollution. So if for example, access to markets is improved, sanitation laws are relaxed, or animal health services improved, what are the impacts likely to be, and who will gain and who lose out?

Mainstream economics has a wide array of tools to assess these sorts of policy changes in a rigorous and quantitative fashion (policy analysis matrices, computable general equilibrium models, etc). EXTRAPOLATE is a rapid screening device, to allow the user to carry out quick assessments of likely candidate policy changes that may have particularly beneficial impacts on the poor in particular situations, the most promising of which can then be analysed further using much more rigorous (and time- and data-intensive) methods. EXTRAPOLATE is still being developed and tested; the framework currently implemented is slightly different from that shown in Figure 3, although the underlying ideas are the same. There are various data requirements for setting up a new case study. First, a set of beneficiaries is defined, together with their livelihood statuses. These may include landless labourers, large commercial producers, smallholder producers, and urban consumers. Next, one or more constraints facing each beneficiary group are identified, such as access to household cash, animal disease, and animal feed supplies. These constraints are then quantified on a scale of 1 to 10 in terms of their importance to each beneficiary group. For example, animal disease may be of no direct importance to urban milk consumers, while access to cash is a significant constraint for smallholders. The next step involves identifying a set of outcomes that are affected by the constraints, such as increased employment, increased milk consumption (with associated health and nutrition benefits within the smallholder household and for local (rural) consumers), increased milk sales (with associated income effects), and increased crop and livestock production (with associated consumer price effects). The strength of the impacts that relaxing the various constraints could have on these outcomes (i.e., the marginal strength of impact) is then estimated by the user. So, for example, if households could gain access to more cash, this might allow smallholders to hire more labour and purchase other inputs to raise production. These different marginal changes in outcomes will have different impacts for the different beneficiary groups; e.g. a change that results in increased employment opportunities may benefit a beneficiary group made up predominantly of hired labourers. Increased milk sales, on the other hand, will benefit milk producers in general, but large commercial producers relatively more than smallholders.

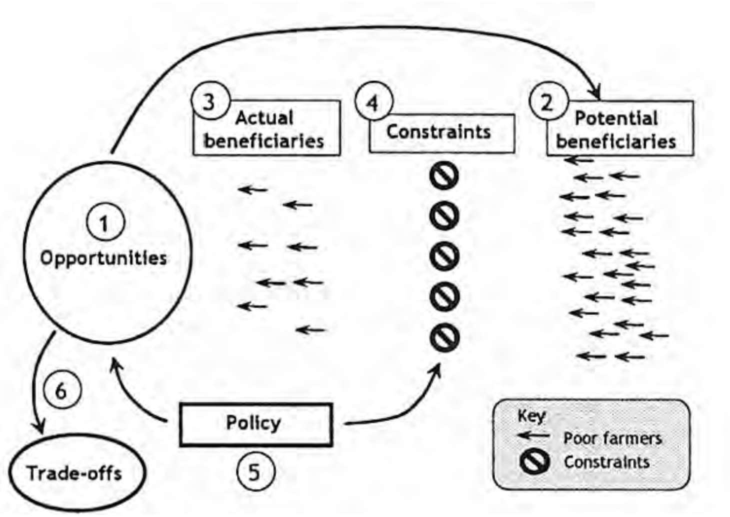

Figure 3 Conceptual model behind EXTAPOLATE

The final data-input step is to identify policies that will have an impact on one or more of the constraints previously identified. These may relate to state provision of veterinary services or to land tenure reform. The potential marginal impacts of each policy on each constraint are then estimated. A policy of subsidised veterinary service provision may have an impact on a disease constraint, but no direct effect on increasing the supply of labour to smallholder households, for example. Once the input data have been specified, the example can be input into the software, and various outputs generated. The livelihood status of the beneficiary groups can be contrasted and compared both before the application of the policy and after, using simple bar charts that reflect any resultant changes in (arbitrary) livelihood scores. Some beneficiary groups may benefit directly from the new policy, while others may be adversely affected. The tool can also summarise the trade-offs amongst beneficiaries that arise from the application of the proposed policy.

EXTRAPOLATE is still highly experimental, but is being tested in Senegal, Kenya and Uganda as part of FAO's Pro-Poor Livestock Policy Initiative. Spatial components are being added to EXTRAPOLATE, so that beneficiaries and constraints can be mapped, where this is appropriate. The usefulness of EXTRAPOLATE for detailed policy analysis remains to be demonstrated, but initial indications are that it has much to offer as a framework for promoting focussed thinking about a case-study and as a rapid screening tool.

Decision support for farmers: Talking Pictures

This example highlights the work of Thorne & Dijkman, (2001) and Dijkman & Thorne, (2003). The lack of effective linkages among research, extension and farmers is a global problem, and there is a real need to generate information in a way that can simplify interactions between extension services and farmers, and that allows farmers to be actively involved in the evaluation of options. As a response, they (Thorne and Dijkman) developed a software package called Talking Pictures, a dynamic, pictorial system used to represent the nutritional management of dairy cows in smallholder farming systems. Talking Pictures makes use of the Dairy Rationing System for the Tropics (DRASTIC) - itself a decision support tool for planning dairy feeding under tropical conditions (Thorne, 1999). DRASTIC is built around a detailed biological model of protein and energy nutrition, and predicts milk production levels when animals are fed a particular mix of feeds. The nutritional variables needed in the model are assessed from simple indicators of feed quality, so that animal performance predictions can be made for variable feed compositions in the absence of highly quantitative data.

Talking Pictures generates pictorial guides that can be printed out and used in the field. These guides consist of several separate pictorial layers that incorporate information on the genotype, animal condition, the stage of lactation and physiological status, the calf rearing system being used, and the quantity and quality of basal and supplemental feeds. The different layers are dynamically linked, and provide pictorial information concerning expected production outputs, costs, and income. Each hard-copy guide produced in Talking Pictures is generated in such a way that the user can choose one of three options that are appropriate to the user's own conditions (stage of lactation, physiological status, animal condition, etc). Each option is either colour- or pattern-coded, depending on whether colour or black-and-white printers are used to generate the hard-copy guides. The pattern or colour for each of the chosen input layer options is transferred with dry-wipe markers to a reusable laminated 'credit card', leading to a unique sequence of five colours or patterns. In an example developed for Kiambu, Kenya, there are option layers for three stages of lactation, three forage quality levels, three calf rearing systems, and three levels of body weight change (in the software, each of these levels has an appropriate, local picture associated with it). The sequence chosen by the user is then matched to the appropriate sequence out of all the available possibilities, which are listed on three pages and linked to a pictorial representation of the expected production level for the animal in question. The user can then turn to the appropriate supplementation page - indicated by a picture of the expected production level. Different pictorial representations can then be selected of supplementary feeds and different levels of supplementation, which are connected to a picture of the total milk production expected. Each of the supplementation choices also supplies pictorial data on the ratio between milk and concentrate prices at which supplementation of the chosen quantity becomes profitable. In preparing a new guide for a specific area and situation, pictures of the appropriate cow genotype, calf rearing systems, recognizable quantities of feed and milk, and types of concentrates, need to be assembled. These can then be entered into a picture library within Talking Pictures and can then be linked to appropriate biological input data for running DRASTIC. Assembling appropriate photos requires the determination and testing of unit sizes and weights for basal diets, supplements and milk, as well as locally-recognizable pictorial representations of calf feeding systems, stage of lactation, animal conditions, and farmers' perceptions of fodder quality.

A prototype of Talking Pictures was developed for dairy systems (TP-D) in Tanzania, Kenya and India, using participatory methods. Dijkman and Thorne (2003) note that TP-D represents a real innovation in effectively enhancing farmers' personal, dynamic and science-based decision-making capacity that has not been offered by previous static extension materials. Farmers using TP-D increased milk off-take compared with control groupss, augmenting milk-derived income often by as much as 25%. Many of the farmers exposed to TP-D in Tanzania were still using the methodology two years later. The ease with which TP-D guides, based on a format originally developed in Tanzania, have been produced for another country (Kenya) and another sub-continent (India), and the ease with which smallholder farmers in these areas effectively use the guides to address their most significant dairy feeding problems, has shown that TP-D is both valuable and generic. TP-D is currently being applied in further pilot sites in India.

The future

The way in which research for development is done continues to change enormously, and working out the implications for providing effective decision support in an increasingly complex and dynamic environment is an on-going and difficult task. Clearly, all the relevant stakeholders have to be fully involved, and the dimensions of smallholders' problems have to be adequately understood; this includes understanding the nature of household decision making, and what it takes to make it more effective; understanding the flow of information between all the various stakeholders; understanding how new or different knowledge can help; and understanding better how researchers can build on indigenous knowledge that has been accumulated by livestock keepers over many years.

Research for development and poverty alleviation is faced with considerable challenges. On the one hand, enormous impacts are needed if the Millennium Development Goals (Morton, 2001) are to be even partially achieved – the need for up-scaling of local successes is critical. On the other hand, the more that is understood about the importance of local conditions, the variability associated with householders' attitudes and objectives and the socio-cultural milieu within which householders operate, the more challenging it becomes to identify the huge gains that may be widely applicable to vast areas and millions of people. One way to deal with this tension may be to acknowledge that impacts (of policy, technology, information provision, etc.) may often be relatively localised, and that appropriate targeting then becomes critical if the poor are to be reached. Appropriate targeting, however, is highly dependent on data availability, and many areas of the developing world are still hampered by chronic lack of up-to-date data for policy makers and development agencies as well as at farm level (Minae *et al*., 2003). One problem is that the most important variables for decision support are often those for which we have the least accurate and most uncertain information, such as livestock disease risk and the prevalence and depth of poverty (Robinson, 2002). On-going efforts such as that led by FAO in cooperation with partners are attempting to assemble production data at the district level for developing countries, but even this (relatively aggregated) level of data collection is problematic. The data problem can only adequately be addressed through integrated, collaborative and wide-scale efforts. Targeted decision support efforts in developing countries will have to continue to rely on widespread use of 'expert opinion' and on using proxies of key variables that have not been quantified reliably, in efforts to assemble the information that is required. There is also a great deal to do on information interpretation, and the idea of converting the outputs of complex tools and complex analyses into quick messages in innovative formats that are useful for decision makers. Tools such as Talking Pictures, PRIMAS and EXTRAPOLATE may show the way forward in some respects. Given the uncertainties of the future, and the continuing intensification of agricultural systems in many places, such work on targeting and decision support is crucial if research is to hit the right developments targets in the coming decades.

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