# Part 3

## Research tools and data sources

You may be surprised that up to this point in the book there has not been much about data collection and statistical analysis. That changes now! But you will still find little in the way of mathematics or technical details. There are two reasons. First, many of the ideas you need to design and analyse good studies can be explained and understood without using mathematics. Secondly, there are many books around that describe the mathematics, and many of the courses in 'research methods', or 'statistics' that you will have followed will have used a mathematical, rather than an intuitive, approach. We want to provide an alternative.

These chapters can only be introductions to important ideas and methods. Maybe they will be all you need. It is more likely that they will raise all sorts of questions that are important in your research, and prompt you to seek out further understanding. They may even help you make sense of that statistics course you took and hated so!

The more technical aspects of a research project are important, and sadly many students have failed, or had to redo parts of their project, through failing to understand them early enough. If the material here raises any questions or uncertainties then you should get help. Biometricians and statisticians are experts in this stuff, so consult them! And any successful researcher must also have a sound grasp, and should be able to help you.

The topics covered in Parts 3 and 4 are only a selection from those that could have been included. We have used two criteria to select them:

1. The topic is essential to most projects, yet commonly misunderstood. (Included here are the chapters on design of experiments, planning surveys, measurement, managing and analysing data).
2. The topic is important but often omitted from research methods courses. (We have included chapters on finding and using secondary and spatial data, and modeling).

The chapters are roughly arranged in the logical order in which they might occur in a project. But please don't wait until the end of your project to look at later chapters! The design of the study depends on how you will analyse it, so you must be aware of the later steps during early stages.

**Richard Coe**

# 3.1

# Agents of change: the role of professionals in rural transformation

*Joseph Opio-Odongo*

- **Science and technology can make a difference in rural transfomation**
- **Agricultural scientists must play a positive role in rural development**
- **Understanding farmer reality and good communication skills are essential for servicing rural communities**
- **Rural communities have the capacity and capability to change their reality**
- **Technologies and innovations must match the needs of the target communities**

*'Agricultural research scientists have been reluctant revolutionaries, because while they have wanted to revolutionise technology, they have preferred to neglect the revolutionary impact of technology on society.'*

**Vernon Ruttan (1982)**

## Introduction

The development and application of science and technology by agricultural research scientists in sub-Saharan Africa (SSA) are part of the global agenda to liberate people from the limitations of the natural world. However, although both positive and negative socioeconomic effects of the liberation should be expected, these have not preoccupied the minds of the agricultural research scientists. Yet how society deals with such change affects both the nature and pace of rural transformation.

Agricultural research scientists, as agents for this transformation, need new ways to deliver the results of applied science if they are to empower farmers to operate as subjects rather than the objects of rural transformation.

## Rural transformation

When you read the literature on agricultural and rural development, you will find that the concept of rural transformation is often talked of in terms of the:

- Changing composition and roles of the agricultural and other sectors in national development
- Dwindling size of the rural population engaged in agriculture
- Increasing prominence of agro-processing in the rural economy
- Declining proportion of the population deriving its livelihood from agriculture
- Substantial reduction in the contributions of agriculture to the gross domestic product (GDP). All these are often used as the indicators of rural transformation.

But, an equally important aspect of that transformation is the changing capacity of the rural population to drive the process of change. This capacity is expressed in the people operating as the subject rather than the object of change as they shape their destiny by tactfully dealing with the present situation and strategically working towards capturing the future. It is this aspect of the transformation that is the focus of this chapter. Of particular interest is how agricultural research scientists could work with the farming communities to help them manage self-propelling and people-driven processes of change that contribute to sustainable livelihoods and the transformation of the rural economy. One way is the Citizen's Jury method which has been successfully applied in India to involve farmers in decisions on technologies including the Genetically Modified organisms (GMOs) (Pimbert and Wakefield, 2004).

For this to happen, four main conditions must be fulfilled.

1. Recognition that rural transformation, as a self-propelling and people-driven process, is possible in any society and that the knowledge system that drives it must be internalised and used appropriately.
2. The internal dynamo for rural transformation has to be recharged after years of debilitation by colonial and post-colonial policies and institutions.
3. Agricultural scientists need to be animators and facilitators rather than interventionists to increase local initiative and reduce dependency.
4. Agricultural scientists must invest in acquiring the skills and art of animation, appreciative inquiry and the others needed to facilitate rural transformation.

**Internal dynamo for rural transformation short-changed**

Colonial rule influenced agriculture in SSA in three important ways. Firstly, it attempted to divest it of its foundation that was built on a theory of knowledge learned from tried and tested traditional methods. The professional and administrative assault on traditional farming practices was meant to transform agriculture from an African way of life into business-based European models of farming. Traditional agricultural practices such as intercropping, although poorly understood by the Europeans, were deemed inferior and were to be replaced by modern ones.

Secondly, it attempted to develop a cadre of 'master' or 'model' farmers who were to be entrusted with the responsibility of recreating the agricultural system in line with the European model.

And thirdly, it introduced a research support system that predominantly served the interests of science and private capital rather than the developmental needs of local farmers. Champions of the traditional knowledge systems and the innovations developed from them fizzled from the limelight, thereby creating space for the new cadre of extension workers to disseminate information from the research stations.

It was in the process of implementing these changes that the **internal dynamo** for rural transformation was **short-changed**. In many SSA countries this situation changed little during the first half of the 20th century. It was not until the mid-1960s that agricultural research scientists began to validate the theories that underpinned many of the traditional agricultural practices such as intercropping. Until very recently, such validation was performed largely within the framework of a delivery model that treated local farmers more as objects rather than subjects of rural transformation. The internal dynamo for rural transformation still remains stalled in many rural communities in SSA.

**Trained incapacity to reckon with local situations**

Formal education is a powerful socialisation tool that professional disciplines apply in training those of their calling to enable them to view and interpret the world appropriately. Under the controlled condition of experiments in laboratories, glasshouses or experimental plots, that tool has served agricultural scientists very well. However, for situations outside these controlled conditions, especially in the world of farming where a number of conditions influence farmers' behaviour towards a technology that is being promoted by agricultural scientists, that tool in its conventional form has been less powerful.

The trained incapacity which comes from conventional higher education, results in a tendency to blame farmers for being conservative or backward when they don't implement new technologies, rather than assessing where the recommendations are failing farmers' needs.

***'Agricultural scientists and researchers do not usually understand the positive and negative forces and changes facing farmers. Current training does not encourage an understanding of traditional husbandry practices. Even students coming from rural communities consider their new knowledge to be superior and have little real appreciation of the inherent logic of traditional systems.'***

**Joseph Opio-Odongo (1992)**

Students are not trained to develop an appreciation of the basic foundation of traditional agriculture. There is growing evidence that farmers' planting strategies, seed selection and preservation, and crop rotation, are based on knowledge systems developed over generations. The same holds true for the local system of soil classification. Farmers continue to develop a variety of agricultural innovations that help them to deal with the exigencies of rural life but which are unknown or poorly understood by agricultural scientists. Researchers and students rarely appreciate why farmers may adopt, but then adapt the new technologies. An example from Uganda in the 1960s helps to illustrate this.

Despite strong recomendation by the research and extension establishments in Uganda that cotton farmers should plant early and use specific fertilizer applications, the majority of farmers developed their own variations of what was recommended. They planted later and applied lower dosages of fertilizers. When the results of field trials based on farmer practices were published – the farmers' deviant behaviour was proved to be rational and valid.

**It is also imperative that students and agricultural scientists be trained to communicate effectively with farmers, and to be exposed to farmer situations so that they can develop vital empathy.**

### The message model of the interventionist

The usual way services are delivered by agricultural scientists in SSA is to use external expertise to define a problem and then to institute measures to resolve it. The role of farmers in dealing with the situation tends to be largely that of passive implementers. It is an example of the classical benefactor-beneficiary relationship.

An example of this 'message model of the interventionist' is one where a representative of a public health system notices a problem and diagnoses it as by poor nutrition. Arrangements are therefore made to enrich the flour consumed in the area with the aim of improving the nutritional status of the community.

Replace the nutritionist with an entomologist or agronomist and the approach remains valid. The entomologist, for instance, notices a substantial drop in the average household income in a community dependent on maize for its income and food security. His/her diagnosis is that poor pest control is resulting is considerable post-harvest losses. The 'prescription' is that farmers should adopt modern ways of controlling post-harvest losses in order to ensure food and income security in the community.

The gravity of the problem and the inherent superiority of the modern methods being introduced are expected to compel farmers to adopt the modern system of reducing postharvest losses. To encourage adoption, on-farm trials are conducted to enable farmers to appreciate the efficacy of the modern methods. Little attention is usually given to such issues as the affordability, accessibility and sustainability of the recommended methods given local constraints.

The interventionist model is basically one that aims to change the direction of human activity in what the intervener deems to be the most appropriate way. The model operates as if its application is based on full information. Yet in most instances agricultural scientists rarely have the full picture of the situation within which they are intervening, especially given their inclination to take a mono-disciplinary approach to problem solving. It is rare to find them working in concert with social scientists in multidisciplinary teams. Neither would they normally try to seek information on what solutions have been applied by farmers in response to the problems at hand and with what results. They also give little consideration to the extent to which their research efforts have yielded technological transformation locally.

**Becoming an animator or facilitator of rural transformation**

Notwithstanding the general intellectual arrogance that delayed the understanding of the traditional knowledge based African farming practices, since the late 1960s there has been an upsurge of interest in such practices, notably in farming systems research. The researcher-extension worker-farmer linkages that farming systems research promoted was consistent with the late President Julius Nyerere's plea that: ***'In the interest of becoming more effective in what they do, African intellectuals have to be part of the society, which they are changing; they have to work from within it, and not try to descend like ancient gods, do something and disappear again.'***

This was a wake-up call for agricultural research scientists to operate more like animators if they expected to have any impact on agricultural and rural development in Africa. It challenged them to shift from the message model of the interventionist to one that is based on the knowledge and value systems of communities and through which the agricultural research scientist facilitates the process of agricultural and rural transformation. Such a model was described as a 'system model of the explicator' that could be applied by agricultural scientists in facilitating rural transformation.

In the system model of explicator, agricultural scientists accept the inherent capacity of people to take charge of their own destiny, thereby drawing upon the internal capacity of the stakeholder community to activate a self-driven transformation process. The model is underpinned by the principles of communication, reciprocity and partnership that are essential in enabling rural people to apply their knowledge and capacities to activating the process of rural transformation.

**The system model of the explicator**

A fundamental assumption of this model is that a farming community is an information-processing structure that draws upon internal and external information to act on situations. The model recognises that farmers have a stock of knowledge and wisdom that agricultural scientists have tended to ignore to their disadvantage.

**It is through dialogue with members of any community that agricultural research scientists can tap the farmers' rich wealth of experience and wisdom in agriculture and use it to stimulate rural transformation.**

Studies in Africa have validated the merit of using such a model, e.g., the indigenous knowledge on soils that was tapped from the Bété and Senufu communities in Côte d'Ivoire, read Birmingham, 1998. A number of techniques have already been developed to enable researchers to access such knowledge including:

- Participatory Rural Appraisal (PRA)
  http://www.worldbank.org/wbi/sourcebook/sba104.htm

- Methods of Active Participation (MAP)
  http://www.fao.org/docrep/006/AD424E/ad424e03.htm
- Participatory Action Research (PAR)
  http://www.fao.org/docrep/x5307e/x5307e09.htm
- Appreciative Inquiry (AI)
  http://www.iisd.org/ai/
  http://www.iisd.org/ai/myradavideo.htm

Fundamentally, the system model of the explicator does not pretend that every popular practice within an agricultural system is welfare-promoting, or that there is never room for improvement or innovation. Rather, its most powerful message is that those improvements or innovations are more likely to succeed and become sustainable in the long run if they are introduced with due cognisance of the existing knowledge systems, needs and capacities of the target communities. Using this model, an agricultural scientist interprets the world of rural people not as a set of unsolved problems, a series of gaps and deficiencies and failures, but

**Implications for your graduate research training and research in agriculture**

If you are to follow this model then you need to:

- Develop skills that allow you to interact effectively with the communities in which you will carry out your research – take some social science courses and try to work with interdisciplinary teams
- Improve your communication and listening skills to capture local knowledge and use it in designing your project
- Be sure that your project really addresses the needs of the people you are trying to help.

The impressions that members of the rural community have of who they think you are and what interests you, substantially influences what information can and cannot be shared with you. If you do not quickly detect and help to dispel a negative perception, it will affect the quality of information you are receiving from the community. If that happens, your interaction with the community could do you more harm than good.

Learn the art of using observations and knowledge of the agricultural systems where you work so that you appropriately factor them into your research design and respond to the priority needs of both the scientific and the farming communities. You also need to understand the interface between science and the economy, or science and commerce. Indeed, many people believe that the increasingly closer interface between science and commerce has been a main factor in the development of biotechnologies. The biotechnology movement did not begin from the usual pursuit of knowledge for knowledge's sake but rather from the decision to strategically apply scientific knowledge to enhance the competitive edge of those investing in the generation of new technologies in a very highly competitive global economy.

You need to be conscious of the primary need that you are serving as an agricultural scientist in the public domain. It may be difficult to hide behind the cloak of neutrality.

The system model of the explicator is not a panacea for all research or rural development problems. Each development situation as it unfolds presents new challenges that pose difficulties in the application of the model. Indeed, given the predominance of the message model of the interventionist in much of rural Africa, farming communities may not initially think that you are serious when you do not provide ready answers to their problems. Helping them to begin taking charge of their situation and destiny is the art that you must possess. It is therefore important that if you try to apply the system model of the explicator, you also make a deliberate attempt to determine what works and what doesn't. Out of that experience, a local research team can then evolve a modified version of the model that is more appropriate to the specific situation in which they are working.

rather as a set of brave attempts, a series of partial achievements, and a sequence of possibilities that could yield rich rewards if the community and the agricultural research scientists worked together. This model promotes empowerment and capacity development by recognizing and building upon local farming knowledge and experience as well as farmer innovations [see Mati, (n.d.) and Pimbert and Wakeford (2002)].

## Resource material and references


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# 3.2 Participatory approaches to research

*Jayne Stack*

- **Participatory research should empower participants**
- **'We' should participate in 'their' research and not 'they' in 'ours'**
- **Effective participatory techniques involve shared learning**
- **Communicate clearly the purpose of the research, your mutual roles and expectations**
- **Try to ensure all are heard – especially the marginalised and soft voices.**

Throughout this book you have been encouraged to acquire a development mind set and invest your time and brain power in acquiring knowledge that has the potential to better the lives of others. If you are serious about taking up the challenge to be agents of development then you will recognise the need to consider closely participatory approaches to research that:

***'....actively involve those who best understand and have the greatest stake in the issues - community members themselves'***

Laws *et al.* 2003, p49

Over the last two decades there has been an increasing emphasis on participatory development, where local people take ownership of the development process and become involved in directing it. This has led to the emergence of a family of approaches to enquiry collectively known as Participatory Rural Appraisal (PRA) where people themselves have much more control and responsibility for determining what information is important, collecting and analysing information and then using the information to make their own decisions for the development of their community.[1] You will recognise that this is not a conventional view of research, and to some extent participatory research defined in this way would be more appropriate in a course on rural development than in a text about how African graduate students should do research. However, it is possible to distinguish between PRA techniques and 'a PRA' as a step in the participatory development process of a community. This chapter focuses mainly on PRA techniques rather than PRA as a participatory development tool. However, in order to use PRA techniques correctly it is helpful to have a good understanding of the fundamental principles of a participatory approach to enquiry. If the approach is wrong, PRA techniques will not work

1 There has been a blossoming of participatory approaches. Some focus on problem diagnosis; for example, AEA (agroecosystems analysis), some facilitate user-led research, for example, IPM (Integrated Pest management) and FPR (Farmer Participatory Research) others are orientated towards community empowerment, PAR (Participatory Action Research).

whether you intend to use them to illicit information from rural communities or as a vehicle for empowering people.

The aims of this chapter are to

- Provide an overview of what is meant by participatory research, the different purposes pursued by participation and the range of ways in which participation in research is possible
- Identify the underlying principles of PRA
- Review some common participatory research techniques including focus groups, ranking and scoring exercises and visual methods such as maps and diagramming
- Highlight some of the issues and problems of participatory approaches to research

## The Concept of Participation

Over the last 20 years or so the words 'participation' and 'participatory' have entered the vocabulary of research institutions and development agencies and it is common for donors and governments to consider participation a 'good idea' and require participatory approaches to be used. But what does participation really mean? According to Chambers (1995) there are three main ways in which 'participation' is used. Regrettably it is often used as a cosmetic label to make whatever is proposed, seem good. For example, many student research proposals indicate that participatory methods will be used and then later state that they have been used, when the reality has often been top down investigation in a traditional extractive style. Second, participation can be used to describe a co-opting practice in which locals participate by providing inputs (information, local knowledge, skills, labour etc) for 'our' research or development project . In this context participation is seen as something which makes research (or projects or policy) better or more efficient. Third, and preferable, it is used to describe an empowering process which enables local people to do their own research, to take command and make their own decisions. In theory this means that we participate in 'their' research or development project, not 'they' in 'ours'.

Pretty (1995) categorises six different levels of participation according to the type or amount of participation exercised by the participants. His typology covers a continuum from 'passive participation' where people are told what research is going to happen in their community, through to 'self mobilisation' where people participate by setting their own research agenda and initiating the research process independent of external agents. A truncated version of Pretty's typology identifies four methods of participation: information sharing, consultation, decision making and initiating action illustrated in Box 1. Each level of participation is characterised by a different relationship between the researcher and the participants. Higher levels imply a more intense form of participation and a greater sense of empowerment.

Such classifications are useful because they remind us that participation is such a varied concept and that we have to be clear about what sort of participation is taking place and for what purpose. The concept of different levels of participation also demonstrates how some processes that are claimed as participatory involve minimal or no change in power relations. In this sense quite a lot of participatory work done by donor organisations, like for example the Participatory Poverty Assessments (PPAs) financed by the World Bank are more elicitive or extractive exercises than vehicles for empowerment.

However, some practitioners have noted that here are problems in viewing participation in a hierarchical manner since it tends to suggest that whatever the situation, a higher level of participation is better for all concerned. This is not always the case. Participation has costs, not least in terms of the time of the participants. As with any research decision, the level of participation that is appropriate depends on the final purpose of the exercise. (Laws *et al*. 2003, p60-61). Laws introduces the concept of a wheel of participatory research, to demonstrate that participation can take place in a number of different ways at different stages in the research process (Laws *et al*. 2005 p62). These different types of participation should not be seen as more

| **Box 1 Typology of Participation** Source: Adapted by author from Lane J. (1995) | | |
|---|---|---|
| **Information Sharing** | People participate by being told about what research is going to happen in their community and by answering questions posed by researchers using questionnaires or similar approaches. Findings of research are never shared or checked for accuracy by the respondents | Research agenda and research process driven by researcher or commissioning body |
| **Consultation** | Participation is seen as a mechanism for consultation with different groups of people (key informants, focus groups, local organisations). Researchers listen to views and may modify problems and solutions in light of people's responses | Research makes use of local knowledge but control is still largely top down |
| **Decision Making** | People participate in joint analysis, which leads to action plans. For example communities identify poorest households and prioritises households requiring assistance. | Participants have some control of research process and how research is used for development but researcher maintains some degree of control |
| **Initiating Action** | People participate by taking initiatives independent of external institutions. E.g carry out own on farm research; individuals or groups of growers contract outside agency to research product markets | Controlled by participants |


Figure 1. Wheel of community participation in research, reproduced from Laws *et al.* p62

or less valuable but as potential windows of opportunity for local empowerment during the research process.

## Principles of Participation

Practitioners are concerned to point out that participatory research is not just a collection of techniques but more of an approach or way of working with people or organisations that favours placing participation at the core of the research process. Three clusters of principles are distinguished by Chambers (2007 p8)

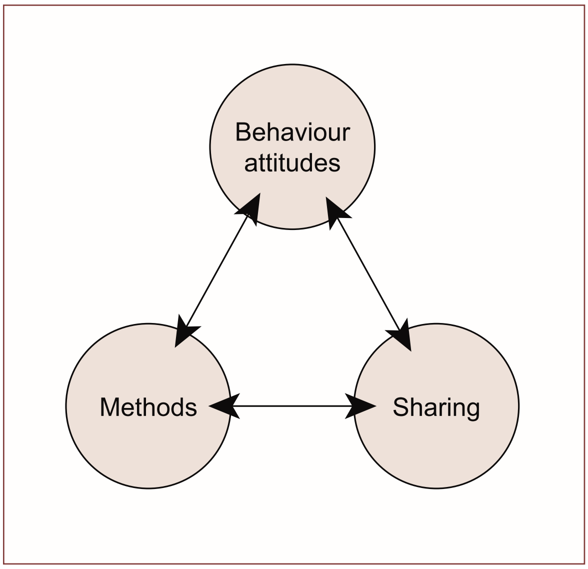


Figure 2. Behaviour and Attitude are the Keys to Effective Participatory Research

### Behaviour and attitudes

Empowering processes require changes of behaviour, attitudes and mindsets and from early on behaviours and attitudes were regarded by many of the pioneers of PRA as more important than the methods. Chamber's (1992) usefully encapsulates the reversal of learning associated with PRA in the following extract :

***'A major difference between research and Rapid Rural Appraisal (RRA) which are extractive and PRA which is participatory, is in behaviour, attitudes, and roles. In extractive research and RRA the outsiders – 'we' – are dominant. We determine the agenda, obtain and take possessions of the information, remove it, organise and analyse it, and plan and write reports. We appropriate and come to own the information. We are collectors, processors and producers of outputs. In PRA this is largely reversed. 'We' encourage and allow 'them' to be dominant, to determine much of the agenda, to gather, express and analyse information, and to plan. We are facilitators, learners and consultants. Our activities are to establish rapport, to convene and catalyse....... We watch, listen and learn. They do some of the things we formerly did (and believed often enough, that only we could do).'***

Chambers, 1992, p19

Researchers need to be very aware of their own attitudes and behaviour. Effective use of participatory techniques involves a process of shared learning. The primary role of the outsider in a 'true' PRA is as facilitator and equal sharer of ideas and information; it is not to extract information from 'them'.

### Sharing

Sharing without boundaries is a core principle of PRA. It refers to the sharing of knowledge, information and ideas between participants and between them and facilitators, and the sharing of training, ideas and insights, across organisations (Chambers, 2007 p8). This spirit of openness has been at the core of the successful spread of PRA methodologies which have been creatively adapted for use in many different parts of the world and in many areas of development work.

### Methods

Many PRA methods include visual or tangible expression for information sharing and analyses. For example, mapping, modelling, diagramming, pile sorting or scoring using seeds, stones or other counters to represent aspects of communities and peoples lives. What is expressed can be seen and touched. Non-literates are not excluded everyone who can see has visual literacy and can actively participate, including children. These methods are not just a means for local people to inform outsiders. Rather they are methods for local people to undertake their own research and can be a potent means of empowerment if used well.

## Techniques for Participatory Research

Some of the most common participatory research techniques include focus groups, ranking and scoring exercises and visual methods such as maps and diagramming. However since the rate of innovation of tools and techniques of PRA makes it difficult to keep abreast with new developments you are encouraged to refer to some of the web sites of organisations involved in participatory research listed at the end of this chapter for a more comprehensive tool kit and examples of application.

### Focus Groups

A focus group is a group interview where people are brought together for a discussion with each other. The purpose of the discussion might be to provide general community level information such as a broad picture of the vulnerability context of rural livelihoods or to discuss a specific topic such as the support needs of families caring for aids orphans. Focus groups can be useful when you need in-depth information about how people think about an issue, their own explanations and understandings or when you want people's ideas about what changes they would like to see. Structured questionnaires are often an ineffective way of exploring these types of questions whereas the focus group allows the investigator to explore issues in a much more flexible way and permits follow up questions to clarify complex responses.

A focus group could bring a diverse group of people together to think about an issue or several focus groups could discuss issues separately with different sub groups (e.g. men and women farmers, young people, people from different socio economic groups etc). How you group people together depends on the purpose of the research.

The selection of participants for a focus group is generally governed by the need to identify as wide a range of view points as possible and is not necessarily linked to the wider population in any quantitative sense. Thus in a rural community, where the researcher decides to run focus groups separately for livestock and non livestock owners , the same number of participants may be sought among the 70% of the people who own livestock as among 30% who are without.

Information from focus groups often plays a crucial role in guiding the interpretation of data from other forms of enquiry such as structured surveys, so where ever possible the principal researcher should be involved in the focus group discussion either as a facilitator or as an observer.

Provide refreshment for participants during or after discussion as not only is this considerate but sharing refreshment together helps people feel at ease with each other and share more openly.

A crucial point to bear in mind is that a focus group is not a series of individual interviews conducted in a group so it should not be used as a tool for generating statistics about the individual participants. It is not uncommon to come across research reports that report focus group information relating to the percentage of participants with particular characteristics or averages for variables such as production, livestock holdings etc. This demonstrates a lack of appreciation of the purpose of the focus group which is to get people discussing as a group but it also statistically unsound since the members of the group are not a scientifically random sample.

As a general guide to good practice in conducting a focus group interview look at Box 2.

### Ranking and Scoring Exercises

Ranking or scoring (or putting things in order) is a useful analytical tool to learn about the values people place on things. Ranking can be used to rank the value of any aspect of the community; different natural resources (e.g species of trees, varieties of crops, uses of wild foods) community problems and priorities for action. Ranking can also be used to rank individuals or households

**Box 2. Checklist for conducting a focus group interview**

- Find a suitable location for the group – somewhere quite and comfortable for participants.
- Keep the group a manageable size, 6-15, works well
- Put people at ease with an informal open approach – take a seat on the same level as the participants, avoid lecturing or advising, state that you are hear to learn, ensure they don't feel that it is a quiz and explain that everyone's views are valued and they don't need to come to any agreement
- Ask 'how' questions first and move on to any 'why' questions once the group has got going
- Make sure that everyone gets a fair chance to speak, don't let anyone dominate
- Encourage interaction between group members
- In closing, thank people for their time and ask if participants have any questions
- Do not rely one focus group to represent a whole group of people's point of view – it is much better to do several.

Source: adapted from Laws *et al.* (2005)

**Fig 3. Example of a priority matrix**
Source: *Participatory Rapid Appraisal for Community Development* (A training manual based on experiences in the Middle East and North Africa) IIED/Save the Children Federation, 1991, p12

Least good + ++ +++ Best

| Innovation or project | Benefit for community | Community participation | Sustainability of innovation | Equitability of benefit | Cost to implement | Time to benefit | Technical feasibility | Feasibility score | Priority |
|---|---|---|---|---|---|---|---|---|---|
| Clinic | +++ | ++ | ++ | +++ | ++ | +++ | +++ | 18 | A |
| Preschool | ++ | +++ | ++ | ++ | ++ | +++ | ++ | 16 | C |
| Well repair | +++ | +++ | ++ | +++ | + | ++ | +++ | 17 | B |
| Credit program | ++ | ++ | + | ++ | + | + | ++ | 11 | D |

for such varied characteristics such as wealth, income and food security. These techniques provide a visual way of initiating discussion and encourage participation by those who might not readily take part in verbal discussion.

Three types of ranking methods are commonly used in participatory research:

**Preference or priority ranking** (ranking by voting) which can be used to determine quickly the main problems of community members, such as constraints to agricultural production or preferences for tree species for a community woodlot (see Fig 3).

**Direct matrix ranking** to identify a lists of criteria for a certain object such as vegetables grown and the reasons for local preferences (consumed most, less water requirement, more marketable, stores well etc (see Fig 4).

**Wealth or well being ranking** together with a discussion of what constitutes 'well being' and conversely poverty can be used to investigate perceptions of wealth differences in a community and provide local criteria for wealth and well being. (See Table 1).

You will find detailed guidelines about how to carry out the different types of ranking exercises in most PRA tool kits. As a general guide once people have a rough idea of what they

**Fig 4. Direct matrix scoring and ranking of vegetables grown (young women).**
Source: Adapted from Mikkelsen, B. (1995)

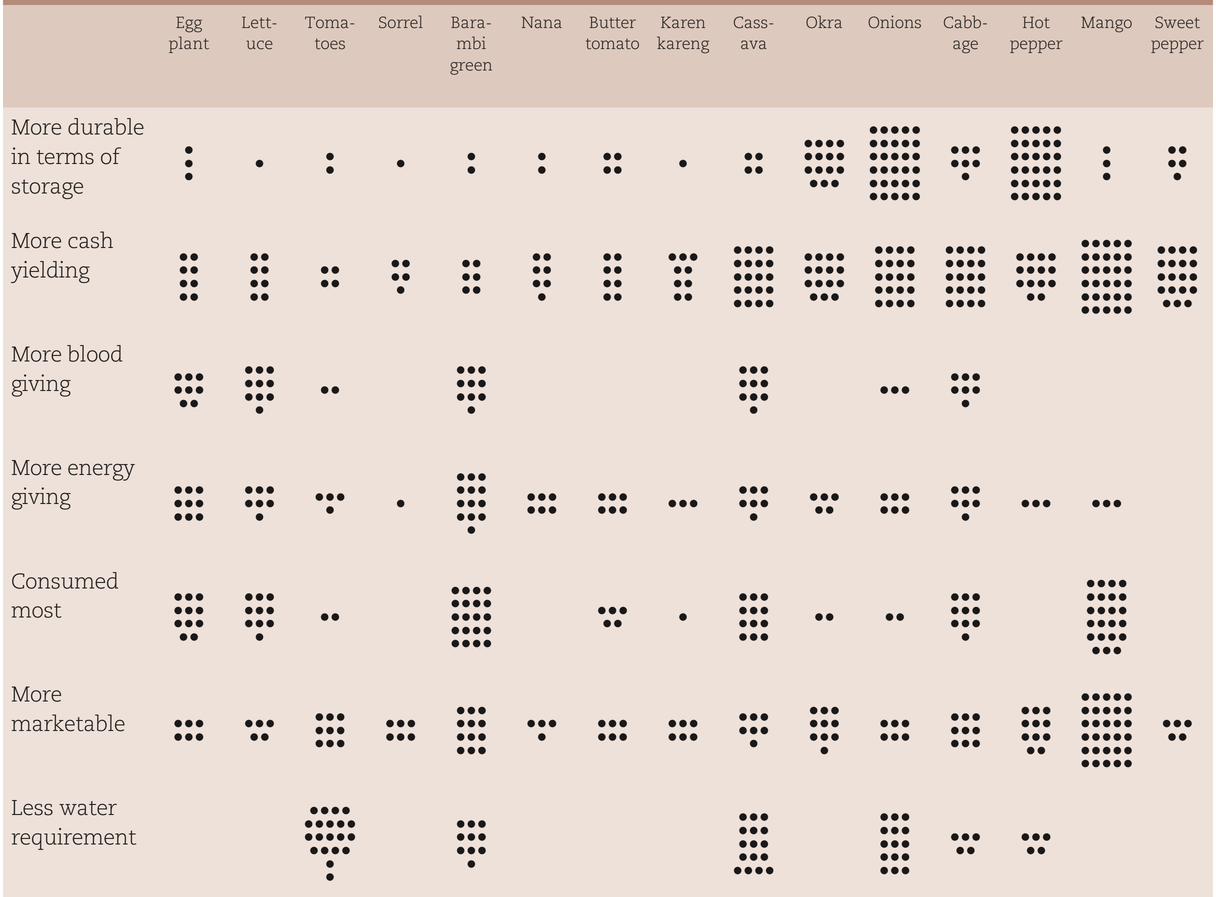


**Table 1. Examples of local criteria frequently used for wealth ranking in Southern Africa**

| | Very poor | Poor but a bit better off | Doing OK |
|---|---|---|---|
| **Food** | • No food<br>• Beg for food<br>• Sleep without food | • Maize meal only<br>• Some income to buy food | • Food always there<br>• Nutritious food |
| **Family & Household** | • Caring for orphans<br>• Widows | • Large number of children | • Children grown up |
| **Employment** | • No one is working | • Employed on farms<br>• Have survival skills<br>• Self employed | • Government employees<br>• Remittances from working children |
| **Schooling** | • Unable to/can't afford schooling | • Able to afford to go to school | • Able to afford post school training |
| **Livestock** | • No livestock | • A few chickens & goats | • Cattle owners |

are doing let them be creative and do it their own way. Probe the reasons for the order of ranking and help people learn from themselves.

Although ranking is a useful tool it has limitations. It can be very time consuming. Bias can be introduced unless you get the perspectives of different groups – e.g. men and women may

| Table 2. Different types of participatory mapping tools and their uses | | |
|---|---|---|
| **Mapping tools** | **What is it?** | **Why use it?** |
| Mobility map | A diagram of places where people go. Different thickness of lines can show frequency, different colours can show reason for travel | Identify where people go, how often, identify what services people use. Indicator of peoples contact with outside world. Compare mobility of different groups |
| Resource maps | Diagrams that show resources and/or services available in a community and who uses them | Identify what resources are available to different people (men, women), understand why some people have access and some people do not, identify strategies for increasing access |
| Well-being maps | A map of the community showing relative well being in different households in the community (those most food insecure or those most affected by HIV/AIDS) | Useful to identify different peoples views of well being and problems, reasons why people experience well-being or ill-being, strategies that people use to improve well-being |
| Community mapping | A map showing important places and institutions in a community – markets, schools, health centre, etc | Identify which places and institutions are important to the community and why, highlight different groups views, explore gaps |
| Transect walks | A transect is a walk through an environment to identify different places, changing land uses and resources | Identify main features, resources, access and management. Can walk same transect with separate groups and compare different issues and explanations |
| Before and now diagram | A diagram that shows change. E.g change in a situation since a significant event such as new project | Useful for exploring changes over time and the reason for change. Explore how interventions have affected people differently |
| Daily activity charts | Show how people spend their time over course of a day or week | To compare different peoples roles and responsibilities, identify problems and obstacles faced by different people |
| Seasonal calendar | A diagram of changes over the seasons – usually a period of 12-16 months | Identify seasonal patterns of change in availability of resources, work, food, income, migration patterns, well being. |

express different preferences for tree species in a woodlot. Another problem is that a method such as well-being ranking is not workable unless people know each other really well. As with all participatory techniques be selective in what you decide to rank and adapt the technique to the requirements of your study.

### Maps, Diagrams and Drawings

The use of maps, diagrams and drawings enables local people to participate, record and discuss the information they share. There are many types of visual methods and just a few examples are given in Table 2.

Visual methods are a good way of learning quickly about how things work in an area and can communicate complex issues or processes simply. As a general rule maps and drawings belong to the community who prepared them so leave the original output of a participatory mapping exercise with those who generated it. With their permission you can make copies for yourself.

**Combined PRA and Surveys**

Participatory research draws on many of the basic tools described above but it would be meaningless to just adopt them as a standard tool kit without taking into account your research questions and what techniques are appropriate for collecting the information required to address them.

Many studies find value in combining participatory techniques and a small scale survey approach. For instance, Ellis used a combined approach to investigate rural livelihoods in Northern Tanzania (Ellis 2000, p200). The research exercise comprised three main components each intended to fulfil different roles (See Box 3). The different methods were not seen as mutually exclusive but rather as playing different roles in achieving a clear picture for policy purposes of the livelihoods situation in the case study area.

**Box 3: The three components of a combined participatory and small scale survey approach to investigating rural livelihoods in Tanzania**

1 **Focus Group Discussions,** provided a broad picture of the vulnerability context of rural livelihoods by looking at the changes and trends over the past decade in five man areas of livelihoods: changes in main income sources, emergence of new activities, agricultural production and marketing problems, access to natural resources and the ways in which life was perceived to have improved or worsened over the past ten years.

2 **A Particpatory Wealth Ranking Exercise** intended to permit the assets and activities of the poorest households to be distinguished from the better-off households.

3 **A sample survey** of 90 households to elicit more accurate and policy relevant information on two dimensions of livelihoods – assets and activities and how the poor differ from those better-off. It dealt with:
- demographic data
- land as an asset and farm income data
- non farm income sources
- household assets, including production as well as consumption assets.

Source: Adapted from Ellis (2000)

## Some of the Issues in applying Participatory methods

Having suggested various ways in which participatory techniques can contribute to research we will now reflect on some of the difficulties and drawbacks of the approach. Firstly, the simplicity and attractiveness of some participatory techniques makes it possible for them to be applied very mechanistically without any real understanding or empathy for those who participate. This is highlighted in the following quotation from Chambers who also notes the problem of research facilitators raising people's expectations without any outcome.

***'With rapid spread, bad practice became rampant. The methods used are so attractive, often photogenic, and so amenable to being taught in a normal didactic manner in the classroom that they gained priority over behaviour, attitudes and relationships ...... ...........participatory research approaches were routinised, people's time was taken and their expectations raised without any outcome, methods were used to extract information not to empower.'***

Chambers, 2007, p11

As with any research activity it is important to be clear with participants about the purpose of the research and what (if anything) they can expect out of it.

A second issue in participatory work is how to ensure that everyone's point of view gets heard. As Laws notes:

> ***'Unless specific measures are taken to counter balance social inequalities, participation can simply mean that those with the loudest voices simply get their way again'***
>
> Laws *et al.*, 2005, p52

People can be excluded from participation because of the influence of powerful groups in communities or other problems such as the presence of a local leader which limits people's willingness to freely express their views. Investigators need to find ways to ensure that people relevant to a particular investigation take part and that meetings take place in an environment in which people can speak freely.

In conclusion, participatory approaches have a great deal to offer in terms of improving the quality of an investigation, making the voices of poor and marginalised groups heard and linking local communities to both policy and programmed focused action but participation in research is not an easy option and empowerment will not automatically result from the use of participatory techniques. The time and resource constraints of most graduate research projects and the limited scope students have for developing long term relationships with local communities suggests few opportunities for graduate research to be an empowering process for development action. Nevertheless, selective use of appropriate participatory techniques will improve the quality of most research investigations and researchers can increase the empowering attributes of fieldwork by ensuring that steps are taken to share the research outputs in an appropriate format with those who generated the information and shared their knowledge. This will require you to think beyond the completion of your thesis to the preparation of other types of research outputs (newsletters, posters, policy briefs, verbal presentations at field days, summary reports for local leaders) that can better inform development action.

The two examples given below from Niger highlight the importance of working closely with people in a participatory way if your research is to have meaning and to be translated into relevant and sustainable development. The examples highlight the importance of behaviour and attitudes on the part of researchers and community members.

**Box 4. The Importance of Ownership and Approaches to Participative Research[2]: Some Examples from Niger By Dr Larwanou Mahamane**

Field research involving participative research requires well defined approaches to ensure not only that the expected results can be achieved successfully, but also – and more especially – that producers are able to take ownership of the research and its results. In West Africa generally, and in Niger in particular, inspirational examples are available of both successes and failures. In both cases lessons have been drawn and used either to disseminate results in the first case, or correct inadequacies in the second case. The examples given here illustrate both sets of cases and originate from research work carried out in Niger.

**Successes in terms of joint environmental field research projects: an example of a project on the remediation of eroded land in Niger**

The primary aim of the project to address erosion in West Africa is to bring eroded land back into use and increase the incomes of rural populations. This project began in 2005 in the

2 Participative Research is used here per the definition provided by http://www.arlecchino.org/ildottore/mwsd/group2final-comparison.html – as opposed to Participatory Research.

rural commune of Bitinkoji in the Kollo Département of western Niger. This area has very significant market gardening potential and *Moringa oleifera* production is practiced widely. Before intervening in any way, a diagnostic study was carried out to list the limitations associated with soil erosion in the area. The main limitation observed was that animals were allowed to wander in the market gardens; to solve this issue, producers use dead hedging made from lopped tree branches. This practice is damaging to the environment due to the trees being lopped year on year to repair the hedging, and is time-consuming for the producers. The producers are nevertheless required to continue this practice as they cannot afford to buy wire fencing or barbed wire.

The research proposed, to be conducted jointly with the producers, was to test the protective efficiency of live hedging made from the producers' preferred native thorny ligneous species. The following species, selected in direct consultation with the producers, were chosen: *Acacia senegal*, *Bauhinia rufescens*, *Ziziphus mauritiana* and *Acacia atexacantha*. The producers were then trained in collecting seeds, growing the seedlings in nurseries, and in the planting, maintaining and managing of the hedging. To solve the issue of watering hedge-planted plants, we decided jointly with the producers to use CMT[3], a water-retention product, during planting. Two years following planting, the hedging has grown substantially and closed up well. This year and having seen the work of their peers, more than 50 other producers have established their own hedging and this work is being duplicated throughout the zone. To everybody's satisfaction the producers have taken over ownership of the project. We collected our data for research purposes and these hedges have increased the intensification and diversification of crops within the market gardens.

This tends to prove that if the farmers and growers are involved from the design through to the execution of the research projects, the results hoped for are achievable. This approach is a good example that has brought about a reduction in damage to the environment while ensuring the producers themselves come out on top.

**Failures in terms of joint environmental field research projects: a trial in a rural environment on improved fallowing in Niger**

The drop in soil fertility is one of the most restrictive problems for agricultural production by small producers. In addition, these latter do not have the means to apply manure, let alone purchase fertiliser. The problem is widely known; in terms of our research, we have tried to establish an environmental trial to test the effectiveness of certain woody species in increasing soil fertility.

The trial was set up using local and exotic species in two neighbouring villages. Following establishment of the trial, a technician collected data on site. However, the local villagers were not made aware of the trial at the outset and their agreement to carry out the trial was not sought. Instead, we were seen by the producers as officials from the city imposing our will on them. During weeding and hoeing, the villagers kept away from the plants we planted, regarding these as having nothing to do with them but instead considering them as State property. When we arrived to supervise operations, we were told by them that our plants were over there! It was only afterwards that we realised they had their own ideas in mind, and how was it that we felt we could come and set up experiments in their fields without their consent! Even the species we used were challenged, as one of the species had cultural implications which were inappropriate to this region.

Once we saw our mistake, we held a village assembly presided over by the chiefs of the two villages. We received all manner of threats despite the high level of authority the chiefs

3 Co-monomer technology, cf. IAEA-C2.RAF/5/048 Limited Distribution Report, March 2002.

wielded. The producers unanimously decided to pull up all the plants planted in their fields.

This approach showed no respect to the villagers and all our efforts in terms of physical work, equipment and finance, were in vain. In terms of rural research, a participative approach must be followed if the anticipated results are going to be achieved. At first we thought that if the results were conclusive, the villagers would just simply adopt them. But in this case, for this research project, it was a total failure due to our poor approach.

## Resources and References


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### Internet Resources

There are many internet resources for participatory approaches but you may be interested in starting with the following:

http://www.iapad.org/toolbox.htm
http://www.eldis.org/go/topics/resource-guides/participation
http://www.chronicpoverty.org/toolbox/Index.php

# 3.3 Using secondary data sources

*Jayne Stack*

- **Primary data are observations you collect yourself to meet a specific research objective**
- **Secondary data are observations collected by others for other purposes**
- **Every research study should start with a review of relevant secondary data before planning collection of primary data**
- **Secondary data can help define the scope and extent of a problem**
- **The value of secondary data may be limited by availability, accuracy, timeliness and the definitions used**
- **There are very many sources of secondary data. International data are increasingly available free on the Internet**
- **Techniques are available to help you use secondary data effectively**

## Overview

At the broadest level information sources that are available to you can be classified as primary or secondary. Primary data are those which you collect yourself for a specific research purpose. Secondary data is information that has been previously collected by individuals or agencies, usually for purposes other than your own particular research study. Secondary data may be qualitative or quantitative. Qualitative data is generally thought of as subjective, verbal and descriptive and includes information captured by a wide range of media. It includes photographs and maps, case studies, reported happenings, in-place observation, and tape or video recordings of conversations and/or activities. In contrast, quantitative data is generally numerical data, collected using some form of measurement and amenable to mathematical analysis. Quantitative data includes information captured by direct measurement through field observation (rainfall, temperature, crops yields, price-monitoring) and by direct measurement within structured questioning (household income and expenditure data collected by governments as part of national households surveys). Although the nature of secondary data influences the selection of tools that can be used to manage or interrogate a data set it is easy to exaggerate the differences. Both types of information are collated, sifted and organised into some sort of meaningful form by looking for connections or relationships in the data. The guidelines for reviewing secondary material outlined in this chapter can be adapted to a wide range of secondary sources compiled by other people.

The aims of this chapter are to:

- Show that no study should begin without first reviewing existing knowledge, regardless of the data-collection techniques to be followed later
- Identify the main sources of secondary information
- Point out and illustrate the need to critically examine the concepts and definitions used in secondary information
- Illustrate some of the conceptual and analytical tools that can be used to 'interrogate' data from secondary sources

- Secondary data analysis is not just a first-stage activity but can and should contribute to every stage of the research cycle.

## Why is secondary data useful?

All too often inadequate attention is given to reviewing existing knowledge before embarking on primary data collection. No research study should be undertaken and without a prior search of secondary sources (also termed desk research). There are several grounds that give us confidence in making such a bold statement. (The following material was adapted from Crawford and Wycoff, 1990):

- Secondary data helps you to: define a research problem, formulate research questions and hypotheses, and select a research design. The assembly and analysis of secondary data almost invariably makes an important contribution to the research process. A review of existing knowledge will improve your understanding of the research problem, including the key issues, core concepts, and on-going debates. It will reveal approaches to data collection (e.g., useful conceptual models, variables for concepts of interest, appropriate analysis techniques) that may improve or complement your own initial research design. In sifting purposefully through secondary data, you may find something else that sends you exploring new regions or ideas you may not even have thought of before. And, you might find evidence that will actually change the shape of your ideas.
- Secondary data may be sufficient to answer the research question. Occasionally you may find the available data are so adequate that primary data collection is unnecessary. If useful secondary data are available, they can be used to substitute for primary data collection at any stage during your research. It is not always necessary for you to collect all the information required for the analysis yourself. For example, daily rainfall records for the last 30 years obtained from the Meteorological Office allow you to draw conclusions about the adequacy of the growing season and the problem of dry spells, or agricultural data from a national sample survey can provide good information on the major characteristics of a farming system.
- Data costs are substantially lower for secondary data than for primary data. A thorough review of secondary sources can be completed at a fraction of the cost and time it takes to complete even a modest primary data collection exercise. Finding a 'ready made' solution in existing sources is unlikely, but even partial solutions help primary data collection needs, and therefore save time and money. For example, the current livestock situation in a country in terms of stocking densities, grazing pressure, herd structure, and management practices could be studied using a combination of secondary livestock data from the Ministry of Agriculture, the veterinary services, and reports of past research studies.
- Secondary sources of information can yield more accurate data than that obtained through primary data. This is not always true, but when a government or international agency has undertaken a large-scale survey or even a census, their results are likely to be far more accurate than your own surveys when these are based on relatively small sample sizes. For example, a national income and expenditure sample survey is likely to yield more accurate results than an income and expenditure study of 200 sample households in a single area. However, it should be remembered that all secondary data was once someone else's primary data. Some people who work with official statistics wrongly conclude that their own analysis is more objective than analyses of primary data, which is 'soft' data.
- Secondary sources help define the population. They can be extremely useful both in defining the population and in structuring the sample you wish to take. For instance, government statistics on a country's agriculture will help to stratify a sample and, once you have calculated your sample statistics, the stratified sample can be used to project those estimates from the sample to the population.

- Secondary data can be used to make comparisons. Within and between nations and societies, comparisons can enlarge the scope for generalisations and insights. Global and regional data sets (e.g., those of the Food and Agriculture Organization of the United Nations (FAO), World Resources Institute (WRI), or the World Bank) are a valuable source of secondary data for between-country comparisons on a vast range of topics including poverty issues, food security, trade patterns, growth rates, and technical change. Within-country comparisons can be made using national data sets disaggregated by administrative or natural regions.
- The availability of secondary data over time enables the employment of a longitudinal research design. One can find baseline measurements in studies made in the past and locate similar data collected more recently. With an increasing emphasis on understanding patterns of change, the use of secondary sources can also be critical to single point surveys, which lack a time dimension.
- Secondary data can be used to increase the credibility of research findings obtained from primary data. The comparative use of other research together with a comparison of data collected during your study with official statistics on the same topic can be very valuable when you reach the analysis stage. Research results are more credible when supported by other studies.

**Limitations of secondary data sources**

The following material was adapted from Crawford and Wycoff (1990). Whilst the benefits of secondary information can be considerable, like any other data collection method, the validity of the data must be carefully assessed. The main problems include:

- **Access.** Once potential sources of useful secondary data have been located there may be difficulties in accessing variables of interest if the data are not in the public domain or are unpublished. If this is the case, you will need to approach the organisation or individual holding the data to seek permission to use the information it contains. Unpublished data sets residing with government or non-governmental institutions are usually made available once permission has been sought in writing, clearly explaining the purpose for which the data will be used and the user's willingness to adhere to specific conditions of use. A supporting letter from the institution sponsoring your research may be helpful. Sometimes the original investigator will not make data available, particularly if they are still using it to pursue their own research. This can be frustrating, especially if data analysis is taking a long time. Sometimes researchers may be willing to provide some data in aggregate form ahead of publication. This can be used providing its source is acknowledged.
- **Relevance.** There is an inevitable gap between primary data collected personally by an investigator with specific research questions and hypotheses in mind and data collected by others for different purposes. It often happens that there is an abundance of secondary data, but much of it is not of direct relevance to your specific research problem. During the early stages of examining secondary data, you explore and gather anything and everything that you think might be of interest or use. However, as you begin to organise the material you have collected to support one or another of your ideas some secondary data will not be relevant. Every bit of evidence that you include must justify its existence; it can only do so in support of an idea. Use the list above to ask yourself on what grounds the secondary data you have collected is useful.
- **Reliability.** The reliability of secondary sources may vary substantially and it is difficult to ascertain if insufficient information is available about how the data were collected and potential sources of bias and errors. It helps considerably if you are able to speak to individuals involved in the collection of the data to gain some guidance on the level of its accuracy and limitations. There have been evaluations of the reliability of many large scale official statistical datasets. You should always try to find such evaluations and ensure the quality is sufficient for your purpose.

- **Definitions.** A common problem in using secondary data is how various terms were defined by those responsible for its preparation. Terms such as family size, income, credit, farm size, output sales, and price need very careful handling. For example, a family size may refer to only the nuclear family or include the extended family. In census data a household is often a group of people who stayed the census night in the dwelling unit, irrespective of whether they are part of the nuclear family or not. Income data often exclude the value of own-produced goods. Credit and sales statistics often ignore transactions that pass through the informal sector. Even apparently simple terms like the year for which the data apply may need care in interpretation. For instance, in Zimbabwe, the marketing year 2002/2003 refers to the period 1 April 2002-31 March 2003. Any crop sales data recorded against 2002/2003 refers to sales from the 2002 harvest. Sales from the 2003 harvest are recorded under the 2003/2004 marketing year! Special care in interpreting definitions and years is necessary in combining secondary data from several sources to produce a derived data set.
- **Timescale.** Most secondary data has been collected in the past so it may be out-of-date when you want to use it. If the data source includes estimates of growth rates this information may be used to extrapolate figures for subsequent years. For example, population censuses usually include an estimate of population growth that can be used to estimate inter-census population data.
- **Source bias.** You should be aware of vested interests when you consult secondary sources. The objectivity of officials may be affected when it comes to reporting situations for which they themselves are partly responsible. Similarly respondents may provide biased information depending on their perceptions of the purpose of data collection (e.g., planning drought relief, forced destocking,). Further, official economic data may be a very inaccurate source of statistics in situations where the informal economy and/or black market account for a significant share of economic transactions.

**Sources of secondary data**

Secondary data sources can be divided into two categories, internal and external.

### Internal information sources

All organisations collect a range of information during their daily operations. For instance, a marketing board records deliveries of crops, payments made to farmers, stocks, and orders from buyers that are dispatched, and invoices sent out. Such information may be available in a more disaggregated form than is reported in the organisation's internal reports. Much of this internal information is of potential use to researchers, but surprisingly little of it is actually used.

You may be unaware of some of the data collected and the regular reports submitted by the organisation for which you work. Begin your secondary data search with an internal audit. Familiarise yourself with available internal information whether you are a researcher in a government body, non-governmental organisation (NGO), or a business organisation.

### External information sources

The primary sources of official and semi-official statistics are:

- Government statistics. These may include population censuses, national income data, agricultural statistics, poverty surveys, trade data, cost of living surveys, nutritional surveys, the results of commissions of enquiry into particular issues (e.g., land tenure) and possibly data on market prices.

Secondary sources can include:

- Marketing boards, which are likely to have information on quantities purchased of different commodities, imports and exports, buying and selling prices, and stocks

- Extension organisations who will have crop area and production estimates for various crops and probably farm budget data for different enterprises
- Agricultural research institutes that are an important source of information on such agronomic issues as soil fertility studies, crop and livestock breeding programmes and technology
- Veterinary departments who may have data on livestock numbers and disease control measures, e.g., dip tank records
- Hospitals and clinics might have data on incidence of malnutrition, particular diseases and causes of death
- Local administration offices often have lists of households which could be useful in the construction of sampling frames. They might also provide information on project activities in the district, e.g., active NGOs, or registered cooperatives
- Archives are a useful source of information to help you understand patterns of change
- International organisations may have country studies available at their local information centres or offices
- Websites. With the rapid development of information technology and computerised databases, the scope for you to carry out a search of secondary sources and to use secondary data sets compiled by other organisations and posted on websites, has increased dramatically.

The following is a selection of key websites providing access to statistical data of particular interest to African agricultural, environmental and rural development researchers.

### Main collections of wide-ranging development statistics

- World Bank website offers on-line access to country statistics and prepared tables for 207 countries and 18 country groups. 54 time series indicators on people, economy, environment, spanning 5 years are available and you can choose several ways of displaying the data: index, percentage change and graphs and can export the results to other documents. http://web.worldbank.org
- UNDP Human Development Report and Indicators provides statistics on human development indicators including poverty, health, education, food security, employment, urban development, population, environmental degradation and national income accounts. http://hdr.undp.org/en/
- International Development Statistics (OECD/DAC) on-line database covering debt and aid. http://www.oecd.org/department/0,2668.en_2649_34447_1_1_1_1,00.html
- United Nations Statistical Organization (UNSO) has a wide range of statistical databases on-line on trade, national account, demography, population, gender, industry, energy, environment, human settlements and disability. http://unstats.un.org/unsd/default.htm
- World Health Organization (WHO) website for health related statistical information. Also provides supporting materials including analysis software. http://www.who.int/whosis/en/
- Millennium Development Goal Indicators has 48 social and economic indicators for 1985-2000 used to monitor the implementation of the goals and targets of the United Nations Millennium Declaration. http://mdgs.un.org/unsd/mdg/

### Subject-focused development statistics websites

There are numerous subject-focused websites that provide data on specific topics (see http://www.eldis.org/go/topics). Those of particular interest include:

- United States Department of Agriculture (USDA) provides global and US agriculture data. http://www.ers.usda.gov
- Food and Nutrition and Crop Forecast. ‘Food Outlook’ is a report produced by FAO five times

a year. It provides a global perspective on the production, stocks and trade of cereals and other basic commodities. Food Outlook can be downloaded from http://www.fao.org/giews/english/fo/
- A helpful guide to other sources of food security statistics is the ELDIS Food Security Resource Guide at http://www.eldis.org/go/topics/resource-guides/food-security/
- HIV/AIDS. A resource guide for information and data is available at http://www.eldis.org/go/topics/resource-guides/hiv-and-aids/

#### Country-focused development statistics websites
A good starting point is the ELDIS country profile service. http://www.eldis.org/go/country-profiles/

#### Non-official sources
- Consultants reports (which may be gathering dust on the shelves of the body sponsoring the research!)
- Records of NGO activities including drought relief and supplementary feedings schemes
- Baseline surveys and project documents.

As you can see, secondary information can come from a bewilderingly large number of sources. Perhaps the most efficient and effective way to begin is to talk to people. Find the authorities in the field; search out the researchers working in your areas of interest. Conversations with them can get you further faster than almost any other search method. Researchers outside your own country can usually be contacted by e-mail and many are happy to forward copies of their own publications. Develop a network of contacts in key positions and cultivate them over time. Such contacts are particularly useful sources of semi-official and unpublished reports from research institutions and universities. In addition, experienced researchers have usually built up their own list of favourite websites that provide material on key research themes in development.

#### Spatial Data
There is a rapidly growing collection of spatial data in the public domain, ready formatted for use in GIS systems (**Chapter 3.4**). Data cover such things as climate, land use, population, soil type, infrastructure, poverty, water sources and many others.

### Recording details of secondary data material
Mountains of information can grow alarmingly quickly and it is imperative that you keep a record of the material that you have consulted in the course of your research so that you can acknowledge all the sources. The most important aspect of collating secondary data is to establish a 'trail' so that you or anyone who wishes to check your sources can easily find them again. Note the source of every piece of information you find useful. There is no single universally accepted format for referencing but a common order for the required information is:
- Author(s)
- Date of publication
- Title of the work cited
- Publisher
- Place of publication.

When referencing data from the internet give the location (URL) and the date it was sourced, unless the site specifies an alternative. Unfortunately URLs change, and there is no guarantee that data found there today will still be available in the future.

## Evaluating secondary information

Information obtained from secondary sources is not equally reliable or equally useful. As mentioned earlier, just because data is published it does not mean that it is accurate. Just because data is available it does not mean it is useful for your particular study. If you are using secondary data, be it quantitative or qualitative, you should routinely ask the following questions, according to Dillon *et al*. (1990).

- What was the purpose of the study? Data are usually collected for some specific purpose, that ultimately determines the study variables of main importance, the reporting domains and the degree of precision
- Who collected the information? Because you are not collecting the data yourself, a natural question concerns the expertise and credibility of the source. Find out how the data were obtained and what sort of training and expertise is present in the organisation providing the data
- What information was collected? It is important to check this exactly. For example, in a study on household income were all income sources included, or only cash income?
- When was the information collected? The time the data were collected plays a role in its interpretation. For example, information on the nature of the season should be examined when interpreting household information on incomes or food security
- Which geographical area does the data represent? Not all data is collected for the same spatial area. Administrative boundaries often differ from geographical boundaries and may also vary depending on the organisation collecting the data. Boundaries also change over time as new administrative districts are formed by splitting or amalgamating existing units. The boundary issue is generally most problematic if data from different secondary sources are being combined and/or information from various points in time is being compared
- How was the information obtained? The method used to collect data is an essential ingredient in evaluating the quality of secondary information: for example, the size and nature of the target sample, whether it is based on observation or recall, how it is collected (key informant interviews, household surveys, focus group, satellite imagery, etc.) and if surveys were from single or multiple visits. Some methods or combinations of methods are better than others at providing specific types information. Familiarise yourself with the alternative ways of obtaining information so that you can make an informed assessment of secondary data quality
- Is the information consistent with other information? A valuable principal in data collection is that of triangulation where information is collected from multiple sources. If similar conclusions can be drawn from different sources of data this lends credibility to the findings. If differences exist, you should try to find out why, and which source is more reliable. The consistency of information is frequently a problem with agricultural production statistics from different sources.

## Working with secondary data

Research studies use secondary data in several ways, the following are three broad types:

1 Research which uses aggregated secondary data to inform a study that will generate its own primary data as a major source of information.
  For example:
  - Study of consumption and marketing decisions of smallholders where the major source of information is a household sample survey, but where secondary data on grain production and marketed surplus by region are combined with official population data to examine past trends in agricultural production and marketed output. Here the analysis of secondary data provides a context for the analysis of the primary data
  - Investigation into the feasibility of edible insect farming using an experimental farm,

where secondary information on artificial feeding is used to identify alternative feeding methods for field trials
2 Research which uses aggregated secondary data as a major source of information, when interpreting this information. For example:
  - International comparison of various development indicators using a World Bank's global data set
  - Regional human poverty comparisons made by the United Nations Development Programme (UNDP) for Zimbabwe using a poverty assessment study survey undertaken the Ministry of Public Service, Labour and Social Welfare and other secondary data sets (UNDP, 1998)
3 Research which uses disaggregated secondary data, perhaps in raw form, as a major source of information, with a new analysis of the same data. For example:
  - Modelling agricultural supply response using a data set derived from secondary data found in official statistics
  - Construction of a food balance sheet using official statistics
  - Lenin's' famous analysis of peasant differentiation using Zemstov house-to-house census data as his major source of data (Lenin, 1961).

The conceptual and analytical tools used to interrogate secondary data will vary depending on the role that secondary data play in the study. For instance, if secondary data are the major source of data for your research task, the analytical process, (specification and estimation) is likely to be a central component of your thesis. On the other hand, if you are assembling secondary data to improve your understanding of the socio-economic conditions in a field study area you are more likely to use simple descriptive statistics to highlight important trends and characteristics.

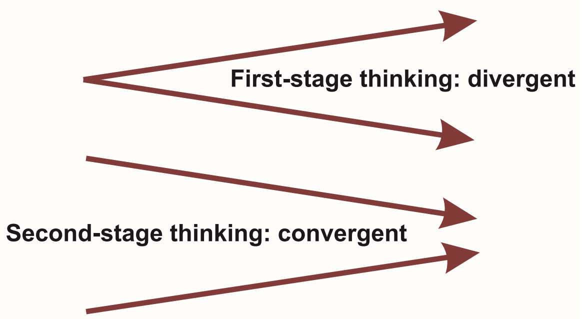
Regardless of the way you intend to use secondary data some general comments can be made about methods of interrogating it.

## General

Research, like any other types of thinking, can be thought of as involving two stages. [The distinction between first stage and second stage thinking was first brought to my attention in a highly recommended course called 'Writing for effective change' (Fahamu, 2000)]:
- First-stage thinking: exploration, discovery, generating ideas
- Second-stage thinking: collating, sifting, organising the ideas into a robust structure.

**First-stage thinking.** Sometimes called 'divergent' or 'radiant' thinking; during this stage, you explore and gather anything and everything that you think might be of interest or use to your study.

**Second-stage thinking.** By contrast this is sometimes called 'convergent' or 'focused' thinking. It organises the material you have collected to support one or another of your ideas.




We tend to be much better at second-stage thinking than at first-stage thinking. So much so that we often fail to see first-stage thinking as thinking at all, but we ignore it at our peril. No amount of excellent second-stage thinking can compensate for poor or inadequate ideas. You must spend time generating ideas from secondary information before trying to assemble them into a structure.

Two techniques can help you:

- Mindmaps are powerful devices in first-stage thinking, they will help you gather and initially sort ideas
- Grouping and summarising is a second-stage thinking technique that helps you to organise your ideas.

**Mindmapping**

Mindmapping has been around for a long time, but the person who has done most to explain it and make it popular is Tony Buzan (1993). Mindmapping exploits our mind's extraordinary ability to create meaningful connections between ideas. Mindmapping helps us to see – or make – connections in our thinking, increasing our creativity and making thinking more efficient.

Brainstorming is the first step in mind mapping. Figures 1-3 show how a mindmap was developed to think about how to improve feeding systems using traditional practices (The mindmap example is adapted from 'Writing for effective change' distributed by an NGO called Fahamu, Learning for Change). Begin by writing the main research question or concept in a circle in the centre of a page. Then, jot down any ideas that come to mind when you think of this concept. (Figure 1). As you think of each new idea, new branches are created from the central balloon and the idea is written along the line (Figure 2). The next step is 'free associating' on each idea to build a verbal map of words or images that are connected to it. Sub-sets of ideas are drawn as twigs from the appropriate branch line (Figure 3). Gradually a verbal mindmap tree of associations is built up. The final stage is to introduce hierarchies and categories to order or structure your mindmap. In the final mindmap you could use colour to emphasise hierarchies of ideas. The five main ideas for improving feeding systems radiating from the central image are shown in white whilst the sub-sets of ideas radiating from each of these ideas are black (Figure 3).

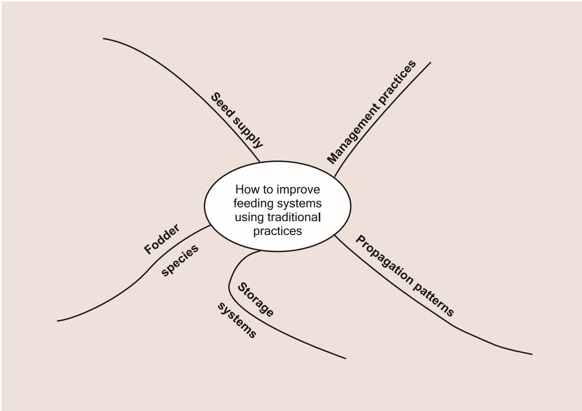



Figure 1. Example mindmap (4)

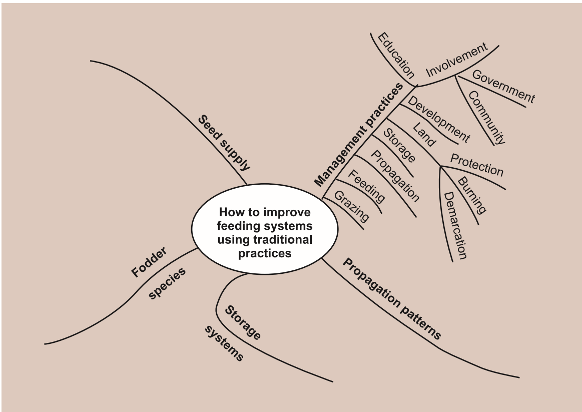



Figure 2. Example mindmap (5)

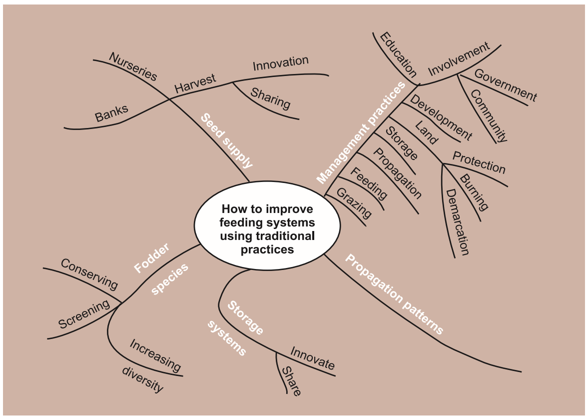



Figure 3. Example mindmap (final)

**Grouping, summarising and organising ideas**

It is unlikely that secondary data can be presented at the same level of detail in which it was previously collected. In other words you will not be able to report all the secondary material you have reviewed in its raw form and will need to summarise and present your data in a way that reveals patterns and trends in the data set. In order to summarise and present data it must be organised. There are various ways to do this. Some of the most common techniques that enable you to interrogate both qualitative and quantitative secondary data include:

### Selecting categories in which the data can be summarised

A simple but effective way of revealing patterns in secondary information is to reorganise the information into new categories. The categories selected will depend on what is relevant to the topic being considered but if you are investigating food security you could use a data set of district-level information on estimates of per capita food availability to identify different categories of districts on the basis of their potential vulnerability to food insecurity. A study concerned with trade could rework information on the value of exports and imports between different countries by country groups to show the relative importance of different groups of trading partners. Putting available information into a tabular format is another way to organise either qualitative or quantitative information. Information from earlier studies was used in one study to compose a table showing different types of natural resource-access systems [individual,

**Table 1. Categorising and characterising different mopane woodland access systems in southern Africa**

| Land tenure institution | Who controls and how? | Who harvests? | Who benefits? | Who excluded? | Management implications |
|---|---|---|---|---|---|
| **Individual** | Individual | Individual | Individual | All others | Every owner has to exert effort to protect<br>Cost of protection low if resource close to residence |
| **Regulated common property** | Rural Councils / Community resource management groups | Community members<br><br>Licensed outsiders Community members<br><br>Outsiders Licensed outsiders | Harvesting members<br><br>Non-harvesting members (from licenses)<br><br>Licensed harvesters | Unlicensed harvesters | Organised collective action to manage and protect resource.<br><br>Potential economies of scale in protection activities.<br><br>Transaction cost of formulating management rules and enforcing them may be too high for resource to be effectively regulated |
| **Unregulated common property (open access)** | Traditional control mechanisms | | All harvesters | No one | If traditional regulations on extraction of resources break down, tragedy of commons results in overexploitation and deterioration over time |
| **Centralised management of common property (e.g., State land)** | Forestry Commission | | Licensed harvesters<br><br>State (from licenses) | Unlicensed harvesters | Organised centralised management system<br>Potential economies of scale but cost of protection high for minor forest products<br><br>Weaknesses in management may result in resources being ineffectively regulated |

regulated common property, and unregulated common property (open access)] cross-tabulated with information about who controls access, who harvests, who benefits, who is included, and management implications. Organising the information in a tabular format highlighted the differences and similarities between each system more clearly than if the same information was just presented as paragraphs of written text (see Table 1).

### Production of derived (secondary) data – new data sets

Very often the use of simple descriptive tools such as percentages, means, indices, or rates of growth can highlight patterns and trends in a data set that are not obvious in the original format of the data. For example, if crop production and sales data are available for two different farming sectors (smallholder and large-scale commercial) calculating the percentage share of each sector in total output and sales is a useful way of examining the relative importance of each sector. If information on the volume, value and prices of exports of a particular commodity are available over a period of time, then calculating instability indices for each variable will demonstrate the level of export earnings instability and the extent this is due to either export price instability or instability in quantity exported.

### Combining secondary data sources to form a derived secondary data set

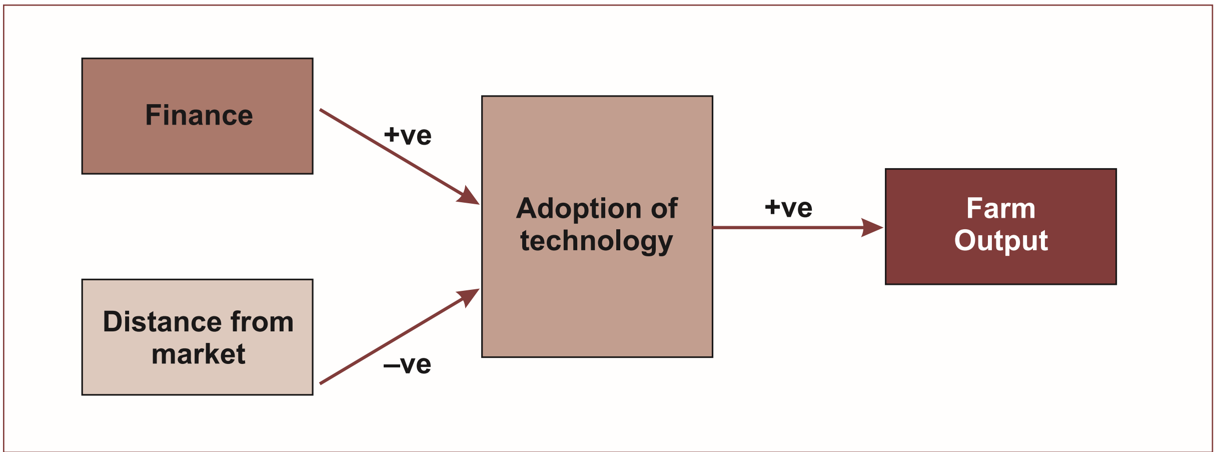
Combining secondary data sources may create a new data set that is more informative than each separate data set. A common calculation that illustrates this technique is the use of population data to express data sets of such variables as production, income, or cultivatable land in per capita terms.

## Conceptual models and diagramming

Diagrams are very powerful tools for organising qualitative data. At its very simplest this could be diagramming a hypothesis about the main factors affecting a variable of interest using descriptive information from earlier studies.

**Diagramming hypotheses** (Dixon *et al.* 1995)

For example, in the following diagram, two concepts, finance and distance from market are hypothesised to be related as independent concepts to the dependent concept, adoption of technology. One of the independent concepts is seen to be positively related and the other negatively related to the dependent concept. Technology adoption is in turn hypothesised to positively affect farm output. Diagramming hypotheses promotes clear thinking and it is a useful way to summarise information from earlier studies. Use secondary data to diagram what you plan to study and even beyond the immediate research issue to show where your research fits in to the larger frame of reference.



However, diagrams can also be a useful way of conceptualising links and feedbacks within a system. For example, the livelihoods framework illustrated in Figure 4 is useful for thinking through livelihood circumstances of individuals, households, villages, and even communities and districts. The limitations of any such 2-dimensional representation of a process as complex as livelihood formation are recognised from the outset. The purpose of such a diagram is to organise ideas into manageable categories and identify the main components (assets, mediating processes, activities) and the critical links and dynamic processes between them (Ellis, 2000).

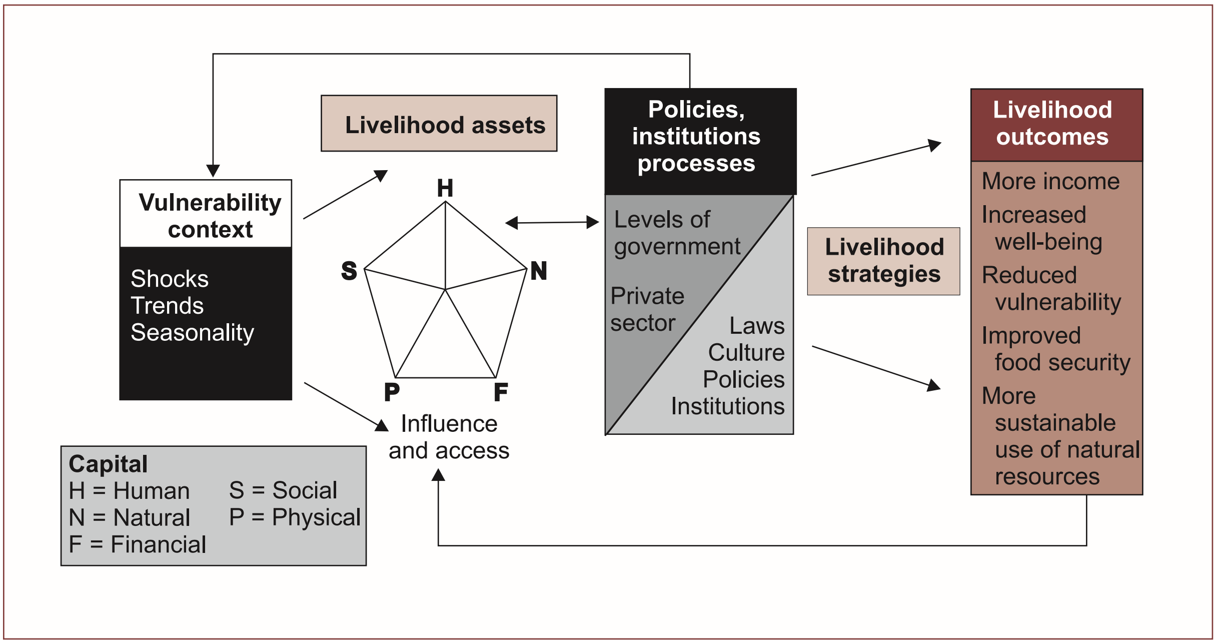



Figure 4. Sustainable livelihoods analytical framework

**Analytical frameworks**

Analytical frameworks are useful tools that enable you to concentrate on the broader picture. For example, food policy analysts may compute a food balance sheet using secondary information to examine food availability and identify key characteristics of domestic food consumption. Economic statisticians use accounting frameworks to prepare a country's national accounts and balance of payments based on secondary data.

## Conclusions

A lot can be learned from secondary data and you should be prepared to explore various alternative ways of interrogating available information. Data sources should always be acknowledged and some guidance provided on the reliability and limitations of data used. In practice the collection and interrogation of secondary data is not just a first-stage activity but is something that can and should contribute to every stage of the research cycle. As noted in the opening section, secondary data can assist in designing a sampling frame, and in identifying a potentially useful method of analysis or appropriate conceptual framework. Secondary information provides a context for the analysis of primary data. The comparative use of secondary data can be especially valuable at the analysis stage and a good researcher will highlight areas of contrast and similarity between their own data and research findings of earlier studies on similar topics. Whilst findings gain more credibility if they are supported by a number of other studies, you should not be afraid to indicate where findings are different.

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# 3.4 Spatial data and geographic information systems

*Thomas Gumbricht*

- **Understanding the spatial context of an agricultural and resource management problem will probably be an important part of solving it, so can not be ignored in your research**
- **Geographical information systems (GIS) allow you to manage and manipulate spatial data**
- **Simple manipulation of data sets that has already been prepared can be learned quickly. However, using data from multiple sources for more complex tasks can be a major undertaking**
- **Many basic spatial data sets are available for Africa but poor Internet connections may limit access to them**
- **Freely available software is now sophisticated enough to be useful in many spatial research projects**

## Introduction

The Earth is a sphere with an average distance to the Sun of 150 million km. The Sun radiates energy, which is received by the rotating Earth in diurnal cycles with annual modulation as the Earth completes its annual ellipse. The energy that hence reaches the Earth is mainly dissipated at the Earth's surface. It rotates the hydrological cycle, releases nutrients that feeds the ecosystems, and drives photosynthesis (all which have been largely altered by man since the Industrial Revolution). Thanks to these processes life exists and the Earth's surface has developed a 'natural' logic. In dry areas with poor resources vegetation is sparse, in valleys where water and resources accumulate the vegetation is more luxurious. If there is a trough and enough water a body of water will form. In a similar way the human landscape is also logical, with fields in fertile valleys and dwellings along the ridges. Cities have to be close to large sources of water. These logical landscapes are also evident on a much smaller scale. Most vegetation is bound to specific habitats narrowly defined by conditions of climate, soil and water; that can shift within a scale as small as one metre. At an even finer scale a human thought is also dependent on energy dissipation at interfaces – in a very well described spatial context between the synapses of nerve cells. Image analysis and location information systems are hence very important tools in medicine, sociology, anthropology, biology, ecology, geology, hydrology and many other sciences.

For a particular study the spatial information needed might only be a map – as were the descriptive studies conducted by the first European explorers. In most instances a researcher is probably more interested in extracting more information in order to test a hypothesis. This could be comparing two district-level data sets, perhaps one on poverty and one on incidence of malaria. This is easily done in a geographic information system (GIS), and you still only need a single map, with attributes (databases) on both malaria and poverty. But malaria is a vector-borne disease, and the mosquito carrying the parasite breeds in water, so proximity to water is most probably important. To test that hypothesis an additional data layer of water availability is needed. This step is a major complication that has yet to be fully taken in the case of malaria. Rivers and lakes can easily be found, and their proximity to each population group calculated. But now you ideally also want population and malaria data on village level, not just for districts. Then you realise that mosquitoes can breed in water tanks, small puddles, or even water trapped in an old bucket or boot. Now the comparison becomes almost impossible, and you need to get data on rainfall and temperature in order to calculate the daily water balance. This calculation is possible; the data are there (as you will see below), but the calculation is not a trivial task.

In general, a thematic study will need more refined data, whereas an interdisciplinary study must probably be satisfied with more generalised data. Often this is because detailed data of different origin are seldom compatible in their spatial resolution. However, the use of GIS and spatial data can be very rewarding. The first level, including a map, is almost always welcomed and very simple, it will only take a few days. The second level, comparing ('overlaying' in GIS jargon) attribute data related to the same spatial context is also quite simple, and will take a week to a month. The third level, analysing spatial relations introduces complexity, but can still be done by most standard GIS packages (and some of the freeware packages listed at the end of this chapter), but it will take some months to a year. The fourth level of integrating GIS with dynamic (time-resolved) models is quite complicated. This level will demand in-depth knowledge of both GIS and modelling, and most probably of programming as well. It will take longer than a year.

## Mapping and modelling with GIS – A game of chess

### Capturing the chess board

It is seldom convenient to have a sphere to portray the Earth's surface; so humans have used two-dimensional (2D) maps for at least 5000 years. Most GIS are also static 2D, even if the processes occurring on the Earth's surface are often 3D and dynamic. The most common GIS spatial data model represents space as 'vectors' (points, lines and polygons). This model is suitable for human-created objects and concepts (wells, roads, states, cities, rivers and lakes). Natural phenomena are better represented as continuous fields (elevation, land cover, vegetation density), which in GIS translate to a 'raster' or grid data model (Figure 1). For simplistic reasons, the raster model is often preferred in modelling. It is also the implicit format of satellite images or photographs.

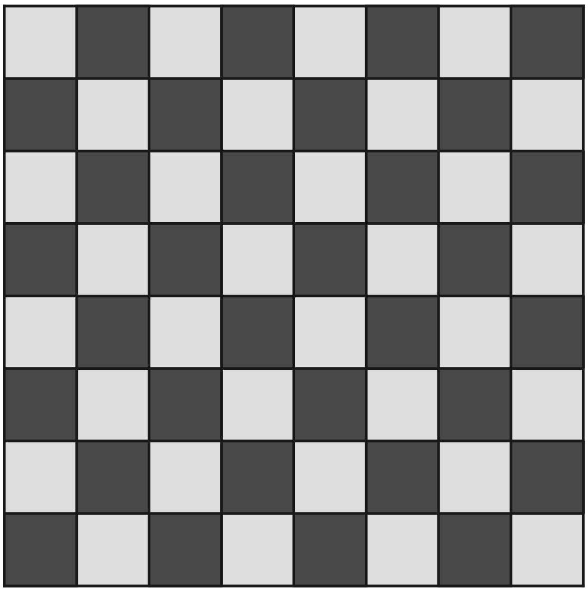

Figure 1. A raster

The raster landscape in Figure 1 is also the landscape where the game of chess takes place. Let us assume that you are unaware of the game of chess, but want to understand it by using GIS. Once you have identified the problem from a GIS perspective you must decide which data model (raster or vector) to use and how to *capture* the data. The chessboard can be captured as primary data (from satellite image or digital photograph) or from an existing analogue (secondary) source (digitising or scanning). Whatever you choose you will, implicitly or explicitly choose a certain grain size (or spatial resolution) when you capture the data (Figure 2). *Meta*-information on capture technique, resolution, and who did it should ideally always follow the GIS data, but is frequently lost on the way to the end-user.

For most spatial phenomena that are studied, you usually have a conceptual idea about the spatial patterns and dynamic processes that are occurring. If you assume that you already have some existing knowledge of chess, you can decide on a stratified sampling of data. For each square of unit distance, take one sample at a randomised point. You can further assume that there is neither an error in position, nor in the obtained value. A point is the simplest kind of vector data, and you can assign attributes to it – you can form a database describing the properties of this point (in this case colour, but it could also be some other capacity such as depth, elevation, or type). Then you can *manipulate* the point data by *rasterising* it to arrive at something that looks like a chessboard. If you honour the value of the measurement in each cell (or *p*icture *el*ement – pixel) you will arrive at the correct landscape (that you happen to know in this simple case) (Figure 3).

If instead you manipulate the data by using a geostatistical interpolation function, which do not honour the observed value *per se*, you get more or less erroneous results (Figure 4).

The high cost of field and inventory work requires the fullest use of existing data and the application of interpolation methods. Hence, the sampling grid is generally much sparser than the interpolated grid (Figure 5).

Note that the interpolation of the chess

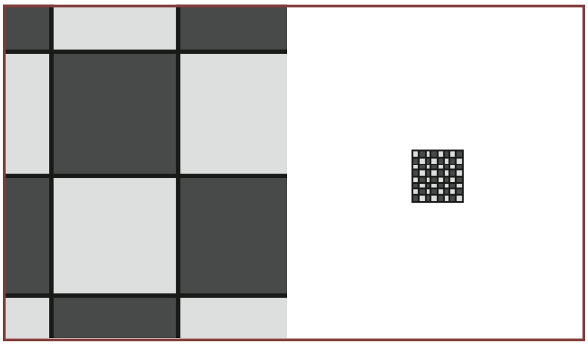

Figure 2. Two raster data sets with different grain size. The ease with which you will be able to understandchess will obviously be dependent on the resolution or grain size used to capture the chessboard

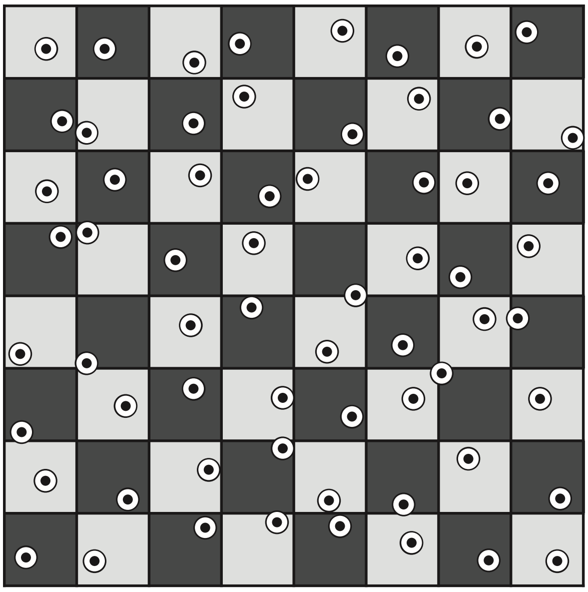

Figure 3. Sample points (vector data) and rasterised pattern

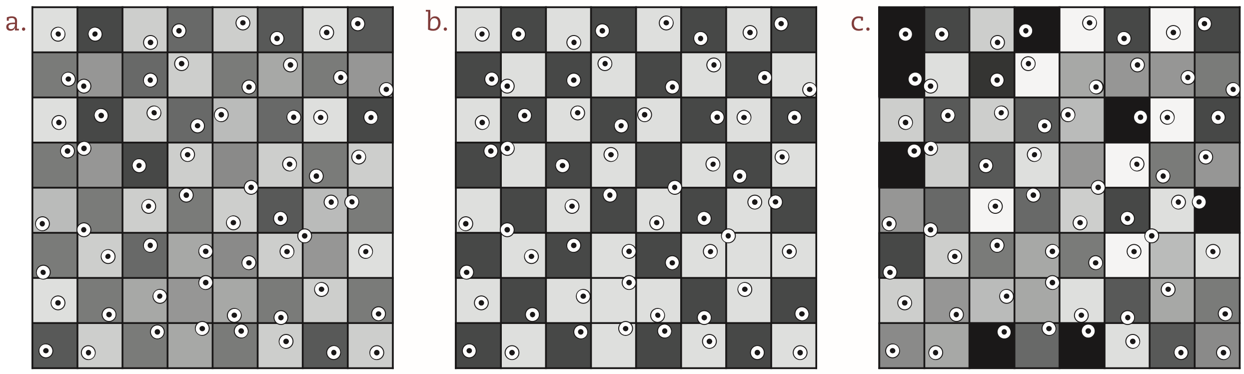


Figure 4. Interpolated 8x8 raster image from 64 Boolean sample points, randomly placed in each grid cell: a. Inverse distance weights (IDW) to 8 neighbours, b. Reclassification of a, c. Spline smoothing function to 8 neighbours. The reclassification is done as a threshold using the value 0.5. Both illustrated interpolation methods can be parameterised to get a true chessboard, that, however, demands iterations and skills, together with knowledge about the pattern of the generated surface

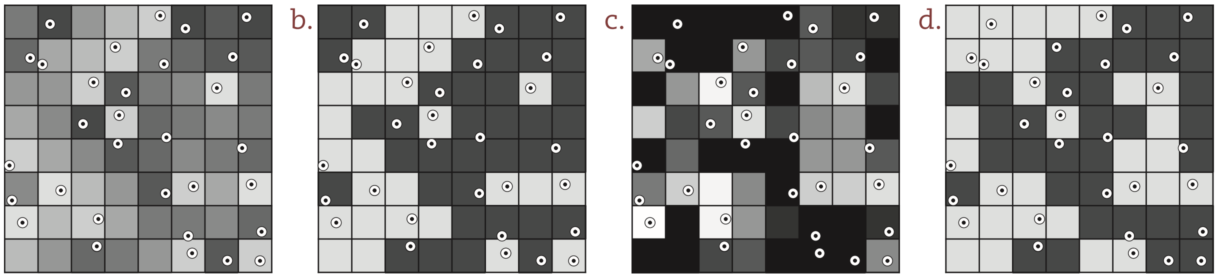


Figure 5. Interpolated 8 x 8 raster image from 31 randomly selected points (see Figure 4) a. IDW to 8 neighbours, b. Reclassification of a, c. Spline smoothing function to 8 neighbours, and d. Reclassification of c. The reclassification is done as a threshold using the value 0.5

board data are truly 2D, whereas the Earth's surface is a spheroid and interpolation with different geoids and projections render different results. To choose the right projections for a particular purpose is not trivial, but is beyond the scope of this book).

Primary data capture from remotely sensed imagery to GIS is an important part of the integration of GIS and modelling, also in social science for updating or downscaling census data (see below). Remotely sensed data have a definitive grain size and thus resolution. Apart from grain size, problems with sensor quality, spectral properties of the observed phenomena and georeferencing introduce errors when interpreting and classifying remotely sensed data (Figure 6).

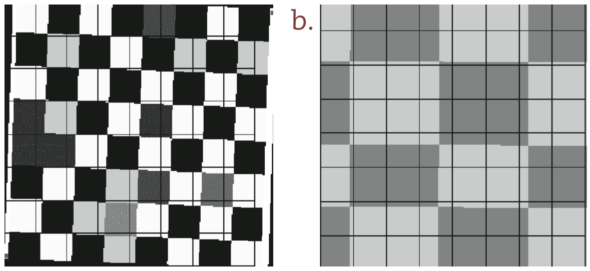


Figure 6. Schematic examples of problems with using remotely sensed data to portray the Earth's surface: a. Georeferencing and spectral properties of the observed phenomena, b. Grain size and geometrical distortions in the sensor

**Monitoring the dynamic game**

Having established the chess-playing arena, a working hypothesis for the processes that are occurring needs to be formulated. For most dynamic phenomena an initial inductive approach is almost inevitable. Only after a set of observations is available is it possible to use coincidental data to formulate a deductive hypothesis. Observations of natural and human phenomena are often made at regular intervals. Satellite images over an area are usually taken at the same time of day with a given interval (approximately 14 days for Landsat), as are many climate station data, water flow and water quality measurements. Measuring the chess game every morning at 09.30 (cheapest because it is outside the coffee room) always gives the same result (Figure 7). But if you work late one evening and chance to look at the chessboard, and suddenly see something has happened, you realise that there is obviously another time scale to the daily one (weekly, monthly or annual). So you start to observe the game regularly when you are working late. A rather erratic series of observations turns up (Figure 8).

Because of the strange observation angle (from above or 'nadir' in remote-sensing jargon) the visualisation of the players is poor, and it is difficult to distinguish the actors. However, a few hypotheses on their roles can be put forward:

1 One species (Bishops) seems to be bound to a certain feature type, or habitat, (namely black or white) in the playing ground.
2 The smallest and most common species (Pawns) seems only to be able to move in one direction like water downhill.
3 The species in the corners (Rooks) seem to be the most home-bound.

After some months of random observations hypotheses 1 and partially 2 are corroborated

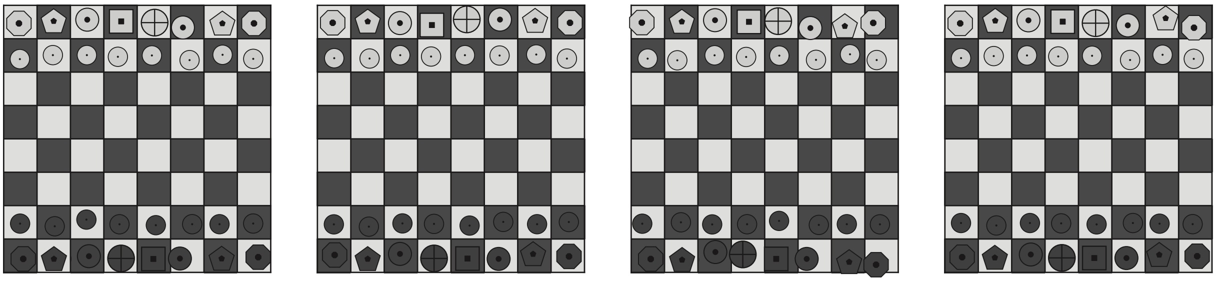

Figure 7. Observations of a chess game on four occasions. At first the game is apparently static. Only with a more detailed scrutiny it is revealed that the players actually are shifted a little between each observation. However, as we have no hypothesis or information of sub-cell pattern or process we neglect this as observation error

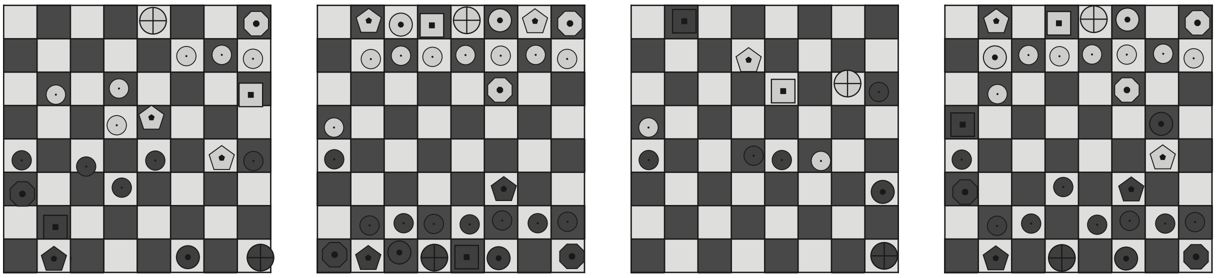

Figure 8. A series of temporally random observations of the chessboard

whereas 3 is falsified. After several years of fund-seeking the observations can be transformed into intense evening campaigns. With observations down to 10-minute intervals some of the players rules crystallise themselves, however the role of the knights escapes a robust formulation. Finally, a sensor connected to a real-time observation can capture the full sequence of activities, and the role of each player can be formulated.

**Modelling the full game**

The identified role of each player leads to a surge in modelling the game, mostly by using a rule-based (rather than statistical) approach where the roles of each player can be unambiguously defined. The formulation of initial (setting at start) and boundary conditions (edges of the playing arena) are straightforward. The application of an object-oriented approach for each player is favourable; a certain actor can only do a certain action, which cannot be done by another actor. However, even though the game is spatially defined, it is not possible to use the toolbox of any commercial GIS to play the game. And, only a few softwares have architecture open enough to allow the GIS game to be programmed to them, but with great difficulties. With a customised GIS it is possible to create a graphical user interface (GUI) that can help to set up initial and boundary conditions, and even to allow the set-up of the players' positions in the middle of a game, and the use of that as an initial condition. This leads to the development of an intermediate coupling of the chessboard and the game simulator through their sharing a common file format. It is a bit cumbersome to use and never reaches widespread use to improve the social awareness of the game. For thegameitself, the combination of such advanced machine-learning as artificialneural networks and faster computers, mean more alternative game outcomes can be foreseen after each activity (draw). Finally, one computer (Deep Blue) succeeds in winning the game. This is now more esoteric interest among the chess community, but the general public, policy-and decision-makers are unaware of this development.

**Implications**

A game of chess always aims at checkmate – which is unambiguously defined, as is the role of each player. The rules of the game show no evolution, neither in space, nor over time. If you change the extent of the arena, the role of the players or the outcome for checkmate to an unknown event, the computer would have little chance of winning. In a transient social or natural environment that is how the evolutionary game is played. In the simple case of chess there are only two scales that are of importance, that of a cell and the whole board. Furthermore, the game as such has no influence on the arena. In a landscape all discretised scales are arbitrarily chosen, the real landscape is a continuous nested hierarchy: but some scales have dominance-generating spatial architectures and temporal cycles, entrapped by key stone species and related processes. This also leads to the conclusion that the processes are forming the patterns rather than the other way around – and that the systems has feedback loops at various scales. All those aspects can be disregarded in the special (and simple) case of the chess game. The general conclusion that can be drawn is that modelling in GIS is hampered by several shortcomings, that care must be exercised when using distributed data for modelling, and that the quality of many GIS integrated models is poor. They are also poor because they have poor GUIs, fail to visualise the results, and hence do not reach the intended user community. In order to secure high-quality GIS-integrated models the following issues need to be considered:

- Close co-operation between GIS model researchers in general, and particular among
  - researchers studying the same phenomena but adopting different methods and/or scales
  - researchers, planners and decision-makers
- Up- and down-scaling, and nesting models of different resolution
- Spatial and temporal domain, grain size and sampling intensity when integrating data from various sources
- Strategies for sampling spatial phenomena to get representative data
- Selection of spatial interpolation methods and spatially correlated error tracking and tagging
- Methods for evaluating the influence of error and error propagation on model performance, and error visualisation for communication information on uncertainty
- Integration of remote sensing into GIS models
- Integration of temporal processes into GIS (3D- and 4D-GIS)
- Integrated systems that support a complete digital data flow from data collection with mobile field GIS (Global Positioning Systems, GPS) to visualise and exchange results via networks
- Formulation of versatile criteria for evaluating the prediction power of GIS-related environmental models
- Compilation of high quality, accessible (shared) databases to be used as back-drops to evaluate the predictive power of different GIS-related environmental models
- Establishing baseline and framework data
- Development of guiding GUIs that can lead the user to select the best method for the formulated problem and the available data
- Development of friendly interfaces that promote the dissemination of GIS and integrated models to domain experts, planners and managers.

## Using GIS in Africa

Studies involving spatial dependence and GIS in Africa are hampered by lack of data and computer resources, and poor knowledge and communications infrastructure. However, with the growth of geoinformatics over the Internet, global and continental-scale data are becoming increasingly available. Together with more powerful free GIS and remote-sensing software, there is a good chance that the data and software needed for many studies are available, either directly or via map algebraic modelling and other manipulations applied to available GIS data in combination with satellite imagery. The global trend in adopting remote-sensing data for spatial studies is strong in traditionally data-poor regions. Free high-resolution satellite images [Landsat Thematic Mapper (TM) and Enhanced TM (ETM)] are now available for the whole

African continent. Access to this data in Africa, however, is often illusive due to poor Internet connections. The global data sets derived from satellite data (including land cover) are seldom adjusted for continental needs, leading to semantic discrepancies and interoperability problems when merging data sets. Local knowledge is mostly disregarded. Further, studies employing global data in Africa are often esoteric, and seldom used for policy or management inside Africa.

### GIS and remotely sensed (RS) databases for Africa

In this chapter spatial databases have been divided into framework databases and field databases. **Framework databases** are base maps holding mostly information on anthropogenic-derived features – e.g., political boundaries and infrastructure, but they sometimes also have more object-oriented physical themes like elevation contours and hydrography. These databases are typically object-oriented and in vector format. They can be used to create simple thematic maps. Framework databases available for Africa typically contain data at district level, and hence simple descriptive statistical analyses (population density, travel distances, etc.) can be done at a level based on this data. Framework data can seldom be used directly for advanced analyses and modelling (environmental studies). Environmental studies demand field data, usually in raster format for such parameters as population density, soil classes, drainage, elevation, temperature, and precipitation.

### Framework databases for Africa

The foremost baseline framework database for Africa (and other parts of the world) is the Digital Chart of the World (DCW). DCW is a 1:1 million scale thematic map developed by the Defense Mapping Agency (DMA) and compiled by Environmental Systems Research Institute, Inc. (ESRI). For large parts of Africa these base maps are the largest scale maps available, either due to lack of other data or to the larger-scale maps being classified. Themes in DCW include political boundaries, populated places, roads/railroads and other infrastructure, hypsometry, hydrographical data, and rudimentary land coverage.

Based on the DCW, ESRI has assembled a more easily accessible database and has also developed a more field-oriented World Thematic Database. Several other GIS software producers have also established databases based on DCW (and additional sources mentioned below) for bundled delivery. The most comprehensive probably being the Mud-Springs Geographers – AWhere Almanac Characterisation Tool (ACT). This and other software tools (listed at the end of this chapter) are a very good way to learn GIS using data over Africa. AWhere-ACT is especially powerful for analysing climate data (supplied with the software) for agriculture and natural resource management applications. In many cases the software and bundled data are free for use in Africa by non-profit organisations.

Several recent efforts in creating more-detailed (large-scale) regional framework databases for Africa have been made. The most comprehensive is probably the Africover project by the Food and Agricultural Organization of the United Nations (FAO). This database also includes detailed land cover derived from combinations of Landsat ETM data and topographic maps. The agencies of the UN have also initiated an attempt to create a common depot for their GIS data – which has led to the Data Exchange Platform for the Horn of Africa (DEPHA) (see the end of this chapter for a more complete list of framework data sources available).

### Field databases for Africa

#### Elevation

For Africa the elevation data in DCW (contour lines and spot elevation data) together with generalised 3-arcsecond digital terrain elevation data form the primary source for the global 30-arcsecond (approximately 1 km) GTOPO30 elevation database released by the United States Geological Survey (USGS) in 1996. The data in GTOPO30 have been hydrographically corrected and resampled to a 1-km grid, to create the HYDRO1k database. From the hydrologically corrected HYDRO1k Digital Elevation Model (DEM) seven derivative themes have been extracted: flow directions, flow accumulations, slope, aspect, compounded wetness indices, stream-lines and basin areas. Several individual countries have better elevation databases. The next elevation data set covering the whole of Africa will be the Shuttle Radar Topography Mission (SRTM) database (90 m resolution), expected to be released during 2004.

### Land use/cover

Two global land cover data sets covering Africa in 1-km resolution are presently available. The latest is derived from TERRA-MODIS (Moderate Resolution Imaging Spectroradiometer) data (2000/2001) and was created by the University of Boston. MODIS has also been used to create a global tree cover database in 500-m resolution available from the University of Maryland. The older land cover is produced by the USGS from NOAA-AVHRR (Advanced Very High Resolution Radiometer) data (1992/1993). It exists in several versions useful for different applications and also includes monthly vegetation data from April 1992 to March 1993. The Africover database mentioned above is superior to these global databases but does not yet cover the whole continent.

### Climate and vegetation

The United States Agency for International Development (USAID), as part of the Famine Early Warning System (FEWS), continuously provide 10-day composites of vegetation density (Normalised Difference Vegetation Index – NDVI) derived from NOAA-AVHRR in 8-km resolution covering the whole African continent. The data set goes back to 1981 and is archived and disseminated by the USGS. It can be retrieved from the African Data Dissemination Service (ADDS). Thermal Meteosat images together with 760 ground precipitation stations are used to estimate precipitation over Africa as part of USAID FEWS. Processing is based on 30-minute image intervals for cloud top temperature combined with the ground data and derived fields of humidity, winds and DEM. The data extends from 1995 and are archived and disseminated by USGS (ADDS webpage) as 10-day composites. More coarse resolution databases that cover climate together with scenarios of climate conditions under various assumptions of human impacts on the climate are available from the Climate Research Unit (CRU), University of East Anglia, UK, either directly via the Internet, or from the Intergovernmental Panel on Climate Change (IPCC) as a CD.

### Population

The best and latest population figures are the 1-km resolution Landscan project data for 2000, 2001 and 2002 from the Oak Ridge National Laboratory, USA. These figures are created from census data and downscaled using intelligent interpolation (using relations such as light at night, slope, or elevation, which correlates strongly with population density). The Center of International Earth Science Information Network (CIESIN) hosted by University of California, has compiled global population data for 1990 and 1995. The data has an original resolution of 5 arc-minutes (approximately 10 km), but for Africa the data mostly represent averages for larger regions. United Nations' African population figures for selected countries covering the second half of the 20th century are available from Central African Regional Program for the Environment (CARPE).

### Soil map

FAO has produced a Digital Soil Map of the World (DSMW) in 1:5 million scale. Soil classes are given as polygons, with derived characteristics attributed. The soil map is only available as a CD. For some regions FAO also has a 1:1 million scale soil map.

### Satellite imagery

Remote sensing (RS) data are increasingly important for creating and updating both physical/ biological and socio-economic databases. Access to RS data is constantly improving thanks to: lowered prices, declassification of historical high-resolution data, a new generation of multi-sensor satellites (TERRA and ENVISAT) that are now operating, improved computing power and better software-user interfaces. For national to continental studies NOAA-AVHRR and TERRA-MODIS data and their derivatives are the most easily accessible. Other data of similar resolution that can be easily accessed include the European Space Agency (ESA) ERS-2 satellite and its ATSR 7-band sensor (which can be downloaded from the Internet in near real time), and the SeaWiFS 6band sensor. Full coverage, high-resolution Landsat TM and ETM data are now also freely available for the whole of sub-Saharan Africa via the University of Maryland. Landsat E(TM) composites in Mr-SID compressed formats of the whole globe are more easy to download and available from NASA. To find all available Landsat MSS, TM and ETM scenes, and other satellite data sources use the NASA Earth Observing System Data Gateway. The original TERRA-MODIS and NOAA-AVHRR scenes that were used for the land use/ cover classifications (see above) are all freely available as composites from University of Maryland (TERRA-MODIS) and USGS (NOAA-AVHRR). The Africa NOAA-AVHRR tiles for vegetation are also available from the International Centre for Insect Physiology and Ecology (ICIPE). Additional, raw, NOAA-AVHRR data are available via the NOAA Satellite Active Archive on the Internet, or from USGS at the cost of reproduction.

### Georeferenced time series point data for Africa

Time series point data on climate (weather station data) and hydrology are available via a variety of web pages. As this is outside the main scope of this chapter we recommend the ICIPE data server as a source of archived weather station data from around Africa.

### Data accuracy and merging

Most of the older global and regional databases are not quality labelled, neither for positional error nor attribute accuracy, thus potentially leading to large problems in interpretations and applications. Even if most data that can be downloaded are georeferenced, their accuracy often does not allow mapping at higher resolution than 1:1 million. The dataset with highest spatial accuracy is the NASA geocover (downoadable as MrSID images), which is within 50-m and can hence be used for geocorrecting other data sets. Another problem is that the semantics used, for instance, for the land use/cover maps are not coherent with those used in different parts of Africa. This is also due to a poorly developed unanimous semantic cover of natural geography in Africa. Semantic inconsistencies lead to information loss and prevent sound conclusions being drawn. For most spatial studies, it is necessary to merge data. Most satellite images must be georeferenced to a projection that fits the geographic location (and the framework data) before they can be used for analysis and further studies. This is not a trivial task. Field data sets continuously vary over time and space on different scales. A satellite image is already an aggregation of the land surface over the pixel size. Field data, including socio-economic data are often up- or downscaled, or aggregated. The quality difference between data sets of the same origin but presented at different scales is seldom reflected in the metadata. It is extremely important to know the timing of acquisition, grain size and scaling of field data when analysing, interpreting, and applying such data. For most of the global data sets available this is seldom a problem. However, most local users are ignorant of the problem and secondary data sets derived from such sources often lack meta-data.

### Points to remember

- Increased data availability and the ease with which distributed data layers are created from point and line data, and remote sensing, have led to a widespread coupling of GIS and remote

sensing to existing (non-topological) cause-effect models in, for example, hydrology and erosion studies, and to updating and downscaling land cover and population density maps
- Data availability for Africa has now reached a point where it is possible to do such studies, often with freely available data
- The major problem for the individual researcher is in accessing the data, and in acquiring the skills of GIS and RS needed to 'massage' the data into a coherent database
- The free GIS software programmes available today are powerful enough for you to learn GIS, and to create basic databases
- The bottleneck for using GIS for research in Africa is poor Internet access and poor GIS skills
- If you want to use GIS you should download the necessary data or order it via CD/DVD (usually possible for a small fee), and you should learn GIS by using one of the listed free software programmes
- As most of the software programmes have very similar interfaces, learning one means that learning a second becomes an order of magnitude easier. So going from DIVA-GIS to ArcView is very simple (also because they share data formats).

**Expert systems**

GIS and RS (or geoinformatics) have developed from being tools for data storage and presentation to also include analyses and modelling. Overlaying two or more thematic maps (see Figure 9) is a simple but often illustrative means of identifying relations in spatial patterns. More advanced analyses include using map algebraic formulae combining several thematic layers. Such 'expert system' approaches are widely used to rank vulnerability of natural resources, food security, or water availability. One example is the DRASTIC method (Depth to groundwater, Recharge, Aquifer media, Soil, Topography, Impact of rootzone, Conductivity) for groundwater vulnerability analysis, where each of the seven factors has a physical related value.

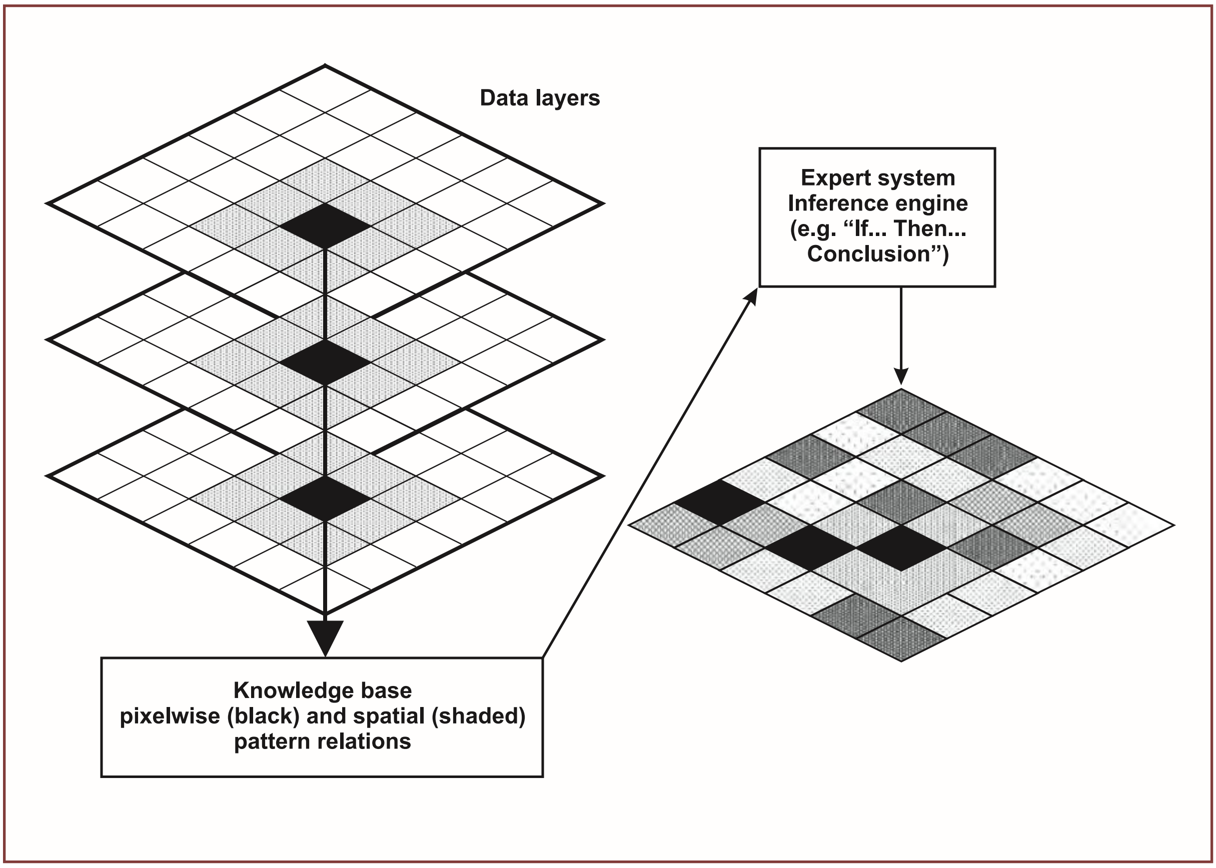


Figure 9. Schematic structure of an expert system approach for spatial data analysis

Development is towards more advanced expert systems including object-oriented methods, and considering ancillary and multi-temporal data, and spatial relations (Figure 9). Expert systems are like the game of chess – unambiguously defined with a set of strict rules. Expert systems are thus said to be data- or forward-driven. However, GIS is also becoming a decision-support system (DSS), e.g., for ill-structured (localisation) problems. Used as a DSS GIS becomes more of a tool for discussions and illustration of decision alternatives. Formal methods have been developed to involve various stakeholders in such discussions, including multi-criteria evaluation (MCE). In contrast to expert systems based on predefined rules and weights of physical parameters, DSS are related to different stakeholders perceptions, and as the aim is to reach a solution (for allocation of land use/development, water or nature protection), the method is said to be goal-driven.

Whether studying natural or social science, GIS can be very useful, and there is a plethora of methods, models and techniques that you can apply to analyse or present data that deals with spatial relations. But it is critical that you formulate a sound hypothesis and use adequate data of sufficient quality. To avoid mistakes a parsimonious approach, and rigourous meta-data description is essential. This will make it easy to update and eventually publish your data and results.

## Resource material and references

Burrough, P. and McDonnell, R.A. 1998. *Principles of Geographical Information Systems*. Oxford University Press, Oxford, UK.

Fotheringham, S. and Wegener, M. 2000. *Spatial Models and GIS*. Taylor and Francis, London, UK.

Goodchild, M.F., Parks, B.O. and Steyart, L.T. 1993. *Environmental modeling with GIS*. Oxford University Press, New York, USA.

Goodchild, M.F., Steyart, L.T., Parks, B.O., Johnston, C., Maidment, D., Crane, M. and Glendinning, S. 1996. *GIS and environmental modeling: Progress and research issues*. GIS World books, Fort Collins, Colorado, USA.

### Framework databases for Africa

Geography network
http://www.geographynetwork.com

ESRI downloadable data
http://www.esri.com/data/free_data/

Data Exchange Platform for the Horn of Africa: UN organisations Geo data depot.
http://www.depha.org

Digital Chart of the World (DCW): Basemaps for all the countries of the world.
http://www.maproom.psu.edu/dcw/

Food and Agriculture Organization of the United Nations (FAO)
Very good land cover maps over East and Central Africa
http://www.africover.org

Global GIS database – Digital Atlas of Africa
http://webgis.wr.usgs.gov/globalgis/

### Field databases for Africa

GTOPO30 global topographic data
http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html or
http://www.ngdc.noaa.gov/mgg/topo/globe.html

Hydro1K HYDRO1k Elevation Derivative Database
http://edc.usgs.gov/products/elevation/gtopo30/hydro/

Landscan population data Oak Ridge National Laboratory
http://www.ornl.gov/sci/landscan/

Global landcover from NOAA-AVHRR (1992-1993 data)
http://edc2.usgs.gov/glcc/glcc.php

MODIS land cover from Boston University (2000-2001 data)
http://duckwater.bu.edu/lc/mod12q1.html

MODIS Global Vegetation Continuous Fields from 500m MODIS data 2000-2001
http://glcf.umiacs.umd.edu/data/vcf/

CIESIN (Center for International Earth Science Information Network) Colombia University Including climate data and global gridded population data from 1990 and 1995
http://www.ciesin.org

CARPE (Central African Regional Program for the Environment)
http://carpe.umd.edu

### Satellite imagery and related data

University of Maryland Global Land Cover Facility
A very good source of free Remote Sensing (Landsat (ETM) and TERRA MODIS) scenes
http://glcf.umiacs.umd.edu/

USGS Land Processes Distributed Active Archive Center
http://lpdaac.usgs.gov

USGS Earth Explorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

USGS NOAA-AVHRR used to create global landcover – 93 original scenes (1992 to 1996)
http://edc2.usgs.gov/1KM/1kmhomepage.php

Africa Data Dissemination Service (United States Geological Survey – USGS)
http://earlywarning.usgs.gov/adds/

NASA Earth Observing System (EOS) Data and Information System
http://edc.usgs.gov

NASA Earth Observing System Data Gateway.
http://wist.echo.nasa.gov/~wist/api/imswelcome/

NASA global Hydrology and Climate Centre (Weather satellite data)
http://weather.msfc.nasa.gov/GOES/

Goddard Institute for Space Studies
http://www.giss.nasa.gov/

National Geophysical Data Center
http://www.ngdc.noaa.gov/

MrSID images (excellent geocorrected – can be used for georeferencing other spatial data)
http://zulu.ssc.nasa.gov/mrsid/

Japan Aerospace Exploration Agency
(Free JERS-1 radar images over most of Africa can be ordered on CD)
http://www.eorc.jaxa.jp

SRTM (Shuttle Radar Topography Mission)
http://www2.jpl.nasa.gov/srtm/

Visible Earth – NASA site with preprocessed satellite images of Earth
http://visibleearth.nasa.gov

Microsofts image database (terraserver)
http://www.terraserver.com or http://terraserver-usa.com

Digital Globe (very high resolution data sets over selected cities)
http://archive.digitalglobe.com

Geocommunity spatial news (incl Landsat viewer)
http://spatialnews.geocomm.com

**Free software sources**

Dynamic Maps (A free ware GIS with many predefined functions for natural resource management)
http://www.skeinc.com or via http://www.africover.org

DIVA-GIS (A fully functional GIS developed by the International Potato Center)
http://diva-gis.org

Arc-Explorer (Light-weight GIS by ESRI that also produced Arc-Info, Arc-View and Arc-GIS)
http://www.esri.com/software/arcexplorer/explorer.html

ERViewer (viewer for many image formats)
http://www.ermapper.com

WINDISP (A simple freeware for image processing from FAO)
http://www.fao.org/WAICENT/faoinfo/economic/giews/english/windisp/dl.htm

Mud Springs Geographers (A fully functional GIS bundled with free GIS data for Africa)
http://www.mudsprings.com

Mapmaker basic (Light-weight GIS freeware)
http://www.mapmaker.com

GRASS (Advanced GIS and image analysis for UNIX or Linux)
http://grass.itc.it

Microdem
http://www.usna.edu/Users/oceano/pguth/website/microdemdown.htm

# 3.5 Designing experiments

*Richard Coe*

- **Experiments are a central part of the scientific method because they allow you to test cause-effect hypotheses**
- **Many students learn about experiments in the context of studies of small fieldplots, but the key principles of experimental design are equally important in all studies**
- **All aspects of the design of an experiment depend on its objectives, so the objectives have to be carefully and thoroughly developed**
- **The details of the design of a good experiment will balance theoretical optimality with practicality**
- **Every experiment should have a written protocol that can be shared with others, so the design can be improved before the experiment starts**

## Experimenting as part of research

Experimenting is a part of everyday life. In an informal way you experiment when you check whether your tea is too hot to drink, whether the bus is less crowded if you leave for work earlier or whether your supervisor approves of your style of writing. Within formal agricultural research, experimentation has long been the key tool. To many people 'agricultural research' is synonymous with field plot experiments. If you visit an agricultural research station one of the main things you can see are small plots for comparing different crop varieties or different management techniques. Much of the current theory and the methods for carrying out experiments were developed in the context of agricultural experiments, most notably by R.A. Fisher, a geneticist and statistician working at Rothamsted Experimental Station in UK.

Today field plot experiments on research stations are not the only avenue for agricultural research, but the ideas and methods of experimentation are still central to good research. Why?

Experimentation is concerned with the 'testing theory' step of research (**Chapter 2.3**). Theories which help in problem solving often describe what will happen if a change is made:

- If we use this new variety of maize there will be less damage from stem borers
- If we substitute dairy meal with calliandra fodder milk production will not be reduced
- If we train farmers in pest management they will be able to grow cabbages more profitably
- If communities are better informed they will be more effective in managing common grazing.

Now in order to test your theory the obvious thing to do is to make the change and observe whether the predicted outcome occurs. This is the basis of experimentation, and the reason it is so important.

There are situations in which it is impractical or unethical to experiment, in these situations other ways of testing theories have to be found. It is not feasible to experiment if your prediction is:

- If the average annual temperature rises by 2oC then maize production in Kenya will drop by 15%

You could test the prediction by setting up simulation models (**Chapter 4.4**) that describe the relationship between production and temperature. But those models will themselves be based on theories tested by experiment. Here is another well known prediction made some years ago:

- Regular smoking will lead to an increased chance of lung cancer and other diseases.

It was not possible to test this by experimentation as that would have involved taking a group of people and requiring some of them to smoke. This theory was tested largely by surveys (**Chapter 3.6**) which are distinct from experiments. In a survey you observe what is happening without making deliberate changes. Thus the effect of smoking was investigated by comparing the health of people who smoke with those who don't, and a clear correlation emerged. The limitations of the study design are clear: if the smokers have a higher rate of lung cancer we can not be sure the smoking **causes** the lung cancer. Perhaps there is some unknown factor that tends to lead people to both smoke and get lung cancer. This is a problem of the survey approach to investigation, and means that theory testing is harder using surveys than using experiments. In the case of the health impacts of smoking, various possibilities for such factors were suggested (diet, genetics), and then eliminated by surveys which controlled for them, each providing evidence in support of the theory. However there will always be people who think of one more factor that could be the explanation. This would not be the case if the theory could be tested by a well designed experiment.

This chapter summarises the key decisions that have to be made if you are to conduct a well designed experiment. A prerequisite is understanding the principles and language of experimental design, described in the next section.

## Basic ideas of experimental design

Think of the simple problem of determining whether the new maize variety 'Boreproof' is less susceptible to stem borer damage that the commonly used variety M512. That is the **objective**, and the objectives of the experiment will determine all other aspects of the design.

You could plant a field of Boreproof and measure the stem borer damage. But with what will that be compared? The objective requires checking it has less damage than M512. You need to make a **comparison** and so plant a second field with M512. The two varieties being compared are the two **treatments**. They are compared on fields, so the two fields are the **experimental units**.

How effective will this design be? What might you conclude when you get the data? If 50% of the plants in the M512 field are damaged, but the Boreproof field only has 20% damage has the theory been confirmed? Hardly! Any agriculturalist will tell you that stem borer damage can vary greatly between fields, as well as between different parts of the same field. So an alternative design is suggested. Have several fields each of Boreproof and M512. Suppose the results show the fields of Boreproof as having damage levels of 20%, 10%, 40% and 30%, while M512 has 50%, 60%, 40% and 35%. The **replication** of the fields allows you to check the consistency of the results. These results show a tendency for Boreproof fields to have less damage than M512 (the mean is 25% compared with 46%) but the results are not very convincing, with some M512 fields having less damage than some Boreproof fields.

A third alternative design is tried. Since you know that the pest pressure will vary between fields irrespective of the varieties being grown, maybe you can increase **precision** by growing both varieties in the same field. Make the experimental unit a **plot** (say 10m x 10m) of maize, with two plots in each field. Then put M512 on the left-hand plot and Boreproof on the right in each pair. You can now compare the two treatments within each field, and differences between fields become less important. Using the fields in this way is described as **blocking**, with each field being a **block**.

The results from this design are shown in Table 1.

**Table 1. Results of a simple experiment**

| Field | Stem borer damage (%) M512 | Boreproof |
|---|---|---|
| 1 | 50 | 20 |
| 2 | 20 | 10 |
| 3 | 30 | 20 |
| 4 | 60 | 30 |
| 5 | 60 | 40 |
| 6 | 20 | 5 |
| 7 | 0 | 0 |
| 8 | 40 | 10 |

Are these results more convincing? They certainly show consistency: Boreproof had less damage than M512 in every field except field 7, which has no stem borers anyway. But look carefully at the way the design was described. The M512 was always placed on the left-hand plot. Maybe the difference in stem borer damage is nothing to do with variety, but due to some other consistent difference between left- and right-hand plots. Maybe the wind blows from the left, bringing the pests or stressing the plants. You may know that is not the case, but could have trouble convincing others. And you can never be sure that there is not some other systematic difference between left- and right-hand plots. The solution is to **randomise** the allocation of treatments to plots. In field 1, toss a coin to decide whether Boreproof or M512 goes on the left-hand plot. Then randomise again in field 2, and so on. In field 1 you might end up with Boreproof on a plot with less stem borer damage for reasons unconnected with the variety, but over the whole experiment you can be sure that the only systematic difference between plots with Boreproof and plots with M512 is indeed the variety. The basic ideas of experimentation described above should also help you understand studies which, though they involve comparison, are not experiments and can not demonstrate cause. For example, suppose a study showed that farmers in Central district have less stem borer damage in their fields than farmers in West district. They also have higher adoption rates for the Boreproof variety. This study involves comparing districts, but is not an experiment as the differences in adoption of Boreproof were not imposed by the researcher. It is also common to make comparisons over time, for example, by comparing stem borer damage levels before and after introduction of Boreproof in Central district. In such studies the change may be devised by the researcher, but it should only be considered an experiment if other features are present, e.g., some other districts in which Boreproof was not introduced, random allocation of the introductions, and some replication.

## Diverse applications, common principles

The simple example in the previous section explains the basic ideas and terminology in the context of a 'classical' agricultural experiment – a variety trial. This section shows the correspondence with three other studies of different types. Each discipline tends to produce its own language and standard practices and it is important to recognise the commonality between them, and to make sure that you really understand the logic of the design. The same topic is discussed elsewhere in different contexts.

The examples in Table 2 are all different. One investigates field plots, one animals, and two people. Of the last two, one focuses on individuals and the other on communities. The practicalities of carrying out each of these studies will be quite different, but the fundamental logic of the design is the same in each case. The social sciences do not use the terms **treatment** and **unit** but the rationale for their approach is similar to research in the natural sciences. The roles of comparison, replication, randomisation, and controlling variation are the same for all of them. It is common for these aspects to be forgotten in studies involving people, particularly community-based studies like the last one in Table 2.

## Design decisions

Now you understand the basics of designing experiments you can start thinking about the design of your experiments. You may need one substantial experiment, several smaller related

| Table 2. Four examples of experiments | | | |
|---|---|---|---|
| **Objective** | **Treatments** | **Units** | **Measurement** |
| Determine if Boreproof is more resistant to stem borer than M512 | 1 Boreproof maize<br>2 M512 maize | 10m x 10m plots of land | Percentage plants damaged by stem borer |
| Find the effect on milk production of substituting dairy meal with calliandra fodder | 1 Base diet + dairy meal<br>2 Base diet + calliandra<br>3 Base diet + 50% calliandra + 50% dairy meal | Dairy cows for 2 weeks of third month of lactation | Milk production in the second week |
| Check whether training in pest management allows farmers to produce cabbages more profitably | 1 No training<br>2 Attendance at farmer field school on pest management | Farmers for whom cabbage production is a main enterprise | 1 Farmers' knowledge<br>2 Profitability of cabbage enterprise |
| Evaluate the effect of community information and organisation on common grazing management | 1 No intervention<br>2 Information provided<br>3 Information provided and village 'grazing committees' facilitated | Villages in areas where common grazing is degrading | 1 Community views on grazing problems<br>2 Range quality |

experiments or possibly no experiments. If you are going to experiment then there are many decisions you will have to make about details of the design. How can you make those decisions? There are several sources of help:

- The fundamental principles of experimental design – the outlines above and more details in other texts
- The more practical ideas in the following sections, and in other texts
- Papers and reports describing similar experiments that others have done
- Other researchers who have worked on a similar topic (maybe in a different region) or used a similar method
- Your observations of other experiments
- Your imagination
- Pilot studies in which you try out techniques and arrangements before committing yourself to an expensive or long-term experiment.

There is no single correct way to design your trial, but there will be plenty of ways that are wrong – designs which will not lead to valid conclusions meeting your objectives. Even if you design a trial that will give valid results it may be inefficient – not give you as much information as possible for the time and effort spent. Avoid these scenarios by:

1 Thinking.
2 Using all the sources of help listed above.
3 Showing your design to others and getting their comments.
4 Envisaging the data your design might produce and the way in which you would then interpret it. Some researchers sketch out the tables and graphs they would use in the analysis of the data, then making sure the design will generate the required numbers to complete them.
5 Thinking of the practical as well as the theoretical requirements. You have to manage your trial (set it up, look after it), cope with the travel requirements, have enough time and

equipment to measure all the plots, and so on. And you have to be able to afford it!

6 Iterate. Start with a possible design, think through the consequences then go back and revise it until you have something sound.

7 Thinking.

In the following sections the main ideas you need to make decisions on each of the key points are described together with some of the common mistakes that you must try to avoid.

**Objectives**

All aspects of the design depend on the objectives. Therefore you must get the objectives right! Objectives must be:

- **Clear.** If the objectives are vague it will not be possible to decide on the rest of the design
- **Complete.** Often the statement of objectives is incomplete so that the experiment can not be designed
- **Relevant.** In applied research, experiments are made to help solve real problems and fill knowledge gaps in the process. The objectives of the experiment must be relevant to solving the problem. It must be clear how you will be a step nearer solving the problem once you have the results from the experiment
- **Reasonable.** The objectives must be reasonable given current understanding of relevant phenomena and other observations. Avoid objectives that contain elements of alchemy or wishful thinking
- **Capable of being met by an experiment.** Some research questions do not need an experiment. Two problems which often arise here are:
  - objectives that require a survey rather than an experiment
  - objectives that require two or more experiments rather than a single one.

Make sure that the objectives fit in well with the overall strategy of the project. You have to be able to explain what the next step will be after the experiment is completed.

**Common mistakes to avoid**

1 Objectives which are too vague. The objectives in Table 2 all fall into this trap! Real experiments would need to have objectives that made it clear, for example, what sort of base diet is to be fed to the dairy cows, how much training in pest management should be given, or where the rangelands are located.

2 Objectives which just say 'the objective is to compare the treatments'. Treatments should be a consequence of the objectives, not the other way around.

3 Loading too many objectives into a single experiment, so no design can be found that meets all of them. For example, in trials in farmers' fields, understanding details of biophysical processes usually requires a high degree of uniformity, and hence the researcher taking control. Eliciting farmers' assessments of the technologies requires them to have a free hand. Thus the two objectives will probably not be met in a single trial.

**Treatments**

There are four ideas you need when choosing treatments:

1 **Comparison and contrasts.** Experiments involve making comparisons. The exact comparisons that meet the objectives can be defined as contrasts, i.e., the numerical expression of the comparison. Make sure your experiment has all the treatments needed to make all the comparisons implied by the objectives.

2 **Controls.** 'Controls' or 'control treatments' are the baseline treatments against which others are evaluated. In the stem borer experiment M512 might be considered the control.

3. **Factorial treatment structure.** Many experimental objectives require looking at several 'treatment factors'. For example, in the stem borer experiment you may also want to look at

the effect of sowing date (early, mid, or late). Then the experiment might have 6 treatments (Boreproof sown early, mid, or late and M512 sown early, mid, or late). Factorial treatment structures are important for two main reasons:

- they tell you about **interaction** – such as whether the difference between Boreproof and M512 depends on when they are sown
- if there is no interaction they give information about both factors with the same precision as would be obtained if the same amount of experimental effort went into investigating just one of them. This is the 'hidden replication' described in textbooks.

4 **Quantitative levels.** Some experiments require varying a quantity that could have many different levels, such as sowing date or amount of fertilizer applied. Choosing the levels to use as treatments in the experiment depends on the exact objectives and what you already know about the response to varying it. Generally fewer rather than more levels are needed, and there is rarely a reason for using more than 4 different levels.

### Some common mistakes to avoid

1. Including extra treatments 'because they might be interesting' rather than because the meet a clear objective.
2. Missing suitable controls, so, for example, the new varieties are grown but there is nothing against which to assess them.
3. Thinking 'control treatment' means 'do nothing' or 'zero input', even though those might be appropriate in some cases. Control treatments are just treatments needed make the required comparisons, so you may have two or more controls corresponding to different objectives.
4. Using too many levels of a quantitative factor. Using 10 levels, say 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90 kg N/ha will give more information about response to fertilizer than just using 0, 20, 50 and 90 kg N/ha. But if you can make a total of 20 observations (e.g., if you can only afford 20 plots) then 2 replicates of those 10 different treatments will almost certainly give less information about response to N than 5 replicates of the latter set of 4 levels.

Another key idea is **confounding**. Suppose that in the stem borer experiment M512 was sown on 20 March but Boreproof was not sown until 2 April, because there was a delay in procuring the seed. When the stem borer damage is observed to be less in Boreproof we can not conclude that the variety is resistant. The difference in damage may be due to the different sowing dates or different varieties. Sowing date and variety are said to be 'confounded'. **Treatments must be defined in a way that does not confound different effects.**

### Units

With crop experiments, decisions have to be made on size, shape, orientation and arrangement of plants within the plot. There are a few guidelines based on theory:

- Many small plots often give more precise results than a few large plots taking up the same area
- Long thin plots often give more precise results than squarer plots.

These guidelines have to be modified by practical considerations:

- Plots have to be large enough to manage (sow, weed, spray, harvest) in a way that represents what a farmer could do
- Plots have to be large enough to take measurements, allowing for the possible disturbing effects of destructive measurements during the experiment (**Chapter 3.7**)
- Borders may have to be left around each plot to make sure that anything happening on one plot does not influence what goes on in the next plot.

These considerations, particularly the last point, often overrule the theory.

If the units are not plots of land but animals, people or communities then there are often more decisions to make and few general guidelines. **Base the design of the experimental unit on the experience of others who have done similar experiments.** What did they use as the unit? What problems did they have? How will your experiment differ from previous ones? Does that imply any changes in unit?

Think of the experiment with factorial treatment structure, with two varieties (Boreproof and M512) each sown early, mid, and late. A common design for this type of experiment is the **split-plot**. Large plots are defined and the early, mid, or late sowing date allocated randomly to each one. Then each large plot is divided into two, with M512 and Boreproof randomly allocated to the two halves. A split-plot design can have practical advantages, for example, you are less likely to disturb the early sown plots when sowing the later ones. However it does have disadvantages. There are two sorts of plot (large plots and split plots). This complicates the analysis because variation between both types of plot has to be considered. The precision of a split-plot trial is generally less than for that of alternative of random allocation of all treatment combinations to the smaller plot. **Don't use a split plot design unless practical considerations require it.**

### Some common mistakes to avoid

1 Plots are often too small, so it is not possible to manage or measure them realistically. An extreme example occurs when measuring labour. It is not possible to estimate the labour required for a task such as weeding if the plot is very small, because weeders will not work at the same rate per unit area as they would in a larger plot.
2 In situations other than annual crop experiments, interference between plots can be hard to see, but can seriously bias results. Water and insects can move from one plot to the next. Tree roots can grow into neighbouring plots. If the unit is a farmer, he or she may talk to another farmer and influence results in an unplanned way.
3 Some researchers seem to believe that experiments with factorial sets of treatments have to be done in split-plots. This is untrue.
4 Split-plot designs are useful but overused.

### Replication

Replication (having several units of each treatment) is important for four reasons:
1 **Estimating precision.** The uncertainty in an average is estimated by the variation between the observations being averaged.
2 **Increasing precision.** Calculating an average over more values from a replicated experiment will increase precision since the calculated value will be closer to the true value.
3 **Insurance.** More replications in an experiment will provide some insurance against things going wrong with one or two replicates. Without such insurance an experiment may be rendered useless by, for example, goats getting into the field, or some participating farmers dropping out of the study.
4 **Increasing range of validity.** Replication can increase the range of validity of a result if the comparison is repeated under a range of conditions.

There should be enough replicates to satisfy all the above reasons for replicating:
1 **Estimating precision.** Look at the **error d.f.** (degrees of freedom) from the analysis of variance, 10 d.f. can be considered a reasonable minimum. Much more than 20 has no particular advantage.
2 **Increasing precision.** If you have an idea of the precision you need and the variation in your experimental material then it is possible to estimate the number of replicates needed. Details are in books, and software is available to help.
3 **The number required for insurance must depend on the risks.** A long-term trial in a risky environment (e.g., one that might be burned in the dry season) may be worth insuring, by adding replicates. A short-term trial that can easily be repeated if something goes wrong is not worth insuring.

4 **Increasing the range of validity.** Suppose the stem borer trial had some replicates on sandy soil, some on loam and some on clay soil. Then you could be more confident that the results were generally valid than if the experiment had only been done on sandy soil. The importance of this will depend on the objectives.

### Common mistakes when planning the number of replicates

1 Using the 'usual' number of replicates (in field experiments this is often 4, for some unknown reason) rather than rationally selecting the number of replicates.
2 Forgetting the 'hidden replication' in experiments with factorial treatment structure.
3 Insisting that all treatments have the same number of replicates. In the absence of any other information this is sensible, but it is not necessary. Suppose you decide you need 10 replicates of Boreproof and M512, but only have enough Boreproof seed for 8 replicates. That does not mean you have to also use 8 replicates of M512. It may be sensible to continue with the 10 replicates.
4 Forgetting that in split-plot and similar types of experiments there is more than one type of unit and each has to be replicated sufficiently.
5 Estimating the number of replicates needed, finding it is too large to manage or afford, and proceeding with far too small a number. The experiment will not meet its objectives! If you can not afford to meet the original objectives then modify them rather than carrying on with an experiment that will almost certainly not be useful.
6 Assuming that sub-samples from one plot are really replicates.

The last point is particularly important and is a common problem in student projects. Suppose you measure stem borer damage by selecting 10 plants at random from the 10m x 10m plot and measuring the damage on each one. 10 plants from one plot do not tell you the same thing as 10 plants from different plots. If different treatments are applied to different plots, it is variation between plots which is important, not variation between the plants within a plot. The parallel mistake in the community experiment would be confusing the information from responses of several people in the same village with responses from several different villages.

### Site

The site(s) for the experiment will be determined by the objectives. It has to be representative of the problem area, both on a large scale (for example, in the same agro-ecozone) and on a small scale (for example, having the appropriate soil type and previous management). The site also has to be practical. It should be:

- Accessible
- Secure
- Large enough.

An experiment will have to be made at more than one site if any of the following apply:

1 The problem area is too variable in key characteristics for a single representative site to be found.
2 You are unsure of the key environmental (biophysical, social or economic) characteristics that may determine the outcome of the experiment, so cannot be sure they are represented by a single selected site. Getting consistent results from several sites will give you confidence that these results really do apply to a wider area.
3 The objectives of the trial require conditions to be compared that cannot be controlled as treatments, such as soil type, rainfall or soil depth. Cases 1 and 3 require sites to be selected in the same way that single sites are selected. There is an argument in case 2 for sites to be chosen by random selection, but that is rarely practical.

The same considerations apply when experiments are carried out with farmers and communities. Do not simply choose the villages or farmers in which last researcher worked, but look carefully at the objectives and decide on which characteristics it is important to have represented.

### Some mistakes to avoid

1 Choosing a site, such as a university research farm, for its convenience rather than its suitability in meeting the objectives.
2 When working with farmers and doing experiments in farmers' fields, biasing experimentation to wealthier farmers and more fertile fields. There are techniques to avoid this.

If practicality requires you to do either of these things, then you need to be upfront and clear about how you expect them to influence your results.

### Blocks and allocation of treatments

Once you know where the experiment will take place and what the units or plots are, you can define a set of units for the experiment. If the units are field plots then you could mark out the field into plots, avoiding places that are clearly unsuitable (a patch with surface rocks, an old termite mound, the strip adjacent to large trees). If the units are not plots you can do the equivalent:

- **If the units are farmers.** Produce the list of farmers who are willing to take part and meet the criteria determined by the objectives. (Make a special note of the potential bias of using only farmers who are willing, or able, to spare the time to take part)
- **If the units are tracts of rangeland.** Map out their location and negotiate their use with the communities who look after them
- **If the units are villages.** Contact those villages that meet the criteria determined by objectives.

Next, determine which treatment will be applied to each unit. Random allocation should be used. Random allocation does not simply mean 'mixed up'. Avoid any possible bias by using an explicit random process. For example, use pieces of paper with treatment names put into a 'hat'. The number of pieces of paper for each treatment will be the number of replicates. Then decide the treatment for the first unit by drawing a paper from the hat without looking, again for the next and so on. There are computer programs to help with this.

The precision of almost every experiment can be improved by blocking. Whatever units you have, you know they will vary. Some variation is predictable. Try to arrange the units into homogeneous groups, each of which will become a block. Table 3 gives some suggestions on characteristics that might be used to block different types of unit, but what is suitable for your trial will depend on the objectives of your trial. For the stem borer experiment, the level of stem borer damage in the previous season may be a good characteristic to use to group units into blocks. However it would be irrelevant if the trial was about N leaching or weeding regimes.

If:

1 Every treatment will have the same number of replicates and
2 Every block has the same number of units and
3 The number of units in a block is equal to the number of treatments

then the best design is to put exactly one replicate of each treatment in each block. **The allocation of treatments within a block should be random.** This is the **randomised-block design**.

If the blocks are not all the same size, or the number of units in each block is not equal to the number of treatments, then you will have an incomplete block design. Take care when deciding which treatments go into each block. Software is available to help you with this.

### Some common mistakes to avoid

1 Assuming blocking is only useful in field experiments. The idea and terminology was developed in the context of field experiments, but it is just as important in all other

| Table 3. Possible factors to use in definition of blocks | |
|---|---|
| **Units** | **Characteristics used in blocking** |
| Field plots | Soil type<br>Previous crop yield<br>Slope<br>Weeds present |
| Animals for dairy experiment | Weight<br>Previous milk yield<br>breed |
| Farmers in pest management experiment | Education level<br>Length of time growing cabbages<br>Size of farm |
| Villages in community resource management experiment | Ethnic group<br>Presence of community organisation |

experiments, though researchers often fail to block experiments with people or experiments carried out in laboratores and nurseries. **Blocking gives extra precision at little or no cost and is almost always worth doing.**

2 Assuming blocks have to be the same size and equal to the number of treatments. Incomplete block designs can be very useful. If you have to get a bit of help designing and analysing them it will be worth it.

### Management

In a field experiment, 'management' means preparing the land, sowing, weeding and all the other agronomic practices needed to raise the crop. In other types of experiments there are equivalent management activities. The management of an experiment is often not considered part of the design, yet it can have a large impact on the success of the trial.

1 Decide whether the objectives demand that you manage the experimental material to a very high level (e.g., zero weeds) or a realistic level (e.g., farmers' weeding practice). The first may be appropriate if you are studying processes such as water or N uptake, and don't want weeds to obscure results. The second will be appropriate if you are evaluating technologies and want them to represent farmers' systems.
2 Avoid confounding treatments with management differences.
3 Aim for uniform management. Often the difference between a successful and a failed trial is in how well the crops (or animals or people) were managed, and whether this was done uniformly. You can improve uniformity by, for example, training fieldworkers and monitoring the way they execute operations.

### Measurement, data management, analysis and reporting

The measurement and analysis of the trial will also have implications for design, and have to be thought through at the design stage. Details are in **Chapters 3.7** and **4.2**. You will also have to plan a scheme for looking after the data, details are in **Chapter 4.1**.

### Writing it up – the protocol

The protocol is the written description of everything that will be done in the experiment, starting with the objectives and going right through to the analysis, interpretation, and use of the data.

- A protocol should be written for every experiment
- The protocol must be shared **before** the experiment starts to get input from others. There are always other people with expertise that will help increase the quality of your protocol. You should share the protocol with at least:
  - scientists at your location (who understand the local context and constraints)
  - scientist in the region (who understand what else of relevance is happening in the region)
  - a subject-matter specialist (who should be aware of relevant developments around the world) – other students
  - your supervisor
  - a biometrician
- The protocol must be sufficiently detailed for someone else to take over the experiment part way through, or to make sense of the data at the end of the experiment, even if you are no longer around
- The protocol should be kept up-to-date. It is not just a plan, but a record of exactly what you actually do.

The protocol must be securely archived so that information about the activity can be found in the future.

**Finally: involve a biometrician**

Biometricians and statisticians are trained in the art and science of experimental design. They may not understand all the practical constraints and opportunities in your particular study. But they will be able to help with such technical details as choosing the number of replicates and allocating treatments to blocks. They will also be able to spot flaws in the logic of the design, and help you make sure it will really meet the objectives.

Many researchers only consult an biometrician when they get stuck with statistical analysis of the data. That is too late. Get a biometrician's advice early, thereby guaranteeing a good design for your study.

## Resource material and references

Coe, R., Franzel, S., Beniest, J. and Barahona, C. 2003. *Designing On-Farm Participatory Experiments: Resources for Training*. World Agroforestry Centre (ICRAF), Nairobi, Kenya. 135 pp. Available from http://www.worldagroforestrycentre.org

Mead, R., Curnow, R.N. and Hasted, A.M. 2003. *Statistical methods in agriculture and experimental biology*. Third edition. Chapman and Hall, London. 472 pp.

Robinson, G.K. 2000. *Practical Strategies for Experimenting*. Wiley Series on Probability and Statistics. John Wiley and Sons, Chichester, UK. 282 pp.

Schroth, G. and Sinclair, F.L. 2003. *Trees, Crops and Soil Fertility – Concepts and Research Methods*. CABI, Wallingford, UK. 437 pp.

Stern, R.D., Coe, R., Allan, E.F. and Dale, I.C. (Eds.) 2004. *Statistical Good Practice for Natural Resources Research*. CABI Publishing, Wallingford, UK. 387 pp. (In press).

Over the years the journal *Experimental Agriculture* (http://journals.cambridge.org/action/displayJournal?jid=EAG#) has published many papers on experimental design.

It is important to realise that experiments are not only useful for biophysical research. Experiments are a powerful and under-used tool in some social and economic research. The following two sites contain some interesting general material on experimental design, including social experiments:

http://www.socialresearchmethods.net/kb/design.php

http://srmdc.net/chapter9/1.htm

# 3.6 Designing surveys

*Erica Keogh*

- **A survey is a well organised, reliable observation of what is going on in the world, that can be used to show the current status, compare different situations and identify relationships between variables**
- **The same principles of good survey design apply whatever the subject, whether the observations are of people, land, plants, animals or institutions**
- **Design of a survey requires choosing the unit of study, defining the population of these units, selecting a sample of units to measure and designing a measurement tool**
- **A successful survey requires good management of the planning, fieldwork and resulting data, not just application of sound statistics**

## What is a survey?

A survey is an observation of what is going on in the world at a particular point in time, but we use the term 'survey' in those situations where:

- Data collection is well defined and organised
- Data collected can be shown to be 'representative' and reliable
- Data are competently interpreted
- Resulting information is utilised while the data is of current value.

In research new empirical information about the world can be collected in two ways – by surveys and experiments. Surveys can be distinguished from experiments by the fact that surveys observe what is there. They do not deliberately make changes to observe the effect. Experiments impose planned changes (the treatments) in order to measure the effects they cause, whereas a survey will investigate one or more characteristics of a population. A survey is distinguished from a census in that a census attempts to cover the entire population while a survey attempts to cover a pre-determined portion (or sample) of the population.

Some books, courses, and researchers imply that surveys are only used to study people. People, households, and villages are commonly the 'objects' studied in a survey. But surveys can be used to study just about anything! In agricultural research you might have to carry out a survey of crops, soils, weed populations, or farm animals or the trees, or sediment in the rivers. Many of the principles of survey design and execution are the same for all types of survey.

Survey information can be collected in an extremely structured manner, or may be more informal, or a mixture of the two approaches, or something in between. Whatever the 'tools' used to collect the information, one thing must be made clear – **it is essential to maintain consistency throughout the exercise and to avoid errors arising from inadequately prepared tools**.

## Why conduct surveys?

Many situations present problems into which you can gain insight by the collection and analysis of survey data, thereby allowing you to:

- Determine existing conditions
- Monitor change over time
- Evaluate new projects
- Forecast future needs.

A survey may seek to

- Describe existing conditions
- Establish relationships between different quantities
- Make comparisons
- Test hypotheses,

or a mixture of all of these.

**A survey may target a large sample or a small one – the size will be determined by the sampling methods used and will have an impact on the future use of the results.**

### Example 1

- **Problem 1.** Increased elephant damage has been reported in some villages. Are the elephants moving along normal migration routes or are they roaming more widely than before?
  Here you would be interested in **describing existing conditions** and, possibly, trying to **make comparisons** with conditions in previous years. The research could be extended over a period of time, thus **monitoring** the situation over a number of years.
- **Problem 2.** Is infestation of maize fields by *Striga* worse when fields are suffering from soil erosion?
  In this case you could do a preliminary investigation into whether there is a measurable **relationship** between *Striga* infestation and the level of soil erosion. Alternatively, if there is prior information about this relationship, you can **test the hypothesis** that this relationship exists and is quantifiable.

**Types of surveys**

There are various ways to distinguish one type of survey from another, but perhaps in the present setting it is best to provide examples which will illustrate the wide variety of studies that are possible.

- Street interviews to assess public opinion about price increases of seed maize
- Household interviews to measure food production and consumption for monitoring food security
- Field observations to estimate earworm infestation in the current maize crop
- Field observations and community discussions to quantify the effects of elephant damage to crops
- Household interviews to gauge the effects of HIV/AIDS on labour availability for household agricultural activities
- A case control study to compare old and new tillage practices in different communities
- An enumeration of tree species in quadrats within a specified area for assessing biodiversity.
- A study to estimate soil fertility prior to land preparation
- A study of a sample of records from the meteorology department to track rainfall patterns over the last 50 years
- An investigation of sections of river banks to determine silting levels arising from gold panning.
  From the examples you should realise that a survey may entail interviewing people, or

collecting specimens, or measuring items, or studying records, or a combination of one or more of these activities. Thus, the type of survey you are planning is determined by the objectives and dictates what measurement instruments you will be using (e.g., a questionnaire for interviews or a tape measure to check the area planted), and also the sampling scheme (the rules for choosing exactly which study units will be measured) you will be using. This matching of 'tools' to the type of study is one of the classic features of surveys, with each survey having a unique set of instruments and methodology for efficient data collection.

### Example 2

Referring back to the problems introduced in Example 1, some of the terminology you are going to meet when designing and implementing surveys can be illustrated.

| | **Problem 1** | **Problem 2** |
|---|---|---|
| **Population** | Farmland in area reporting increased elephant damage | Maize-growing areas in western Kenya |
| **Unit** | Village | 2m x 2m quadrat |
| **Sampling scheme** | 30 villages selected at random | 10 villages selected at random<br>10 fields selected at random in each village<br>2 quadrats per field, placed 1/3 and 2/3 of the way across the field from the entrance |
| **Measurement tools** | Questionnaire for village meeting<br>Visual assessment of damage | Counts of *Striga* plants visible in a quadrat<br>Visual assessment of soil erosion in the field |

## Setting up a survey

An effective survey encompasses many activities, which must all come together to provide a useful and timely report. The actual planning for a survey is as important as its implementation, and the amount of work involved in the planning should not be underestimated. The efficient and successful management of a survey depends to a great extent on a thorough understanding of the population, of the survey topic, and on having well structured administrative backup available throughout. Available resources will often dictate planning decisions, but it is essential to aim to maintain the quality of all procedures by adopting a 'global' viewpoint, i.e., **by considering the impact of each decision made at a particular stage, on the whole project, thereby achieving balance and consistency throughout**. Some examples of surveys have been given. Next we look at the details of survey design and implementation.

### Planning the survey

First and foremost you should specify the objectives of the survey.

- What should be accomplished by the survey?
- What should be measured in order to reach your goals?
- What is the analysis plan for the measured variables?

Ask yourself such questions as **'Why do we need to collect this data?'** Many surveys are multi-purpose, information on more than one topic will be collected, and you need to have some ideas of the precision required in the various areas to be studied. **Define the objectives as simply as possible and ensure they are not self-contradictory**, e.g., will analysis of one variable confuse or assist in the understanding of another? The target and study populations (see later) need to be carefully defined in conjunction with those population characteristics to be studied.

**Familiarise yourself with all possible sources of existing knowledge from previous studies.**

Such information can be used not only to identify gaps and thus emphasise the need for the present study, but also to provide checks on possible sources of bias, to help avoid duplicating work already competently carried out, or to improve estimates previously obtained. It is also important to identify all possible secondary users, i.e., those who may have use for your data in the future. Such users can be of great help with planning, avoiding conflict, and suggesting alternative approaches. You may also be in the situation where your research project is but a small part of some on-going larger research project – in this case it is essential to:

- Maintain contact with those implementing the larger project
- Receive information about results being obtained from other sections of the project
- Ensure your project fits in with the overall larger objectives
- Provide timely feedback on your progress to all other players
- Work with others as part of the larger team.

The flow chart shown in Figure 1 illustrates the phases of a survey, each of which needs careful planning right from the beginning.

Right from the beginning, it is essential to:

- Be aware of all resource limitations
- Be able to identify, for each task:
  - Who is going to be responsible
  - How much it will cost
  - How much time it will take.

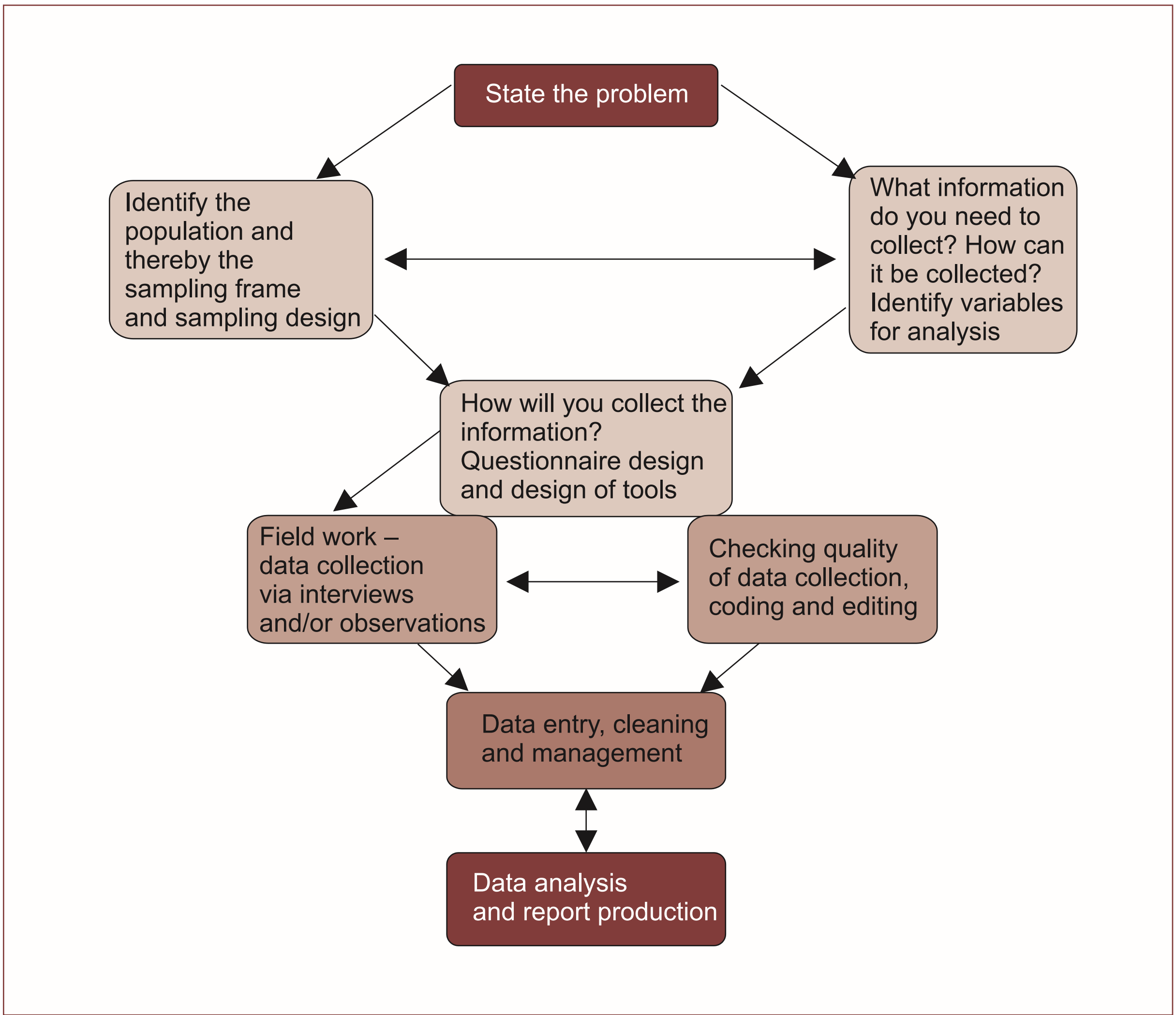


Figure 1. Steps in carrying out a survey

**Table 1. Example of a draft timetable for a crop management survey**
Source: United Nations (2004)

| Task | Week number | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Consultations with communities /publicity | • | • | | | | • | • | | | | | | • | • | • | • | • |
| Questionnaire design and testing | • | • | • | | | | | | | | | | | | | | |
| Sampling design and sample selection | | • | • | • | • | • | | | | | | | | | | | |
| Design of data entry | | | • | • | | | | | | | | | | | | | |
| Data analysis planning | | | • | • | • | | | | | | | | | | | | |
| Field staff recruitment | | • | • | • | | | | | | | | | | | | | |
| Training of enumerators and pilot | | | | | • | • | | | | | | | | | | | |
| Printing of tools (questionnaire) | | | | | • | • | | | | | | | | | | | |
| Fieldwork and checking | | | | | | • | • | • | • | | | | | | | | |
| Data entry and validation | | | | | | • | | • | • | • | • | • | | | | | |
| Data cleaning and analysis | | | | | | • | | | | | • | • | • | • | • | • | |
| Production of graphs and tables | | | | | | | | | | | | | | • | • | • | |
| Report preparation | | | | | • | | | • | • | • | | • | | • | • | • | • |
| Archiving | | | | • | • | | | | | | | | | | | • | • |

Surveys involve large amounts of documentation, all of which have to be prepared in advance and tested for ease of usage. Sometimes you will need to recruit persons who can assist you at one stage or another.

### Timetables and budgets

Organising the timetable and fixing the budget are major components of survey preparation. The time and funding that are available are the major factors determining the scope and extent of your study. **It is extremely useful to use a Gantt chart (e.g., Table 1) for timetabling, since it enables you to maintain an overall view of all that the study will entail.**

There will always be time restrictions to be adhered to in any survey project. It is better to over-estimate, allowing lee-way for unforeseen happenings. It is often at the beginning of the data entry and processing stages that delays occur, but these can be minimised by adequate pre-testing checks in advance. Allow for realistic staff turnover, which may result in delays. Add contingency amounts of time allowing for weather effects, breakdown of equipment, or errors. Identify critical activities which, if delayed, will hold up other activities, and try to foresee possible alternatives. Previous research in the same area can prove useful in the time-planning context since from this you can identify what may have gone wrong before. **Asking the experienced workers is most useful since they have the first-hand experience you wish to know about. It is essential that the data be analysed while it is still relevant; so the report can be published within a realistic time after data collection.** Decide whether an initial overview preceding full analysis will be of benefit and plan accordingly.

### Budgeting

Hand-in-hand with timetabling for the survey, is the survey budgeting. This is probably the **most difficult task of all since the survey design is totally dependent on the budget**, and *vice versa* – so which comes first?

#### The main components of a survey budget

- **Publicity and information** – including meetings, agreements, workshops
- **Wages and salaries** – including contingency planning for ill-health, adverse weather, inflation, resignations, after-hours working, field allowances

- **Transport and communications** – including phone, fax, postage, and e-mail usage, fuel, hire charges, bus fares
- **Meals and accommodation**
- **Equipment and consumables** – including hardware and software, printing equipment, clip boards and note books, maps, files
- **Printing and duplicating** – a major component of the budget
- **Hidden costs** – equipment usage.

**Errors**

A survey requires and combines the techniques of sampling, design of tools, data collection and data analysis, and **the accuracy of the methods employed will determine the quality of the information finally produced**. In any survey there are many potential sources of error which may be broadly classified as sampling errors and non-sampling errors.

**Sampling errors.** These are errors arising because, by chance, the sample is not fully representative of the population. Such errors can be estimated and are a random result of the sampling procedures. Broadly speaking, the larger the sample size, the smaller the sampling errors.

**Non-sampling errors.** This category includes all of those errors which can arise from other sources:

- Variation between data-collection personnel
- Inadequate tools
- Inadequate sampling frame
- Data-entry errors
- Coding errors
- Non-response
- Errors in response
- Effects caused by the way questions are worded.

Each of these can give rise to bias which is often not measurable. Bias means that the results based on the survey are not, even on average, the same as those that would have been derived from a total census of the population, but consistently over- or under-estimate quantities.

Increasing the sample size, so as to reduce sampling error, can very well increase non-sampling errors due to resulting poorer-quality enumeration and lower levels of supervision. **Sampling and non-sampling errors and their relative magnitudes must be considered simultaneously when determining sample size.** Often only sampling errors are mentioned since non-sampling errors are usually not measurable, and sometimes unknown. **You must remember that you will be making many measurements on your sample and that the precision of estimates is likely to vary from factor to factor.**

## Sampling

The theory of sampling is covered adequately in many texts and only some brief notes are made here. There are two inter-related decisions to make: the type of sampling and the sample size. Decisions depend on blending the theoretically optimal with what is really practical, in the light of the survey objectives.

Decisions about sample size must be taken in the global context of the project and must include consideration of the following factors:

- Available resources
- Objectives of the study
- Sub-groups, within a population, that you wish to study
- Practical constraints
- The precision needed
- Homogeneity of the population. Following are definitions and examples illustrating them.

**The population**

The **target population** is defined as all those units in which you are interested. The **study population** is defined as all those units that you can reliably identify. Ideally these two populations should coincide but, unfortunately, this is often not the case, particularly when the population consists of people.

**Units**

When you implement your survey, you are going to be dealing with a **unit**, i.e., you are going to interview a person, or generate discussions with a **group of people**, or count the number of *Striga* plants in a **quadrat within a field**. These are the units of study. In many studies there is a hierarchical arrangement of units. We measure things on people, but also record something about the household they are in, the village in which the household is found, and the district where the village is located. This hierarchy may be used in sampling, even if measurements are taken at only one level.

**Sampling frame**

The **sampling frame** is a 'list' of all the items from which you are going to select your sample, noting that you need a separate frame for each level in the hierarchy of units. Careful construction of the frame is needed since, as mentioned above, unexpected errors can easily arise if the frame is out of date, or if it has inaccurate or duplicate records, and so on. If the frame is inadequate we say it exhibits **over-coverage** or **under-coverage** – these terms simply reflecting the non-match of study and target populations (Figure 2). If you are sampling households, then the ideal frame is a list of all the households. If sampling fields or rivers, for example, the sampling frame may be a map or aerial photo, i.e., an implicit list.

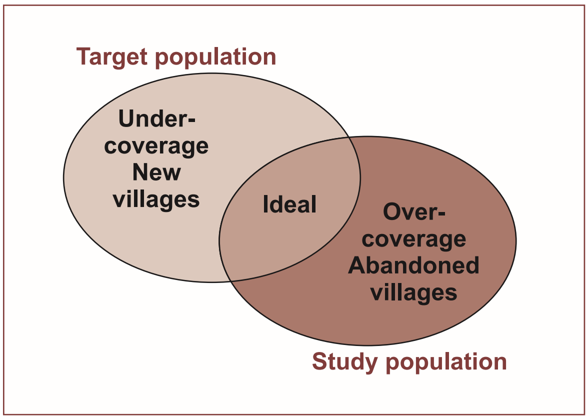


Figure 2. Target and study populations

### Example 3

Refer back to Problem 1 in the previous examples. Not only do you want to observe and measure the actual damage in the fields, but you also will wish to interview the villagers and discuss with them their methods for protecting their crops. Another aspect of interest will be gender differences in managing crop damage. Suppose the district authorities provide you with a map on which the locations of villages in the study area are marked. Your first stage of sampling will be to select villages and thus your **target population** is all villages in the area, whilst your **study population** is all villages marked on the map provided to you. If the map is out of date it may mark a village which, no longer exists because its inhabitants moved out to another area 2 years ago precisely because of high rates of crop damage. We call this **over-coverage** since that village would potentially be selected into the sample (according to the map) and yet it does not really exist. Conversely, if a new village has been formed, with some inhabitants of one village moving away and making it their own new settlement area, then this village may not be marked on the map at all and so will not be available for selection into the sample. We call this **under-coverage** since that village is not (and yet should be) available for sampling. Both of these situations will give rise to **non-sampling errors** that cannot be measured and you may never know they exist.

**Different approaches to sampling**

There are various approaches to sampling and each survey will entail its own unique sampling design. Sampling texts will provide you with the theoretical details and what is aimed for here is to provide a 'feel' for knowing which approach to select. Firstly, two ways of selecting a sample are described.

The simplest type of sampling is known as **simple random sampling**. This involves assigning a unique identification (ID) (e.g., a number) to each item in the sampling frame and then randomly selecting the number of units you require, e.g., numbered pieces of paper placed in a hat and randomly selected one after another. Another very useful method is **systematic sampling**. Here the sampling units are listed in some order that bears no relationship to the topic under study, e.g., listing names in alphabetical order. A starting point is then randomly chosen, and thereafter the sample is determined using what is called the **sampling interval**. This method is often applied to a situation when you have a map or a grid of an area, which can be sectioned into **cells** each of which is then numbered and a systematic sample is easily selected. This latter approach is often referred to as **sampling in space**.

Next, there are a number of ways of classifying the population in different ways before carrying out the sampling, whereby aiming to make use of existing knowledge of the population to ensure the sample is an adequate representation of that population.

**Stratification** of the population is an approach used when the population is heterogeneous and can be subdivided into homogeneous sub-populations, each of which will be of interest in themselves. Random samples are then selected from each sub-population or strata. In **cluster sampling** the population is divided into clusters that are groups of sampling units which are not similar and one cluster can exhibit the whole range of variability of the population. Using simple cluster sampling, divide the population into clusters, then select a random sample of clusters and investigate each study unit in each selected cluster. In **multistage cluster sampling** you can select a sample of clusters but then, within each cluster, further select a random sample of study units.

Clearly it is often useful to classify the population in more than one way, and thus you can use techniques of stratification and clustering together. The final selection of the units you are going to study is usually done using either simple random sampling or systematic sampling. The following examples will clarify these notions.

**Example 4**

Referring back to Example 3 – recall we have a map (hopefully up-to-date) showing the location of villages in the area of interest. As noted before, the villages marked on the map will be the items in the sampling frame for the first stage of sampling. The actual people resident in each selected village, i.e., the households, will represent items in another sampling frame, for a second stage of sampling. Focus for now on this selection of households and recall that you are interested in the gender dimensions (of head of household) of crop protection from animal damage.

Discussions with the district officials and some initial contact with communities in the area will provide you with information about the overall picture of wild animal marauding in the district. You discover that in one area the main proponent of damage are elephants, with lesser damage caused by baboons and jackals, whilst in another part of the district with a different vegetation type, there was apparently an influx of Quelea birds which caused terrific damage during the past month. The remainder of the district suffers little from large animal damage, with only baboons and jackals causing any measurable loss. Obviously, it will be of interest to study the whole district, even though the elephant damage is only restricted to one area – by looking at the whole district you would hope to be able to compare and contrast areas with different levels of elephant damage.

On the basis of the above observations you decide that there should be three strata within the district. Within each stratum, villages can be randomly selected – probably using a systematic sample from the map. This will constitute the first stage of sampling.

The second stage of sampling, that of households within villages, can be approached in a number of ways. Firstly, for each selected village, the village head could be asked to prepare two lists of names of heads of households, a male list and a female list, and a random sample of households can be drawn from each list. Alternatively, you could, with the assistance of the village head, draw up a map showing all households in the village, marking each one as male- or female-headed. Within each group of male and female household heads, each household will be given a number and then, for each gender group, a systematic sample of households can be selected.

Heads of households can be interviewed using a prepared questionnaire to extract demographic details and obtain estimates of crop damage that has occurred in the past two seasons. In addition, focus group discussions can be held with key informants in each village in order to obtain in-depth information and opinions on the issues of crop damage and ways to reduce it.

The process described in Example 4 is called **multistage sampling** – in other words you sample at various stages of the population hierarchy, ensuring that at each stage you select an adequate sample from each sampling frame. **Issues of sample size at each level of sampling will need to be discussed and finalised with someone who understands the theoretical aspects of random sampling.**

**Example 5**

Now let us take Example 4 further, and address the issue of data collection from the fields and storage places of the villagers. This will constitute a third stage of the multi-stage sampling process. One approach is to use the selected sample of households as a starting point for selection of actual sites for measurements of crop damage. Each selected household will have a number of fields under cultivation. Depending on the size of area under cultivation, it may be sensible to sample areas within fields for exact measurements, or another approach could be to sample whole fields from those under cultivation. Sampling areas within fields can be done by mapping the field, dividing it into plots of the size to be examined, and then randomly selecting a sample of plots or quadrats – this can be easily carried out once the map is drawn up. Additional considerations that must be taken into account when planning this third sampling design include the type of crop planted, direction(s) from which animals invade, location of water sources, and any other factors that may have a bearing on crop damage.

An alternative approach would be to ignore the sample of selected households and begin afresh, requesting the community to draw up a map of all planted fields, including crop and animal access information, location of water sources, etc., as above. Planted areas may then need to be clustered before sampling quadrats within each cluster.

Selection of storage places for recording types of storage and amount of damage can again be approached in several ways.

## Sample size

Decisions on sample size depend on a number of factors, including:

- What is required in terms of precision of variables measured?
- Just how much variability is there expected to be in each item to be measured?
- The practicalities – how big a sample can you actually deal with, in terms of both time and resources?
- What sub-groups of the population are really of interest? You need to decide on the sample size for the smallest sub-group of interest to ensure that the sample for this subgroup is adequate for realistic estimation

- Which variable should be used to calculate sample size?

A good way to think about sample size is in terms of obtaining a **confidence interval**, i.e., what width of confidence interval will be acceptable for decision-making, based on the survey results? The width you need will be used to determine the sample size, for each sub-group of the population. Expressing the results in terms of confidence intervals helps in interpreting the results more realistically. **If the confidence interval is too wide then no meaningful conclusions can be made.** As mentioned earlier, **the larger the sample size the narrower the confidence interval** – but increasing the sample size is likely to increase the cost and non-sampling errors. **Managing a large sample survey requires extensive resources and personnel if quality is to be maintained**, and it is only the large agencies who can afford this type of survey. But if the sample size is too small, then once again the quality of the estimates is at stake, and results will not be meaningful.

**It is not true that the fraction (*f*) of the population sampled greatly influences the accuracy of the sample.** The information in a sample of 50 from a population of 10,000 ($f = 50/10000 = 0.5\%$) is much the same as that in a sample of 50 from a population of 100,000 ($f = 0.05\%$), other things being equal. The sampling fraction is not something to consider when fixing the sample size, and aiming for a 10% sample or a 5% sample is not logical. The only exception to this is when $f$ starts to get large – say over 20%.

You should be constantly aware that **each survey study planned and implemented is a unique case and thus 'standard' sample sizes do not exist**. You should familiarise yourself with previous research, but only use it to provide guidelines for your own study. The sample size used last time may or may not be suitable for the current study and you should make your own considerations and do your own calculations, rather than assuming that those used in a previous study were suitable.

## Designing measurement tools

The design of the measurement tools needs to be done in conjunction with:
- Formulating and stating the objectives
- Planning which variables to collect
- Deciding how to analyse the information collected
- Consideration of time and resources available
- Bearing in mind the eventual report to be produced.

**It is all too easy to imagine that you will be able to collect vast amounts of information from each unit studied – the reality is that it is usually not possible or desirable. Hand-inhand with development of measurement tools, must be the preparation of the data analysis plan and drafting the outline of the final report.**

For each item of information collected, there should be one or more corresponding sections in the analysis plan.

If your survey involves communications with groups of people, then you have to be aware of the time you are going to demand from them to assist you in your data collection. Even if your data collection only means laying out and measuring quadrats in someone's fields, they are going to need to accompany you to do this and you have to be able to rely on them.

**People are busy and, in addition, many other researchers may be demanding their time. Thus deep thought should be given to the design of the data-collection tools and, for each variable selected for study, you have to ask yourself 'What useful information am I going to get from this?'**

### Questionnaires

When communicating with people, either via a structured interview or via focus group discussions, or by any other means, it is wise to lay out a questionnaire ahead of time and to know in advance the type of answers you can expect from each question. Questionnaire design is extremely important – when you are interviewing people, you are assuming that:

- Everyone has the same understanding of each question
- Each question does have an answer
- Each question can be relatively easily answered
- Each question should be relevant to your study
- The question is not 'leading' the respondent towards a particular answer.

**Remember that sensitive questions can upset people, which will lead to inaccurate information being provided.** Good questionnaire design can only come with experience and it is wise to always ask for assistance.

Questions can be classified as **open** or **closed**. An **open question** is one for which any answer is accepted and recorded in full. A **closed question** is one in which you supply predetermined **response categories** into which each and every response should fit. Thus, **response categories** should be:

- Non-overlapping, i.e., mutually exclusive
- Exhaustive
- Permit an overview of the situation
- Neither too many nor too few
- Placed in a logical order.

Open questions provide more information than do closed questions but they are correspondingly harder to analyse and **wherever possible it is best to use closed questions. Focus group discussions (using open questions) are extremely useful for finding out general information and situations on the ground.**

Finally, remember that you should place your questions in a sensible and logical order so that the interview/discussion will flow.

### Other data-collection tools

If your survey involves measuring one or more items you will need to prepare for this in advance of data collection. Usually, you should keep in mind the data entry format you will eventually use, since if the formats for both are similar it makes the data entry easier and less prone to errors. Thus, you should design a **spreadsheet** which can be imitated in **data-entry format**, containing clearly defined rows and columns in which values can be recorded, and including a column for comments that will remind you of the circumstances of the collection at data entry time. As with questionnaires, **it is important to collect only the information you really need and which you can really use**. Site details – date, place, time, methods, personnel – can be coded, but must be part of each record. **It is also essential to draw up a protocol for data collection** – this will be a series of detailed instructions and a description of how to actually go about collecting the information required, e.g., how to lay out the quadrats and how to count *Striga* within each quadrat. **The purpose of the protocol is to ensure consistency in data collection methods and implementation**, particularly if more than one person is to be involved in the exercise.

### Testing the tools

Once you have designed your basic data-collection tools, the next step is to test them. We call this first testing exercise a **pre-test**, and it serves not only to see whether the tools are suitable, but also to gauge the responses to be expected and thereby to refine, adjust, and further develop the tools. This testing should be carried out using a small sample of units that will not be involved in the main survey. Those people testing the tools should be experienced researchers so that they can react properly to needs which will be highlighted. After pre-testing it is 'back to the drawing board' again to prepare the final draft of the tools, and the final draft of the data-analysis plan. Mobilising resources and personnel will also be undertaken during this time, until finally you are ready to conduct the **pilot study**. The purpose of the pilot study is to test not only the measurement tools, but also to act as part of the training for personnel, and to test the data entry and data analysis plans. Usually the pilot study is carried out in the same area as where the intended study will take place, using a sample (from each sub-group of the population) that will not be involved in the final study – thus **the sampling design must be completed and known prior to the pilot study**. All personnel to be involved in the final study will also be involved in the pilot study – in some ways it is like a 'mock' study of all procedures. When the pilot is complete you can finalise the measurement tools and reproduce them in bulk as required.

**The time between the pilot study and the main study should be as short as possible so that all personnel remain in the correct frame of mind for the main study.**

## Fieldwork and data collection

The pilot study is part of the preparation for fieldwork. Once the pilot study is complete and the tools finalised and reproduced, you should start the main study as quickly as possible. The training of personnel should be thought of as an on-going exercise – before, during and after the pilot study personnel will be becoming more and more familiar with the measurement tools and all the needs of the survey. During the initial start-up period of the survey it is wise to meet with all personnel on a daily basis so as to maintain standardisation of data collection. The team leaders should be moving from one person to another to:

- Check that each is collecting the information in the required manner
- Check through collected data
- Pass on the completed forms for further checking
- Code and data entry
- Liaise with other team leaders.

Once team leaders are satisfied that their members are acting as expected, the teams can disperse, but the team leaders should continue close monitoring and liaison with each other.

## Data management

**A survey generates a huge amount of data and thus it is essential to be absolutely organised for every aspect.** Data collection forms should bear unique ID numbers which, by means of codes, will enable the data manager to know exactly where that data was collected, and by whom. The team leaders should check each completed form in the field and, if there are problems, the person who collected the information will have to return to the site and repeat the process. Once the team leader is satisfied with a form, he/she will pass it on to the data manager. If any coding is to be done it is now that it should occur – for instance, categorisation and consequent coding of the content of open questions can take place at this time. Thereafter the form is ready for data entry. Often data will be entered twice – **double data entry** – an approach that is recommended since it nullifies errors of entry – many statistical packages offer this facility. Those doing data entry should have been involved in the planning so that they are aware of the survey objectives, familiar with the measurement tools, and thus in a position to spot inconsistencies and/or errors on the data forms – in this way **cleaning** of the data begins even at the data-entry stage.

Full-scale cleaning of the data usually takes place once all data has been entered and the data files merged into one. **Cleaning** involves examining each variable in turn, looking for **outlier values** and **inconsistencies**, particularly in respect of other variables that provide complementary information. Once the data is pronounced clean the data analysis plan can be put into action and results obtained for input into the final report. Additional **recoding** may take place during the data analysis, e.g., merging categories of responses for more realistic analysis.

**Data storage**

The importance of **backing up** your data files cannot be emphasised too often. At least three copies of each of the following files should be kept, preferably on CD's

- Original data entry files, obtained before cleaning
- Cleaned data files
- On-going analysis files
- Records of comments on data collection
- Records of progress on data collection
- Records of coding and recoding
- Tables and other results of the analysis plan
- Reports.

All of this information will, eventually, feed into the data archive that should be set up on completion of the survey.

## Reporting

The survey report should follow the phases of the survey. **Each phase should be reported upon fully, including both good and bad aspects.** Full details of measurement instruments, training instructions, field reports, coding procedures, cleaning procedures, and the data analysis plan, should be available as appendices to the main report. **Don't forget to report on the non-sampling errors!**

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### Internet resources

A quick search of the internet will reveal vast numbers of resources on survey design. Some are little more than advertisements for consulting companies and many are narrowly focused on market research is countries. However there are also very many useful guides, tools, examples and datasets relevant to agriculture and small farmers in the tropics. Use the advice in **Chapter 2.2** to slim down the search, and be skeptical of resources you find until you are sure of the orinigin, purpose and origin.

# 3.7 Measurements

*Jane Poole*

- Measurements generate the primary data in your study, whether it is a survey or experiment
- You will have to measure not only the primary quantities that meet your objectives, but those data that help explain and qualify them
- There are always alterative ways of measuring anything. Choose the method that best meets your objectives while being practically feasible
- Pay attention to quality control: careless measurement can jeopardise a whole study

## Introduction

'Measurement' is a general name for many types of data collected. Measurements may be numbers that a scientist collects, such as yields of a crop in a field trial. But they can also, for example, be notes of a farmer group discussion, climatic data provided by a local meteorological station, or responses to survey and interviewing questions.

Every aspect of your research study needs careful design. This includes choosing what measurements to take, when to take them and why. You must also consider how to measure and how much to measure. For large trials and surveys it may be necessary to delegate data-collection to other scientists, local extension officers or farmer representatives – you will need to decide who takes the measurements. This chapter provides general guidance on how to make these choices and highlights important issues to be considered.

## What are measurements?

Measurements generate the data you need for your research. You require these data and their analyses to make your research conclusions. There are many different types of measurements and your choice of which to use will depend on the objectives of the study, and on other details of the design. Likewise, the measurements needed will also determine some aspects of the design.

The following are examples of measurements that may be taken for different types of agricultural research. These examples are just a small selection of the hundreds of possible measurements you could take.

- **Laboratory trials** – chemical properties of soil and water samples, pathogen growth on petri dishes, insect mating and offspring production, eating routines of insect pests
- **On-station and on-farm field trials** – plant heights, insect pest and disease levels, crop and biomass yields, root damage of plants, farmer-participatory evaluation of varieties, labour requirements
- **Participatory research** – farmer group characteristics, farmer perception of new technologies, farmer evaluation

of on-station demonstration trials

- **Biophysical surveys** – site location and characteristics, plant varieties, crop management, scientist-evaluated disease infection levels, farmers' perception of disease infection levels
- **Socio-economic surveys** – site location and characteristics, household and farmer characteristics, farmers' perception of crop management practices, farm labour information
- **General/environmental measurements** – weather data (rainfall, temperature), soil type and properties.

### Types of measurement

#### Qualitative and quantitative

Both qualitative (e.g., farmer opinions of new technologies) and quantitative (e.g., crop yields) data require taking measurements. **Quantitative** measurements are necessary for many analyses and interpretations. **Qualitative** data can often add insights and explanations that are hard to capture in numbers. The distinction between the two is not always clear. Qualitative data (e.g., farmer reasons for crop failure) can be quantified after coding, (e.g., by noting whether or not 'drought' is given as reason for crop failure and then reporting the proportion of farmers who give different coded answers).

#### Example 1

An on-station researcher-managed trial was conducted to investigate sorghum varietal resistance to stem borers. Quantitative measurements were taken of the number of stem borers in the stems, stand count and crop yields. Local farmers were then invited to the station to view the different treatments and group discussions were held to elicit farmers' opinions on the performances of the varieties. These additional qualitative data provided the researchers with information about: characteristics farmers considered important, the opportunities for transferring the experiments on-farm, and the likelihood for farmer uptake of the most resistant varieties.

#### Repeated measures

Measurements taken on the same unit (plant, plot, household) repeatedly during a study are called '**repeated measures**'. These type of data are frequently used in laboratory and field trials, e.g., plant disease levels estimated every week, the growth of a fungal pathogen on a petri dish measured every 3 days. When you are collecting repeated measures how often should you collect the data? In some cases, when the occasions are defined, the answer to this question is simple (e.g., data are required after chemical spraying or rain). In other instances it is up to you to decide how frequently to measure.

General guidelines when choosing the number of repeated measures to take:

- If you want to fit a (growth) curve to your data then 4-5 time points are usually sufficient
- When you don't know which time points will give you information (e.g., plant disease levels in a field trial may stay constant for some time) then you may need to take measurements regularly (once a week). Note that for the plant disease example there is no point taking measurements at the start of the trial if there is no disease present. In this case you should be checking the site regularly and then start taking measurements when the disease starts to appear, otherwise you will spend a lot of time collecting a lot of zeros!
- It is not essential that the observations be taken at equal time intervals. However, it is important to record details of each time point so that the patterns observed can be accurately plotted (time plotted on the x-axis on the correct scale).

These same guidelines can be used when you have repeated measurements 'in space' as opposed to 'in time'.

### Destructive and non-destructive

An important decision to make when taking laboratory and field trial measurements is whether they are to be made **destructively**, such as when a plant is cut down to measure root sizes, or **non-destructively**, such as when you simply measure plant height. If it is your trial, make sure destructive measurements will not disturb further observations. If you intend taking destructive measurements in farmers' fields ensure they understand and agree. The 'destructive' option is not usually applicable to socio-economic surveys and participatory methods of research!

### Example 2

A researcher wishes to measure above-ground biomass in an agroforestry trial, over a period of 3 years. The plot size is set at 10m x 15m. He/she has several measurement options for evaluating the amount of biomass, some 'destructive' and others 'non-destructive'. What measurement(s) could he/she take? Some options are in Table 1.

**Table 1. Options for measuring biomass in an experiment**

| Measurement | Advantages | Disadvantages |
|---|---|---|
| Destructively sample a few plants per plot at regular intervals | • Collect large amounts of data on biomass production | • Lower precision of yield estimates (increase plot size to overcome this)<br>• If plant size within a plot is highly variable then a large sample is needed for a precise estimate of biomass<br>• Time requirements are high |
| Destructively sample a few plants from the guard rows at regular intervals | • Collect large amounts of data on biomass production | • Guard rows may not be representative of the plot<br>• Over time the guard rows will lose their ability to 'protect' the crop<br>• Time requirements are high |
| Destructively harvest the whole plot at the end of the experiment only | • Time requirement is low<br>• Does not require extra plot area | • Have no idea of the biomass production over the 3-year time period |
| Record the plant heights at regular intervals and harvest the whole plot at the end of the experiment | • Does not require extra plot area<br>• Large sample (whole plot) can be measured<br>• Plants can be followed over time | • The height measurements may not be representative of the biomass yields |
| Record the plant heights at regular intervals. A sample of plants grown close to the trial are harvested regularly | • The harvest measurements from neighbouring plants can be used to calibrate the non-destructive height measurements | • Requires a lot of experience to correctly calibrate the measurements |

### Bulked samples

Some measurements, like soil samples can be measured by **bulking** together samples collected in a plot (or laboratory, site, etc.). You take N samples from a plot/location and mix them together to form a single composite sample. M sub-samples are then extracted from the composite mixture and measurements taken for each. Things to note about this type of measurement:

- The variation you observe between the M sub-samples is due to measurement error and/ or poor mixing. It has nothing to do with the variation in the plot as each sub-sample is NOT what you could call a replication
- The closeness of the measured values to the plot value is determined by the N field samples. The more samples you bulk together (i.e., N is large) the more representative of the site your composite mixture will be
- If the N field samples are highly variable, or collected in a way that introduces bias (e.g., all samples taken from one corner of the plot), then increasing the number of sub-samples you take (M) will not help.

Think carefully about the information you really need. Do you want to know how soil P, for example, varies between different samples from the same plot or how it varies between different plots? If you only need the latter then maybe M can be 1, but N may still have to be large to make sure the bulked sample really represents a whole plot.

## What measurements to take and why?

Your choice of measurements (the what, when, why, how and how much, who to measure?) depends primarily on your **research objectives**. You must ask 'What data do I need to collect and analyse in order to achieve my objectives?' Careful consideration of your detailed objectives, together with the practicalities of measurement – this means the resource availability, will assist you to collect the relevant data. **Researchers often take measurements that will not help them to answer their objectives and/or take measurements which duplicate the information. This is usually because they have not given sufficient consideration to the data they need.** Collecting data you don't really need is a waste of time, and in some cases is even unethical (for example, in a household survey in which you take up the householder's time). Failing to collect data you do need will mean you can not achieve your objectives.

Measurements may be **primary responses** that are central to answering your research objectives or **variables** that help to explain them. Examples of primary responses may be crop yields (Objective: compare yields under different management methods) or disease infection levels (Objective: map the geographical distribution of the disease in a region). Primary responses are usually highly variable, with variation at every level of the design hierarchy. You therefore need to investigate the reasons for this variation and may also want to make comparisons with similar research.

In example 2 the researcher collected additional data on potential sources of variation such as soil type, climatic conditions and crop management. These are examples of measurements that are variables helping to explain the researcher's primary response biomass measurements. The following are examples of measurements that may be relevant to specific research objectives.

### Example 3 – On-station field trial

Objective – Evaluate the effects of 5 treatments on cabbage crop aphid numbers. (Detail – treatments include chemical, biological and un-treated control, 4 blocks). (Table 2)

**Table 2. Suggested measurements in cabbage experiment**

| Primary response measurement(s) | Additional explanatory variable(s) |
|---|---|
| Plant aphid counts (every 7 days) | Yield at harvesting (to investigate the aphids' effect on yields) |
| | Rainfall and temperature (changes in climatic conditions may affect aphid numbers, how do these relate to the treatment effects?) |
| | Soil fertility measurements |

### Example 4 – Socio-economic survey

Objective – Investigate farmer perceptions of the impact of *Striga* on their maize yields. (Detail – 200 farmers interviewed in one district of Kenya).

NB. This survey could be combined with a 'researcher observed' level of *Striga* to compare farmer perception to the actual levels of infection.

- Look carefully at your research objectives
- What are the primary response measurements you should take so that you can answer your objectives?
- What are the additional variables you could measure (Table 3) that will help you to explain the patterns you observe and enable you to compare your research to similar work?

**Table 3. Suggested measurements in *Striga* survey**

| Primary response measurement(s) | Additional explanatory variable(s) |
|---|---|
| Farmer perception of *Striga* levels | Maize management methods (that may affect levels of infection) |
| Farmer perception of yield loss due to *Striga* infection | Importance of maize to farmer's livelihood (looks at the impact of the perceived *Striga* levels) |

So, your measurement options are determined by your research objectives. But often you will find that several different measurements could be used to answer the objectives so how do you decide which ones to use, without duplicating the information? The answer to this question depends on your research design, available resources, and practical considerations.

## Research design

Almost all experimental designs have more than one level of hierarchy (villages/ farms/fields/ plots, or plot/row/plant/leaf) and you have to decide what measurements to take at each level. Different quantities should be measured at different levels of the hierarchy, for example, the wealth of a farmer is usually measured at the household level, the crop yield may be assessed for each plot, and tree height has to be measured on individual trees. Other variables may be measured at higher levels, for example, discussions with a farmer group will generate village-level variables.

The type of research you are doing also determines which measurements are appropriate. For a researcher-designed and -managed trial it makes sense to take measurements on every plot and location. In a farmer-designed and -managed trial measurements may only be taken on some plots.

### Example 5

In a farmer-designed and -managed **varietal trial** the objectives require crop yields to be measured. However, on some farms the level of crop management was very low and weeds greatly reduced yields. Yield measurements were taken on the sub-set of well managed farms and conclusions applied to this environment. The reasons for varying management input were recorded on all farms to explain the differences between the well managed and poorly managed sites. In this example measuring the yields on poorly managed plots would not have provided the information necessary to explain varietal differences.

### Research resources

The type and number of measurements you can take will depend on the resources available in terms of time, money, and human resources.

**It is often not possible to take as many measurements as you would like due to a lack of these resources.** So, should you take small samples of many different types of measurements or fewer types with more samples? The answer depends on how precisely (i.e., the size of measurement error) you want to evaluate each type of variation. It is often possible to simplify your measurements, by using indicators and proxies, so that a larger sample can be measured. Review the following two situations and decide which measurement option you would take.

### Situation 1

Conduct a biophysical survey to evaluate the levels of coffee berry disease in five coffee-growing districts. You have enough resources to sample 1000 trees. The majority of farms have around 200 trees and there are approximately 500 farms in each district (Table 4).

**Table 4. Measurment options in coffee survey**

| Measurement options | Gain/loss considerations |
|---|---|
| Sample (all) 200 trees on each farm<br>Visit 1 farm in each district | A precise estimate of disease level on each farm but you only have one observation per district and therefore no idea of variation within the districts |
| Sample 20 trees on each farm<br>Visit 10 farms in each district* | Estimation of variation within each farm and also within each district. Comparison of the two is also possible |
| Sample 1 tree on each farm<br>Visit 200 farms in each district | A good estimate of disease levels within each district but no idea of variation within each farm |

* As an alternative to this option you could increase the number of farms to 20 and decrease the trees sampled per farm to 10 – thereby increasing the precision at the district level but decreasing precision at the farm level.

### Situation 2

Carry out a farmer-managed experiment to evaluate the yield potential of 4 sorghum varieties. You have 50 farmers who are willing to participate in the trial, but you are the only scientist on the project. The crop matures on all farms in the same 2 weeks (Table 5).

Key questions regarding research design and resources that you need to confider are:

- What measurements do you need to take at each level of your design hierarchy?
- What resources do you have for your research – in terms of time, money and labour?
- What use of resources will give you the highest precision for your most important measurements?

## When to take measurements?

One way to categorise your measurements is using the 'Before – During – After' approach. In any research project, experiment or survey, you can take measurements at each of these three stages.

### Before

Measurements taken at the start of your research can:

- Provide you with a baseline for your experimentation, e.g., soil fertility measurements of a field-trial site
- Be used to characterise the plot/farm, e.g., wealth categorisation of farmers prior to their participation in an on-farm 'uptake of technology' trial

| Table 5. Measurement options in sorghum variety trial | |
|---|---|
| **Measurement options** | **Gain/loss considerations** |
| Visit every farm and carry out the harvesting yourself, avoiding the edges of plots, taking into account damaged plants and gaps in the plot, etc. | 1 Time – you don't have enough of it!!<br>2 Should the researcher control the harvesting of a farmer managed trial?<br>3 The assistance provided by you may give a bias to the farmers' perception of the varieties<br>4 Does harvesting the whole plot at the same time (which you would have to do) accurately reflect the actions of a farmer? |
| Take proxy measurements such as stand count and height prior to harvest | 1 Requires less of your time and can be carried out before harvest<br>2 May not always be a good proxy for the crop yield |
| Ask farmers to harvest their own plots and provide you with sorghum yields for each plot , in kg/plot or as a score such as, 'poor' to 'excellent' | 1 There is less time needed for you to interview the farmers about their yields and perceptions<br>2 Farmers maintain 'ownership' of the trial and the trial remains 'farmer managed'<br>3 You do not obtain a precise researcher-controlled crop yield, although you can use the farmer evaluations to answer the objectives of the trial |

- Assist with your design, e.g., characteristics of regional farming population used to select a representative sample for participatory work.

### During

You want to collect data on 'interim' responses whilst conducting your research, e.g.:

- Common measurements on crop trials include plant stand and height. Other measurements may include labour use for different operations, insect pest and disease levels etc.
- You might opt to include the use of participatory research tools, e.g., participatory rural appraisal (PRA) during on-farm experimentation
- Whilst evaluating the use of agricultural information centres or extension offices you may choose to record the daily attendance numbers.

### After

Towards the end of your research there may be follow-up measurements that can help you to complete your understanding of the results:

- You could measure soil fertility levels at the end of an on-station field trial, or farmer perceptions and technology uptake at the end of an on-farm trial, for instance, do they choose to continue using one of the tested technologies?
- Data could be collected to demonstrate the impact of your research, by comparing to your baseline data.

## Data collection and quality control

**Taking all measurements yourself will help to maintain high data quality but may not be possible if you are collecting data over many plots, farms and locations.** If enumerators are used then it is harder to ensure they are using common methods, and you must monitor their performance and follow-up on difficulties and questionable data. Problems are especially likely to arise when carrying out socio-economic surveys or using PRA methods as these require considerable interviewing skills such as probing, performing arithmetic calculations to confirm responses are reasonable, and assessing the attitudes of the farmer. In this type of research it may be better to keep the sample size smaller and conduct the interviews yourself.

**Field trials**

- Ensure data collectors are trained in how to take each of the measurements. Give your enumerators a demonstration of the data-collection methods
- Monitor enumerators' performance by observing at least some of the data collection
- Check through the data as soon as it is given to you and follow-up on any problems with the enumerator immediately – before their memory fades
- Remember to take photographs of significant results or events, and label them carefully for later reference.

**Surveys, interviews and participatory research**

- Interviews and surveys should be kept as short as possible. If your questionnaire has, for example, 50 questions then it probably means you are collecting a lot of irrelevant information, repeating measurements and are not focused on your research objectives!
- When conducting farmer interviews for on-farm trials, socio-economic or biophysical surveys and other participatory research it is preferable to conduct the interviews in the field. Farmers will find it easier to evaluate and quantify their observations if they can see the crop/trial in front of them
- If you are using enumerators to assist in data collection then they must be appropriately trained. Meetings to discuss the survey measurements are useful so that you can agree on common methods of data collection. To standardise the perceptions/abilities of the enumerators you should carry out a few 'mock' interviews with farmers
- As with field trials, check through the data as soon as it is given to you and follow-up on any problems with the enumerator immediately.

Even if you have other scientists, technicians and enumerators working on your study you should be spending time in the field collecting data. Only by being personally involved can you monitor the quality and understand difficulties and things that are not going as planned. You will also gain insights into the problem that you would not get simply by analysing data that someone else collected.

Record ancillary observations, comments and notes along with all your planned observations. Include comments on data such as, 'plot 17 did not look so well weeded as the others' or, 'Mrs Njoroge was recovering from malaria when we conducted the interview'. Include notes on things to follow up, such as, 'I could see trees on the hill top but no one mentioned these in the interview' or, 'there were many more bees on the local varieties than on the introductions'. Include ideas that occur to you as you spend time in the field – 'Maybe we have to sort out insect damage before soil fertility will make any difference'. All these things will add to your interpretation and real understanding of the research you are doing. When researchers used pencil and paper exclusively their field books were usually full of such notes. Now computers are used to capture data, often all you will find are files full of numbers, with no marginal notes and comments. This is not very useful. Such information can easily be recoded in your computer, or you may still use a notebook. But if you do not write down the notes and comments when they occur to you, you will not remember them.

Photographs can also be an important record of the ancillary information. You can use them to illustrate the points you are making in your report and presentations. They will also help you recall the field situation, allowing more relevant and effective analysis and interpretation of numerical data.

## How much data should you collect?

Often too much data are collected, just in case they may be useful. Researchers believe some measurements require little cost and therefore are worth taking. However, even if you have the necessary amount of staff/labour time some 'costs' may remain hidden. For example, staff asked to collect frequent growth data, which they know are rarely used in the final analysis, may not pay sufficient attention to data quality. Additionally, computer entry of the data may take up too much of the researcher's time. **When large volumes of data are collected it is often because staff have not yet given sufficient thought to the analysis.** Careful thought about what measurements are really needed to answer the objectives of the research should help to avoid this pitfall.

## Measurement tools and equipment

**The tools available for taking measurements are varied and you should use the ones most appropriate to the objectives and practicalities of your research.** It is unlikely that your research will require only one type of tool and it is usually a good idea to combine rigourous studies such as quantitative field trials with PRA-type methods like farmer evaluations.

- For quantitative field data standard tools (e.g., balances and tapes) are used. **Ensure that you and/or the enumerators are fully trained in the use of each tool so that data collection is of a consistently high quality**
- When collecting data from farmers other tools will be needed. **Formal individual farmer questionnaires are often used but they are not always the most efficient method of data capture.** They are an intensive method and resources may limit the number of interviews you can do. Using a range of methods from PRA and other types of social enquiry may provide you with just as much information, for less work. **Use of PRA methods requires intensive training and quality control of enumerators.** Many PRA methods are designed for open-ended, exploratory enquiry. They can also be very useful in more-structured investigations, but take care to use them in a consistent way
- Choose tools most appropriate to your research objectives and the practicalities of your work, i.e., available equipment and resources
- This may mean combining tools used in rigourous studies, such as the tapes for measuring tree heights with PRA-type methods like farmer evaluation of the tree
- Use quality control methods to ensure measurement tools are being used appropriately and accurately.

## Resource material and references

There are very few books and papers written specifically to tackle the issue of measurements. 'Survey sampling' and 'Experimental design and analysis' books sometimes contain sections or chapters on data collection methods. There are also subject-specific books with details of measurement methods, some of which are listed below. You may find that scientific or discussion papers covering research topics similar to your work provide the best 'measurement' ideas.

**Appendix 11.** ICRAF. 2003. Genstat Discovery Edition and Other Resources. World Agroforestry Centre (ICRAF), Nairobi, Kenya.

Ashby, J.A. 1990. *Evaluating Technology with Farmers: A Handbook*. CIAT Publication no. 187. Centro Internacional de Agricultura Tropical (CIAT), Apartado Aereo 6713, Cali, Colombia. 95 pp.

Ackroyd, S. and Hughes, J.A. 1981. *Data Collection in Context*. Longmans, London, UK. 155 pp.

CIMMYT Economics Program. 1993. *The Adoption of Agricultural Technology: A Guide for Survey Design*. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico DF, Mexico. 88 pp. cimmyt@cgiar.org

Coe, R., Franzel, F., Beniest, J. and Barahona, C. 2003. *Designing on-farm participatory experiments*. Resources for trainers. World Agroforestry Centre (ICRAF), Nairobi, Kenya. http://www.worldagroforestycentre.org

Feldstein, H. and Jiggins, J. 1998. *Tools for the Field: Methodologies Handbook for Gender Analysis in Agriculture*. Kumarian Press, Hartford, Connecticut, USA. 270 pp.

Franzel, S. and Scherr, S.J. 2002. *Trees on the Farm: Assessing the Adoption Potential of Agroforestry Practices in Africa*. CABI, Wallingford, UK. 208 pp.

Lal, R. 1994. *Soil Erosion Research Methods*. St Lucie Press, Florida, USA. 352 pp.

Mitchell, A. 1999. *The ESRI Guide to GIS Analysis – Volume 1: Geographic Patterns & Relationships*. ESRI. 188 pp.

Philip, M.S. 1994. *Measuring Trees and Forests*. CABI, Wallingford, UK. 336 pp.

Schroth, G. and Sinclair, F.L. 2003. Trees, Crops and Soil Fertility – Concepts and Research Methods. CABI, Wallingford, UK. 416 pp.

Spencer, D. 1993. Collecting meaningful data on labour use in on-farm trials. *Experimental Agriculture* 29: 39-46.

Stern, R., Coe, R., Allan, E. and Dale, I (Eds) (2004). *Good Statistical Practice for Natural Resources Research*. CABI, Wallingford, UK. 388 pp.

**Internet resources**

- Reading Statistical Services Centre (SSC) website (http://www.rdg.ac.uk/ssc/) contains several downloadable booklets and papers. They provide 'easy to read' discussions and advice on various aspects of experimental and survey design and analysis. 'Measurements' are often discussed within these topics.
- Centro Internacional de Agricultura Tropical (CIAT) website (http://www.ciat.cgiar.org)
- Online publications:
  - Horne, P.M, and Sturr, W.W. (2003). Developing Agricultural Solutions with Smallholder Farmers: How to get started with participatory approaches.
  - TSBF Institute of CIAT (2001). Legume Cover Crop and Biomass Transfer Extension Leaflets
- Food and Nutrition Technical Assistance (FANTA) website (http://www.fantaproject.org) (Downloadable: Agricultural Productivity Indicators Measurement Guide & Anthropometric Indicators Measurement Guide – Chapter 5 Taking Measurements)
- International Livestock Research Institute (ILRI) website (http://www.ilri.org)
- International Institute of Tropical Agriculture (IITA) website (http://www.iita.org)
  On-line publications (a few of these need to be ordered from IITA):
  IITA Research Guides:
  - IRG2 – Soil sampling and sample preparation
  - IRG31 – Tips for planning formal farm surveys in developing countries
  - IRG50 – Socio-economic characterisation of environments and technologies
  - IRG65 – Partial budget analysis for on-farm research