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Demand assessment for technologies for on-farm management of natural resources in semi-arid areas of Zimbabwe and Tanzania¹

Scientific report

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1 Introduction

Sustainable management of natural resources by farmers is a prerequisite for achieving food security and poverty alleviation in much of southern Africa. While the debate continues over the long term future of smallholder agriculture in the region (Bryceson, Kay et al. 2000), (Ashley and Maxwell 2001), farming remains a major component of livelihood strategies for the majority of poor rural households (IFAD 2001). CGIAR centres and NARS have invested in identifying ways in which the basic natural resources of soils, biomass, water and plant genetic resources can be enhanced, used more efficiently and managed in a more sustainable manner. There is little evidence, however, of widespread uptake of the outputs of this research by small-scale farming households, particularly in the variable and risk-prone environments of the semi-arid zones which cover much of the region. This raises the question of the level of demand for future research outputs: is it possible to estimate demand for specific types of natural resource management technology so that future research investment can be more precisely targeted?

2 The research problem

2.1 On-farm natural resource management in semi-arid areas

Semi-arid zones cover around 35% of Tanzania and 65% of Zimbabwe, and contain 20% and 70% of the national population respectively (Morse 1996). There are two sides to the problem addressed by the research reported here. First, the productivity of farming systems in semi-arid areas of central, southern and eastern Africa is low and in many places intensification of systems is depleting the resource base. Sustainable increases in productivity are needed to keep pace with the subsistence needs of the rural population which is growing at around 3% per year and to contribute (through sales of crops) to household income and hence to livelihoods. These increases can only be achieved if (a) action is taken to conserve and enhance the resource base, and (b) new, more productive techniques are introduced into farming systems. Of particular concern are the physical and nutrient status of soils (Scoones, Chibudu et al. 1996), making efficient use of the (limited) available rainfall, and the management of plant genetic resources – to preserve and enhance genetic diversity and to enable households to benefit from new genetic material (Friis-Hansen 1996). Second, while agricultural research has shown that productivity can be sustainably increased through new and modified technologies, uptake of these has been limited. Deterioration in the local agricultural terms of trade are adding to the disincentives to uptake. In Zimbabwe, farmers in 1999 were anticipating a fall in grain production as production costs had risen substantially in the previous twelve months and government controlled prices were insufficient to meet these increases (Harford, pers. comm.).

Research and technology development in semi-arid areas face particular problems created by a high degree of variability in the resource base within and between sites (particularly soils) and time periods (particularly rainfall) (Morse 1996). This makes results highly site specific and, for the poorer households, increases the importance of minimising the risk of crop failure rather than maximising output (Upton 1996). An analysis of households' risk management strategies is therefore needed in addressing the question of why technologies are tried or rejected. Site specificity also suggests that a strategy which encourages adaptation based on local experimentation with new ideas is likely to have more impact on farmers' practice than the straightforward

promotion of research outputs.

A substantial plant breeding programme and seed distribution effort in both countries over the past thirty years does not seem to have resulted in small scale farmers in semi-arid areas making much use of new planting material (Friis-Hansen 1992; Friis-Hansen 1996), despite evidence that households in this zone often feel constrained by the lack of diversity in their planting material (e.g. (Wood and Lenné 1993)).

In soil fertility management, use of mineral fertilizers is very low throughout Tanzania, averaging 7 kg/ha (FAOSTAT data, in (Scoones and Toulmin 1999)). Higher mean levels of use in Zimbabwe (53 kg/ha) are attributable to intensive use on commercial farms in higher potential areas. In the communal area of Chivi, negative nutrient balances for N have been recorded (Scoones, Chibudu et al. 1996). Research has shown how available organic matter (crop residues, weed biomass, animal manure) can be used more efficiently than at present. Many commentators conclude that a combination of inorganic and organic sources of nutrient is essential to achieve an increase in productivity in semi-arid systems (Williams, Powell et al. 1995).

With soil and water management, indigenous practices (including terracing, mulching, water harvesting and flood recession farming) are used in hillside and high potential systems of Tanzania, but are not much in evidence in semi-arid areas. In Zimbabwe, soil erosion is widespread. Annual losses, caused mainly by prevailing cropping technology, have been estimated at up to 50 t/ha of soil, and 536, 50 and 8 kg/ha of organic matter, N and P respectively (Elwell and Stocking 1988). Despite decades of extension and research effort on soil conservation, many farmers in the semi-arid zones do not invest in improvements to soil and water management.

These three facets of on-farm natural resource management cannot be looked at in isolation. They interact with each other, and with other features of the farming system. In parts of semi-arid Tanzania and Zimbabwe, perennial and/or parasitic weeds are becoming a significant constraint on production: action to conserve soil and water, nutrients and plant genetic resources may not be an attractive option for farm households unless the problem of weeds is addressed at the same time.

While much is known in general about the factors which influence farmers' decisions on adoption and use of new technologies (Rogers 1995), with respect to any particular technology these are situation and context specific. In order to guide future research investment, including promotion and further adaptive research of existing and future research outputs, it is necessary to analyse the specific factors which are influential in each particular set of circumstances. This will enable potential demand for existing and future resource conserving technologies to be assessed. It is important that this analysis is undertaken within a holistic, livelihoods perspective, in particular with an understanding of the place of agriculture in household livelihood strategies. The incentive to invest resources (time/labour, management, cash) in resource conserving technologies may be influenced not only by the economics of production, processing and marketing of farm output, but by the opportunity cost of those resources in the light of other livelihood opportunities. A rational response of the rural poor to a decline in the state of the natural capital to which they have access may be to build up other forms of capital. At the same time, effective on-farm natural resource management may require investment in other assets such as social and human capital before it becomes viable.

In 1988 sixty percent of the rural population of both countries was below the poverty

line (Jazairy, Alamgir et al. 1992). Groups particularly affected by poverty were those in semi-arid areas and households headed by women (ibid). Human, natural and social capital are the main assets of the rural poor. While the poor in these areas seek multiple sources of income and livelihood, the natural resource base will continue to provide a major source for the foreseeable future. Access to non-farm sources of income is not equally distributed, within and between areas. (Piesse, Simister et al. 1999) show that in more remote areas with traditional farming systems and techniques, households with higher farm incomes have more opportunity to access non-farm income; while in higher potential areas closer to urban areas, non-farm income seems to compensate for inequalities in income derived from farming.

Where non-farm opportunities are available, agriculture competes for labour (and with time for learning and developing new knowledge) with other livelihood activities. This is in contrast to the implicit assumption behind most agricultural research in the region until recently, that the end users of research outputs are full time farmers whose livelihood priority is to increase the productivity of their farming systems. In Zimbabwe, secure access to land for farming is limited by the slow progress of land tenure reform (Adams, Sibanda et al. 1999). Implications for research into demand for natural resource management (NRM) technologies are that institutional constraints (e.g. land tenure) must be included in the analysis of factors in the adoption or otherwise of new technology, and that the analysis must be broken down by wealth / resource endowment, and by gender.

2.2 Demand for technologies

Much of the economic literature on investment in agricultural research is concerned with the supply of innovations rather than the demand for them, and in particular with how to ensure that there are socially-optimal levels of investment in the development of technical improvements. This focus stems in part from the very high returns to research reported by many studies, which suggest there is under-investment (Craig, Pardey et al. 1996; Purcell and Anderson 1997).

Demand for innovations receives less attention from economists. Two notable exceptions are Ester Boserup's thesis that population growth drives intensification of farming, a process in which producers actively seek out technical innovations that will enable them to cope with a declining resource base (Boserup 1965); and Hayami and Ruttan's "induced innovation theory", in which the supply of innovations responds to demand for them which is signalled by the ratio of input prices (Hayami and Ruttan 1985). Their theory suggests that when labour is plentiful and land is short, labour-using and land-saving (or augmenting) techniques will be devised; when land is abundant and labour short, mechanisation to save labour appears. They tested their theory on data from Japan and the USA. Ellis, amongst others, has pointed out that the institutional links through which demand is articulated may be particularly weak in developing countries and for resource poor households (Ellis 1988).

Demand can be looked at from several perspectives. From a natural science point of view, we can estimate what kinds of innovation are *required* in order to deliver a specified level of production, based on an understanding of the physical parameters of crop and animal production. If current production methods are depleting soil nutrients year by year, then innovations are needed which will use nutrients more efficiently or replace them more rapidly. This is the production-orientated, supply driven model which guided most publicly funded agricultural research throughout the twentieth

century. *Demand* is essentially an economic concept: it is the relationship between the aggregate quantity of a good or service that will be purchased and the price of that good or service. Although demand is an aggregate concept, it implicitly recognises the agency of individual purchasers - in this case, farmers. This concept is helpful when the innovation is a private good with a price tag, such as hybrid seed or a new piece of tillage equipment. But while it is straightforward to estimate demand functions for a known input or technology, it is highly speculative to try to estimate such a function for the potential output of a research programme which has not yet been started. Where the innovation is a change in management practice that does not involve purchased inputs, we are dealing with public goods. The cost to the farmer of the innovation comprises the opportunity cost of his or her time and management, the cost of any additional labour, transaction costs incurred in finding out about the innovation, and the risk of loss from switching from a known to a new practice.

Rural sociologists have focused attention on *adoption* and *diffusion* of innovations. Thousands of research studies have tried to pin down the factors which influence farmers' decisions on whether or not to use a new technology. These include the personal characteristics of the individual decision maker, socio-economic factors within the household and wider community, and attributes of the technology itself. Adoption is seen as a (reversible) process, not a one off event. Various authors have proposed "stages of adoption", moving from awareness of an innovation through to eventual confirmation of a decision to adopt or reject it (Rogers 1995). Extension science (Röling 1988) recognises that knowledge, information and skills are essential facilitators of this process and explores how these can be made available to farmers most effectively and efficiently.

At the core of both the economist's "demand" and the sociologist's "adoption decision" is the agency of the individual decision making unit. Economic models tend to reduce the decision making process to a response to prices and other economic parameters. This study has deliberately taken a broader notion of demand, in trying to estimate how many people may choose to adopt new NRM technologies based on the characteristics of those who have taken up recent innovations. This is akin to the approach of marketing analysts who base their estimates of the likely initial market for new products on the consumption patterns of products with which they may be expected to compete.

2.3 NRM technologies and livelihoods

How will new technologies for on-farm natural resource management impinge on the various elements in the sustainable livelihoods framework, and vice versa (DFID 1999)? They should give rural households the opportunity to improve their natural capital assets and reduce their vulnerability to long term trends, seasonal fluctuations and random events. However, the attractiveness of new technologies will be influenced by institutions (markets, land tenure) and government policies. They will also be affected by farmers' knowledge, attitudes and perceptions (human capital): in Tanzania, for example, the acceptance of disease resistant varieties of beans is constrained by the fact that "resistance to disease" is not a familiar concept, nor a selection criterion, for most farmers (Garforth and Hayden 2001). Where new technologies involve a long term return to an investment of household labour, their adoption is affected by the relative importance of farming in households' livelihood strategies. Boyd and Slaymaker's review of case studies in six African countries including Tanzania concludes that a household's decision whether to invest in soil and

water management depends on the importance of agriculture in their livelihoods and their perception of the potential of the investment to lead to increases in yields of high value crops (Boyd and Slaymaker 2000).

3 Method

3.1 Process and steps

The aim of the research was to estimate the likely level of demand for innovations in on-farm natural resource management, specifically relating to plant genetic resources, soil fertility management and soil and water management. This was approached by addressing three outputs:

- (1) Identification and quantification of reasons for low uptake of natural resource management technologies
- (2) Identification of the potential of available technologies to meet production system constraints in ways acceptable to farmers
- (3) Quantification of the demand for different types of natural resource management technology among different categories of rural household.

The design and methodology were developed during a three day workshop among the research team (Garforth 2000) and further refined through email exchanges and discussions with research partners in Zimbabwe, Tanzania and the UK. Using a case control design, the empirical research proceeded through seven steps².

- (i) Identifying technologies and study locations: a shortlist was drawn up on the basis of research project documentation (e.g. NRSP project reports, DFID bi-lateral projects, CGIAR centres and NARS) and circulated amongst the research team for comment and discussion in relation to a set of agreed criteria (see below). This led to the selection of two locations in each country.
- (ii) In each location, identifying what secondary data were available
 - (a) to provide background information
 - (b) to inform selection of specific sites and sampling procedures
 - (c) to define more precisely the technology (or package of technologies) on which the research would focus
 - (d) to provide data on distribution of farm and household characteristics within the population that might obviate the need for a sample survey at step (vii) below.
- (iii) Interviewing researchers and project staff who were or had been active in the locations, to gain a clearer picture of the technology/ies, their impressions of extent of uptake, and reasons for non-uptake or rejection.
- (iv) Undertaking an initial PRA to clarify the history / timeline of introduced NRM technologies in each area, in order to inform our definition of “adopter” and “non-adopter” in step (v).

² Details of how these steps were implemented in each country are given in the respective country Annexes to this report.

(v) (a) Identifying “adopters” of the technology. We needed clear and unambiguous criteria for this.³ We did not necessarily need to encompass the whole range of reactions to technology in our typology. We were not trying to divide the whole population into adopters and non-adopters but rather comparing those who were definitely adopters with those who were definitely not adopters. This suggested we should not include, in the set of households we used to characterise “adopters”, those who had begun to use the technology and quickly decided it was not appropriate for them. We did, however, want to identify these people and find out why they have rejected the technology. We also wanted to include those who had *adapted* the technology so that we could explore factors which support successful adaptation. Our criterion for identifying adopters was that the household had adopted the technology as recommended and was still using it. Adopters were defined as those who had made some changes to the promoted technology and were still using it.

We wanted to include households who had tried the technology and subsequently rejected or stopped using it in the focus group discussions (step (vi) below), but exclude them from the analysis used to identify the distinguishing characteristics of adopters and non-adopters. Methods / data sources for identifying these included project records, key informants in communities within the selected location, extension staff (whose knowledge may, however, be skewed to those with better access to resources), snowball sampling, and quota sampling.

(b) Identifying a matched set of non-adopters. Matching would be done at a fairly crude level – e.g. same agro-climatic conditions (which would be covered by selecting non-adopters in the same community as adopters) and farming system, same number of male and female household heads.

A sample size of 50 adopters and 50 non-adopters at each location was agreed as a reasonable number from a statistical point of view. This was thought to be feasible if most of the data collection at this stage was in a group setting - for example five communities with 10 adopters and 10 non-adopters in each; with two focus groups in each community (one for adopters, and one for non-adopters).

(vi) Collecting information, using qualitative methods with the identified adopters and non-adopters, to identify:

- farm and household characteristics which distinguish between adopters and non-adopters
- critical constraints to adoption
- production system constraints

³ The “technology” was defined in terms of what the project has been promoting. It might be a “package” of techniques – a range of options: in which case we want to identify those who have tried / adopted *any* of the components. This “technology” could be seen as the “lead technology” on which most of the questioning and discussion in step 6 would focus – i.e. it provides the firm criterion on which we distinguish between adopters and non-adopters; but the focus group discussions could also collect “shallower” information about other NRM technologies.

- reasons for adoption, later rejection, non-adoption (including reasons at different levels - household and farm, institutional, markets)
- experience with the technology, including adaptation.
- economics of the technology from the farmer's perspective, and its potential for meeting production system constraints

Methods for this step were to be (Garforth 2000)Annex B):

- (a) focus group discussions
 - (b) individual semi-structured interviews (SSIs) with focus group participants
 - (c) participatory budgets (PB) and scored causal diagrams (SCD) (Galpin, Dorward et al. 2000) with some of the focus group participants.
- (vii) A short and sharp sample survey, with the limited purpose of estimating the distribution within the population of (a) the characteristics which discriminate adopters and non-adopters; and (b) critical constraints to adoption. The questionnaire for the survey was to be similar across locations and countries, with a module that was specific to the location and technology that could only be developed in-country at the end of step 6. A template for the questionnaire, covering the elements that would be common to all case studies, was prepared as the basis for the subsequent design of case-specific questionnaires. In Tanzania, a total of 257 heads of households were interviewed in the survey, of whom 32% were women and 68% men. In Zimbabwe, the achieved sample size was 265 (26 to 27 households randomly selected in each of five villages in each of the study sites: 54% were male-headed and 46% female-headed).

The team recognised that the methodology needed to be as free of gender bias as possible. In FGDs, with mixed (male and female) groups, it may be difficult for women to express their views – even with a sensitive and experienced facilitator. Although the individual SSIs would give women a chance to express themselves freely, the FGDs may influence the questions raised and the researchers' expectations in the SSIs. There are likely to be different perspectives on gender roles in decision making within households concerning the adoption of technologies, and gender differences in the evaluation of specific technologies. Biases were therefore important and had to be minimised.

We agreed:

- on day 1 of the qualitative study in each village, to identify local women's groups as a possible source of members of women-only FGDs, and to encourage women to come to the village meeting on day 2
- that it was important to have separate FGDs for women and for men, even if this increased the time needed in each village and meant we could cover four rather than five villages in each study site. However, in Zimbabwe, farmers were reluctant to meet in separate male and female groups: this seemed to be related to experience on previous research projects (Annex B section 2.2.5)
- that intra-household roles in decision making may vary between technologies: who makes decisions about seed selection or adoption of new small grain varieties may differ from the one who makes decisions about SWM technologies such as contour bunds

- timing of the FGDs, and other research activities, should be sensitive to the availability of women to participate and to the possibility that women from resource poor households are likely to have less time than others to take part in research activities
- testing of FGD and SSI instruments should include assessment of gender bias, including observation of interaction between male researcher and female informant/discussant, and *vice versa*
- with respect to Participatory Budgets and Scored Causal Diagrams, the skill of the facilitator is crucial in determining how well women's views come through in mixed groups.

The team also identified specific gender issues to be explored in respect of each of the categories of data which were to be collected through both qualitative and quantitative methods.

3.2 Case study sites and technologies

The case studies were identified in terms of technology and area. The study sites were selected on four criteria:

- a high concentration of small-scale farm holdings
- a widespread perception among scientists and farmers that resource degradation is a problem in the area
- technologies in at least two of the three categories (PGR, SWM, SNM) having been promoted or made available in the area (so that lack of awareness could not be construed as a limiting factor in uptake), and
- accessibility to the research teams within the time scale and budget of the study.

Criteria for selection of the technologies were:

- scientific consensus that the technologies are important for on-farm management of natural resources
- potential for widespread impact
- potential for positive impact on livelihoods
- existing evidence of uptake
- no evidence of critical constraint to uptake.

On the basis of these criteria, Chivi and Zimuto Communal Areas in Masvingo Province in Zimbabwe, and Hombolo and Ilula villages in Tanzania, were selected (Figure 1). Table 1 shows the technologies that have been promoted by various projects and organisations in the study sites.

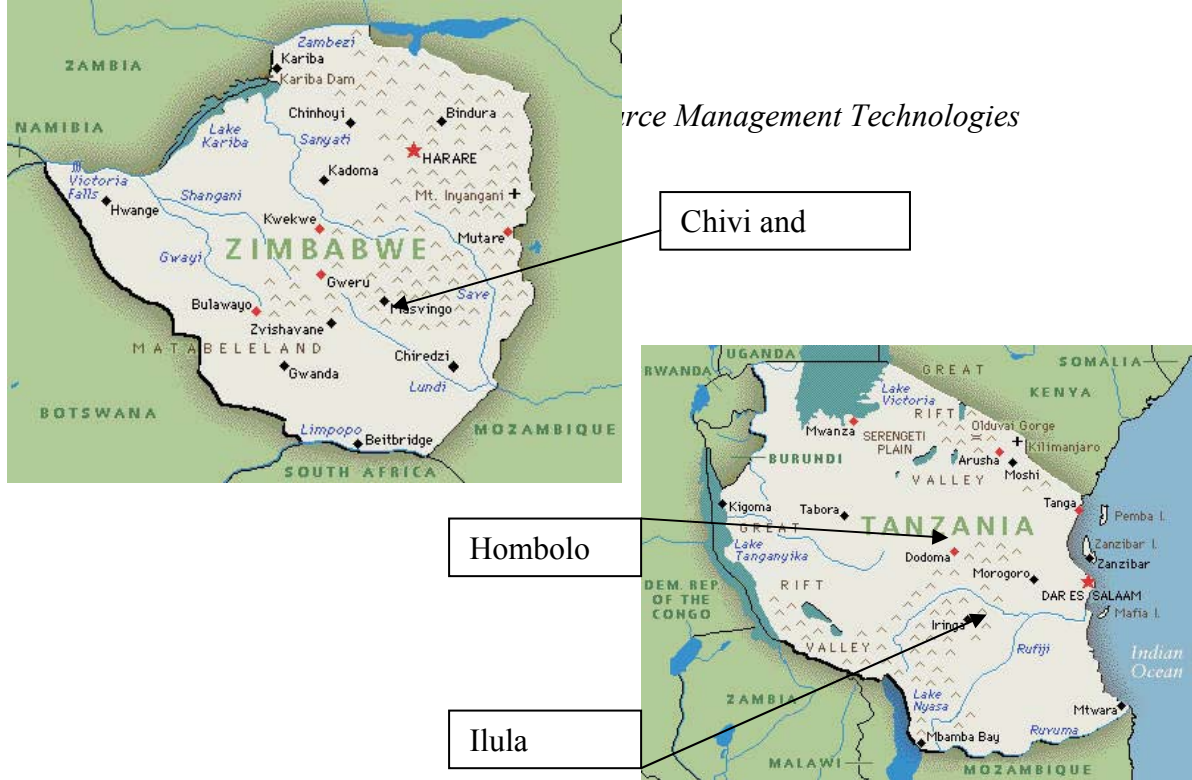


Figure 1 location of study sites in Zimbabwe and Tanzania

Table 1 NRM technologies which have been promoted in the study sites

	Zimbabwe		Tanzania	
	Chivi	Zimuto	Hombolo	Ilula
SWM	strip cropping <i>fanja juu</i> tied ridges mulching vetiver grass contour construction tree planting infiltration pits stone traps dams	tillage OPFP weed control TFP runoff orchards tree planting stone checks vetiver grass banner grass contour ridges tied ridges	improved tillage	
SNM	improved manure improved compost	manure compost anthill soil crop rotations fertiliser green manure		manure
PGR		new OPVs low N maize	sorghum and millet varieties	new maize varieties

Source: Annex B (Zimbabwe) and Annex C (Tanzania)

In Chivi and Zimuto (Zimbabwe), over 20 separate SWM techniques had been promoted over the past thirty five years, along with new varieties of maize, sorghum and pearl millet. Promoted soil fertility technologies ranged from improved

management and use of compost and manure to recommendations for the use of inorganic fertiliser. However, there was a lot of variation between villages in the technologies to which farmers had been exposed (Annex B, section 3, Tables 2 and 4). In Ilula and Hombolo (Tanzania), fewer separate technologies had been promoted which made it relatively straightforward to identify those in Table 1 as the foci for the fieldwork. The site specificity of promoted technologies in Chivi and Zimuto made it inappropriate to select only one SWM and SNM technology for the study: instead, responses were sought in all the Zimbabwe field work on whichever technologies had been promoted in the respondents' and informants' villages.

The PGR technology studied in Hombolo was the adoption of new seed varieties of sorghum and millet, and in Ilula the adoption of new varieties of maize. In Hombolo the study focused on adoption of two new seed varieties of sorghum known as *Pato* and *Tegemeo* in contrast to a traditional variety known as *Lugugu*; and the new variety of millet known as *Okoa* in contrast to the traditional variety known as *Mtama wa kigogo*. In Ilula the study focused on adoption of Cargil 4142 and 4141 maize against a traditional variety of maize commonly known as *Bwana romba*. Both of these new seed varieties (technologies) are promoted with the following recommendations:

- i. planting of approved seeds every season
- ii. proper plant spacing as specified
- iii. preparation of good seed bed
- iv. timely planting
- v. use of fertilisers or manure at recommended rates
- vi. proper weeding
- vii. improved grain storage facilities and techniques.

Soil nutrient management was studied in Ilula. The initial idea was to study composting. Later, it was found that composting technology was still at the early stages of promotion and there might not be enough adopters. The soil nutrient management technique which was found more relevant for the study in the area was the application of farmyard manure (FYM). Recommendation package of the technology included the following:

- i. FYM to be applied when it is matured enough (more than one year old)
- ii. broadcast application after every three seasons at the following rates depending on the type:
 - cattle manure 5 tonne/ha
 - goat/sheep manure 10 tonne/ha
 - poultry manure 0.15 tonne/ha
- iii. deep tillage to incorporate broadcast manure.

Soil and water management was studied in Hombolo. The focus technology was deep tillage. The initial idea was to study tied ridges but the idea was dropped because the technology was found to be still in a development phase. It was at the stage of participatory research: the technology was incomplete and very few farmers had so far adopted. As a result, tillage on flat cultivation was investigated, which was being promoted in the area for the purpose of SWM. The recommended and promoted

practice is to loosen the topsoil at least 20cm deep during primary tillage or immediately after crop emergence. This necessarily requires the use of powered (including DAP) implements during primary tillage or hand hoe when the soil is moist enough. The latter is the only possibility after crop emergence.

Some ambiguity on the definition of tillage arose during the qualitative enquiry. The first weeding operation, which is normally done immediately after crop emergence, was referred to as tillage (*kulima* in Swahili), even if no soil loosening is achieved. To avoid that ambiguity, it was agreed that the Swahili word *kuparura* be used for first weeding when no soil loosening is achieved, and the word *kulima* be used when soil loosening is achieved during the first weeding. The definitions were confirmed during the sample survey.

4 Results

4.1 Reasons for low uptake of natural resource management technologies

Qualitative enquiry elicited farmers' perceptions of the characteristics which distinguish adopters from non-adopters of the promoted NRM technologies. These included households' resource endowment, involvement in non-farm livelihood activities, and personal characteristics. Table 2 below summarises the characteristics identified in focus group discussions in Zimbabwe (Annex B, Tables 3 and 5). The characteristics of adopters are those identified by the adopters' focus groups, and those of non-adopters by the non-adopters' focus groups. It was the latter, therefore, who characterised themselves as risk averse and not fully committed to farm work.

Table 2 Characterisation of adopters and non-adopters, Zimbabwe

Characteristics	Adopters	Non-adopters
Education	well educated	less educated
Risk preference	innovative, risk takers	risk averse
Exposure to information	attend field days, belong to groups, receive training	rarely attend meetings/field days/training; not group members
Resource endowment	own relevant equipment; own two or more cattle	own less than two cattle; do not own equipment
Family size	5 – 10	less than 5
Commitment to work	very committed to farm work	not fully committed to farm work
Age	between 30 and 70	less than 30, more than 70
Gender	majority males	majority females

Income level	earn more income	earn less income
Off farm employment	full time farmers	part time farmers
Soil type ⁴	IOPVs: rich red soils <i>fanja juu</i> : dry soils	IOPVs: sandy soils <i>fanja juu</i> : wet soils

Source: field study; Annex B sections 3.1.3 and 3.2.2

In Tanzania, informants in the qualitative study distinguished characteristics for adopters and non-adopters for each of the types of technology (Table 3). Although the specifics are different for each one, they fall into five main categories:

- livelihood strategy (in particular whether households are producing for the market)
- land tenure status
- natural and physical capital assets (storage facilities, soil type)
- family preferences
- perceptions and attitudes of the farm decision maker.

Table 3 Characterisation of adopters and non-adopters, Tanzania

Characteristics	Adopters	Non-adopters
<i>PGRs</i>		
livelihood strategy	grows cereals for sale	grows for home consumption
perceptions	rainfall adequate for new varieties	rainfall inadequate for new varieties
family preferences	prefers to eat new varieties	prefers to eat existing varieties
physical assets	improved storage	lacks improved storage
<i>SWM - tillage</i>		
soil type	heavy	sandy loam
farming system	grows maize and/or groundnuts	does not grow maize or groundnuts
<i>SNM - manure</i>		

⁴ cf. ITDG (2001). Zimbabwe Country Report. ITDG/ODI Agricultural Biodiversity Conservation Project. Rugby, ITDG.

which reports that soil type is an important influence on the options farmers have for using PGRs; generally, resource-intensive practices are only worthwhile on good soils.

Characteristics	Adopters	Non-adopters
land tenure	owns farming land	does not own farming land
livestock	keeps livestock	does not keep livestock
labour	labour available	labour constrained
attitudes	others' livestock can graze their farm after harvest	livestock on the land after harvest will damage soil

Source: field study; Annex C section 4.9

Qualitative enquiry in both countries confirmed that poverty is a factor in non-adoption of NRM technologies. Poorer households are constrained by lack of equipment needed for a particular technology; lack of livestock for production of manure; lack of money to buy materials (such as fencing to protect planted trees). The need of the poor, particularly where holdings are small, to seek off-farm employment also means they may be unwilling to invest time in labour intensive SWM activities.

In Tanzania, the qualitative data were used to create simple models which show the combinations of characteristics associated with the likelihood of adopting a particular type of technology (Annex C, section 4.9). Figure 2 shows that those who adopt new cereal seed varieties are likely to be growing primarily for the market and to be satisfied that the prevailing rainfall regime is better suited to new than for traditional varieties. Those who grow mainly for family consumption are only likely to adopt if they have also adopted improved storage practices. Similarly, Figure 3 suggests that households who grow maize or groundnuts, and households who farm light soils, are more likely to adopt tillage practices. For manure (Figure 4), adoption is closely linked to resource endowment: households who own the land they farm, keep livestock and have enough labour are more likely to use FYM.

The importance of these various factors in restricting uptake was confirmed by the sample surveys in which the characteristics of adopters and non-adopters of the promoted technologies were assessed (Zimbabwe: Annex B, section 4 - the data are summarised in Tables 7 and 8; Tanzania: Annex C, section 5). Overall, the main reasons for low uptake were identified as:

- features of the household's production and livelihood system
- institutional factors, including land tenure, group membership and promotional activities
- lack of specific resources required for effective use of the technology
- lack of awareness or detailed knowledge about a technology.

Promotion and dissemination activities also seem to be a factor, particularly in Zimbabwe. Farmers acknowledge that lack of knowledge – and also the restriction of knowledge to one member of a household – is a constraint to widespread uptake.

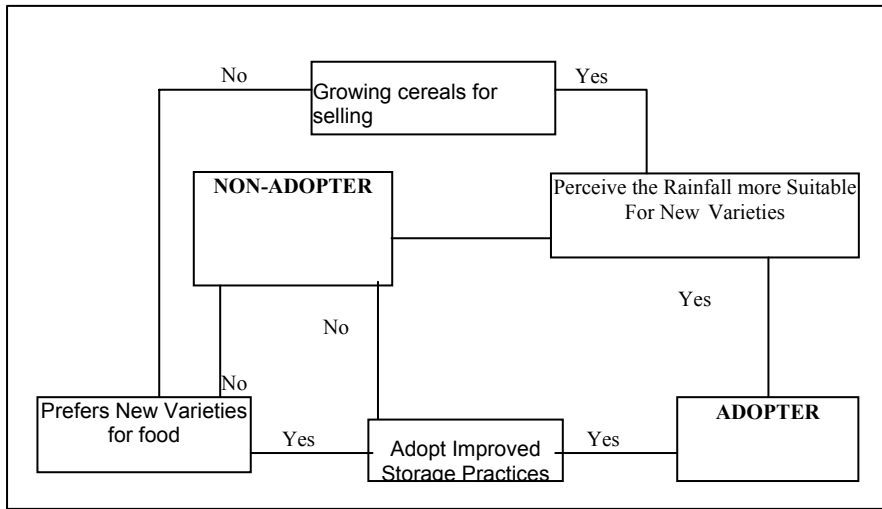


Figure 2 Adoption model for new seed variety, Tanzania

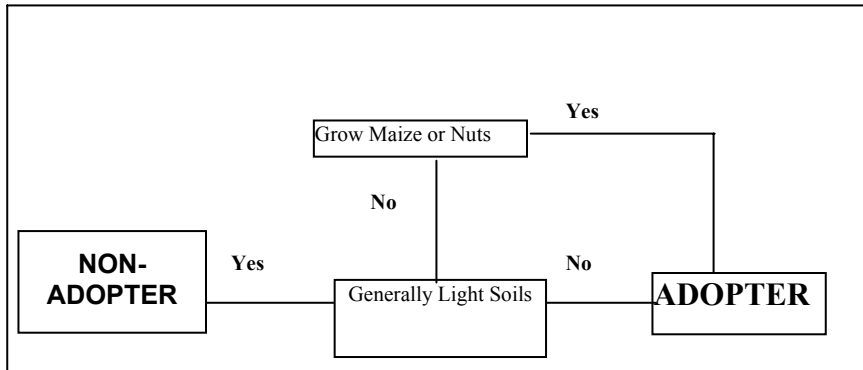


Figure 3 Adoption Model for Tillage, Tanzania

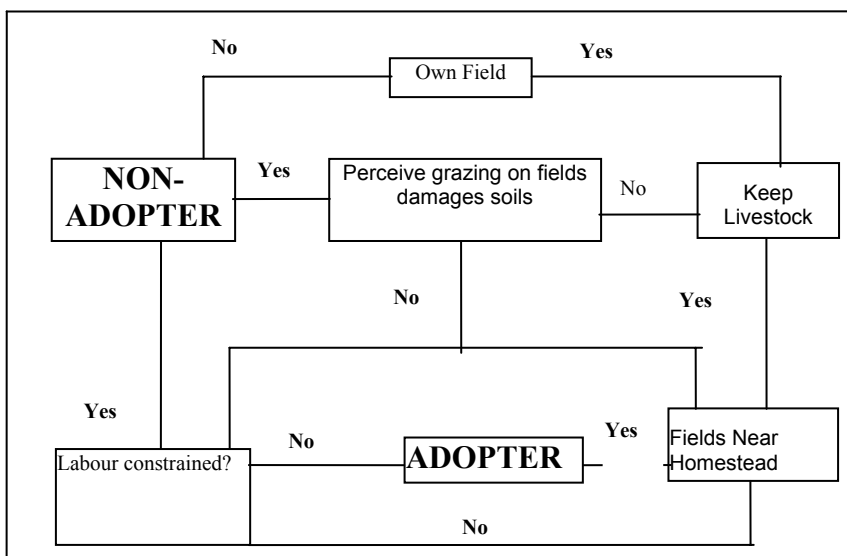


Figure 4 Adoption model for farmyard manure, Tanzania

One of the reasons why women are considered more likely than previously to adopt NRM technologies is that some agencies now deliberately target female headed households and women members of male headed households. This may be the reason for the tendency in Tanzania for women-headed households to be slightly more likely to have adopted new PGRs than men-headed households (21% and 26% for women in Ilula and Hombolo respectively, compared with 18% and 21% for men). Men were more likely, however, to be adopters of the technology. In Hombolo (sorghum and millet), both men and women were more likely to have adapted the recommended technology than adopted it exactly as promoted (32% and 58% respectively for women and men). Adaptation of the promoted maize technology in Ilula, where 67% of survey respondents were non-adopters, was less common (Annex C section 5.1.1.3).

In Zimbabwe, adopters were more likely to have had previous non-farming occupations, to be members of groups not associated with AGRITEX⁵, not to be full time resident on the farm, to be less risk averse, to have a house roofed with modern materials, to own more farm implements, to grow more maize and groundnuts than non-adopters and to have received formal or informal agricultural training. Those factors which distinguished between adopters and non-adopters at 0.05 or 0.01 levels of significance were ownership of implements (harrow, wheelbarrow and number of hoes), and the area and output of maize and groundnuts.

4.2 Potential of technologies to meet production constraints

4.2.1 Production constraints

Farmers are more likely to take up new NRM technologies if they see that they will reduce factors which constrain their production. The research team explored this through participatory farm management methods. SCDs helped identify what farmers perceived as their main production constraints while PBs showed the input and output implications of adopting the currently promoted technologies. Scored Causal Diagrams are a technique for articulating people's analysis and prioritisation of problems and their causes (Galpin, Dorward et al. 2000). At each level of the diagram, those participating allocate a fixed number of "points" to each causal link representing its relative importance or strength.

Tanzania

In the Tanzania study, five SCDs were drawn up in each of the two villages. The key problem that they all focused on was food insecurity, which informants saw as the primary reason for people to engage in agriculture. From the combined ranking of problems and causes across the ten SCDs, four composite main production constraints were identified (Annex C section 4.6).

(i) Unreliable rainfall

Of all the production constraints contributing directly towards poor crop yields, unreliable rainfall or drought was the most frequently mentioned. This is not surprising for a semi-arid area. In this context farmers have indicated that the

⁵ AGRITEX is the public sector agency responsible for agricultural research, development and extension.

presently available technological innovations are inadequate for on-farm rainwater collection that is necessary for improving crop production.

(ii) Poor soil fertility - Continuous cultivation - No fertiliser application

Farmers indicated that poor soil fertility and related factors are their second most frequent set of constraints to poor crop production. Discussion arising within the groups showed that around homesteads of Hombolo the soil is light and exhausted from continuous cultivation with no fertiliser application. On the farms which are relatively far from homesteads, the use of FYM is confined to the few resource access individuals and those with large herds of livestock. In Ilula the use of organic fertiliser is limited too. Large areas have been under maize production for a long time and the natural soil has not been improved resulting in poor soils. Discussion with informants revealed that improvement of soil fertility depends on the ownership of the land: an individual renting in the land is unlikely to take any action to improve the soil nutrient status beyond one farming season.

(iii) Traditional seed and cheap seeds

'Traditional seeds' and 'cheap seeds' are among the most frequently mentioned constraints contributing to poor crop yields. On the one hand, farmers have recognised that some of their traditional seeds are causing poor crop yields. On the other hand, they are obliged to buy cheap seed since the most productive seeds are very expensive.

(iv) Incomplete technology

Over a wide range of climatic conditions technological innovations respond differently and farmers acknowledged these variations. A 'scientific' technology may be appropriate in addressing a problem but may not be adaptable or may contradict traditions that are themselves scientifically sound. Farmers have talked of incomplete technology in respect of composting, storage, and changes in the properties of new seed varieties.

Zimbabwe

In Zimbabwe, SCDs were drawn up by separate groups of adopters and non-adopters in Chivi, and by combined groups in three villages in Zimuto. In both places, soil fertility and shortage of cattle were reported as major (and related) constraints.

In Chivi, the main production constraint faced by the non-adopters was shortage of cattle. The adopters, in addition to shortage of cattle, cited infertile soils, and shortage of cash. Soil fertility and shortage of cattle also featured prominently in Zimuto SCDs.

The different types of constraint are discussed separately.

(i) Shortage of cattle

For non-adopters in Chivi, the most important causes for shortage of cattle were diseases, lack of cattle dipping, lack of money, drought and poor representation by AGRITEX. However, for the adopters, the most important causes were poor representation by councillors and Members of Parliament, shortage of cattle loans and also cash. In Zimuto, shortage of cattle was mentioned in the context of draught animal power. Draught animal power shortages were said to have a bearing on

activities such as tillage, weed control and manure use. Most villagers in Zimuto lost their beasts during the devastating 1991/92 drought. This has led to a decrease in crop production in the area. In addition, ownership of tractors by households in the area is non-existent and some households (especially the poor) have resorted to the use of hand hoe tilling (*kurima ne chibhakera*). Although farmers help each other in terms of draught power sharing, they usually conduct their operations late resulting in a decrease in crop production. In both Mahoto and Chikato villages, drought was cited as the major cause of shortage of cattle. However, the Mahoto villagers pointed to lack of grazing land and lack of breeding knowledge as contributory causes. Shortage of cattle was the major problem for Maraire village and the causes highlighted in order of importance were drought, diseases, poor pastures, and small grazing areas. For Maraire the major cause of poor pastures was overgrazing, while for Mahoto it was poor soils.

(ii) Infertile soils

The root causes of soil infertility in Chivi cited by the adopters were lack of knowledge, traditional practices and high birth rate/high population density. The most important cause of infertile soils was lack of knowledge, and the least, traditional practices and use of fertilisers. The non-adopters cited the problem of too old fields as just one of the other causes of shortage of cattle. According to the non-adopters, the most important cause of this problem was the small size of their fields that resulted in farmers planting crops year after year without leaving a fallow period, and the least important cause was lack of cattle manure.

In Zimuto, soil fertility emerged as the major problem faced in Mahoto and Chikato villages. Soils in Zimuto were said to be very old and, due to continuous cultivation, to have been depleted of the nutrients essential for plant growth. In addition, the farmers in the area use little or no fertiliser (with the majority not using any) hence compounding the problem of soil infertility. Use of cattle manure to improve soil fertility was minimal and was limited to those who were cattle owners. The causes of low soil fertility for Chikato were, in order of importance, shortage of manure, lack of fertilisers, over-cultivation, monoculture and soil erosion. The villagers in Chikato cited lack of cattle as the only cause of shortage of manure, while those in Mahoto cited, in addition to shortage of cattle, lack of money and poor pastures.

(iii) Shortage of cash

Adopters in Chivi cited poor representation by AGRITEX as the major cause of shortage of cash since, according to them, poor representation results in poor transport networks, unavailability of fertilisers, and lack of market for produce, all of which results in them failing to get money. The least important cause of shortage of cash was selfishness among farmers, which results in their not sharing information about production processes or lack of unity when selling produce. Lack of unity was said to be the main cause of stiff competition between sellers, which result in others reducing prices to the point where they make losses. For non-adopters, shortage of cash was pointed out as just one of the other factors leading to shortage of cattle, and its main causes were low selling prices, unemployment of children and poor crop yields.

(iv) Lack of knowledge on soil erosion prevention measures

Gullies are a common sight in Zimuto and some farmers said that they lacked knowledge of how to prevent soil erosion. However, in some areas, IUCN gave

villagers vetiver grass to prevent erosion and also reclaim areas affected by soil erosion.

(v) *Overgrazing*

Farmers said that there were no areas allocated for grazing purposes in some villages. Villagers were therefore letting their cattle graze on any area including land adjacent to streams. Overgrazing has also been one of the contributory factors to the problem of soil erosion.

(vi) *Weeds*

Participants said that the following weeds were the most problematic in Zimuto: “*pfende*” - *Cyperus esculentus*, “*Jekacheka*” – *Cyperus digitatus*, “*Chodhong*” – *Acanthospermum hispidum*, *Chinzungu* – *Richardia spp.*. In addition, due to the problem of a lack of implements such as cultivators and the non-use of herbicide technology, most farmers are left with no other option but use of hand hoes for weeding.

(vii) *Inputs*

Cost and availability of inputs such as seeds and fertilisers were also cited as major production constraints. The local shops in the area usually run out of these inputs which, when available, were said to be very costly. Some local stockists in the area packed fertilisers into smaller bags, like 5kg packs to cater for those who can only afford to purchase small amounts of fertilisers. However, these small packs were said to be very costly. Also, in some cases, seed varieties that farmers used to grow, like R215, had been phased off the market and hence the farmers said that it would be much better if they can get improved seed varieties which they can keep in their homes.

The sample survey confirmed the relative importance of poor soil fertility and lack of draught power as production constraints (Annex B, section 4.3 and Table 9). Among both adopters and non-adopters at the two study locations in Zimbabwe, infertile soils were identified as a constraint by between 43% and 53% of respondents. Others, though with greater variation between locations and between adopters and non-adopters, were lack of draught power (for non-adopters), shortage of labour (for adopters) and water logging.

4.2.2 Potential of technologies to overcome production constraints

The potential of the promoted technologies to meet the main production constraints was explored with farmers using Participatory Budgets (PBs) (Galpin, Dorward et al. 2000) and through direct questioning in the sample survey. Budgets were drawn up separately with adopters and non-adopters of the technologies. The two technologies for which a clear economic benefit was shown were improved OPVs of maize and improved compost manure in Zimbabwe: the PBs indicated a higher gross margin for adopters than for non-adopters. In the case of maize varieties, this was because the OPVs required less expenditure on external inputs. For soil nutrient management using improved manure, adopters reported higher yields than non-adopters in the same village (Annex B Appendix 3). In the Zimbabwe PBs, a high proportion of the total labour input goes on the collection, processing and application of manure and compost (Annex B section 3.1.5).

In Tanzania, the overall output reflected in the PBs is low, and where promoted technologies have been adopted, lower than anticipated by those promoting them

(Annex C section 4.6.6.1). Where inputs and produce are valued at local market rates, most PBs in Tanzania showed an overall negative return, suggesting that food production is valued more highly for family consumption than in the market and that family labour is not regarded as a cost. In sorghum and millet production, the PBs show bird scaring represents about 50% of the total labour input. The highest level of maize production per acre recorded in the Tanzania PBs came from a combination of new variety and the use of manure (in Ilula village), suggesting that new technologies may have more impact when used in combination than singly.

Survey data from Zimbabwe (Annex B section 4.5.3 and Table 17) show that the only promoted technology that a substantial number of farmers see as having the potential to address production constraints is the use of manure. Between 35% and 50% of adopters and non-adopters in the two locations felt that applying manure would counter their production problems. The only other solutions suggested by substantial numbers of farmers were pesticides (in Zimuto), mineral fertilizers and tractor hire. Very few farmers mentioned longer term soil and water management techniques as solutions.

In Tanzania, the most frequent reason given for adopting new varieties of cereals was their short maturity (Annex C section 5.1.2.3), which directly responds to perceptions of low and unreliable rainfall as a main production constraint. On the other hand, available SWM technology is not seen as an appropriate response to rainfall constraints, because farmers perceive that there is not enough rain to justify the required investment in water-retaining techniques. The potential of manure to address the decline in soil fertility is widely acknowledged: however most of the farmers who have livestock and own their farmland are already using it.

Overall, improved use of compost and manure is the main NRM technology that would meet a ready response in terms of addressing farmers' priority production constraints, but only for those farmers with easy access to manure. Improved varieties of staple crops, where these can be demonstrated to perform well in soils of low fertility (Zimbabwe) or low and unreliable rainfall (Tanzania), and with minimum purchased inputs, may also be taken up. However, when asked whether they intended to use technologies that they had heard about but not yet adopted, less than two per cent of Zimbabwe respondents replied positively for PGR (new varieties) compared with much higher levels for soil-water management and soil nutrient management (Annex B section 4.5.1 and Table 15).

4.3 Demand for new NRM technology

The sample survey was carried out to estimate the proportion of households in the population with characteristics matching those who have adopted recently promoted NRM technologies. Most of the single criteria do not, on their own, distinguish very effectively between adopters and non-adopters. For example, 32 per cent of the surveyed households in Ilula (Tanzania) grow modern varieties of maize (Annex C section 5.1.2.1) but only 20 per cent of these grow predominantly for the market. Market orientation is not therefore an accurate predictor of adoption, despite its identification by informants as a characteristic of adopters of new PGRs. It is the combination of characteristics suggested by informants in the qualitative study and represented, for example, in the adoption models from Tanzania (Figures 2, 3 and 4) which were thought more likely to provide an estimate of the potential size of market for NRM technologies. Table 4 shows the proportions of households in the survey

samples with characteristics associated, by informants in the qualitative study, with adoption of the various types of NRM technology. The proportions of those households who have not adopted the promoted technologies are shown in columns (2) and (3) and range from zero to 91 per cent.

Table 4 Adoption and non-adoption by households with characteristics of adopters

	Households with adopter characteristics (percent of survey sample) (1)	Proportion of those in column (1) who have:	
		adopted (2)	not adopted (3)
Tanzania			
PGR	5.8	100	0
SNM	12.5	68.8	21.9
SWM	19.8	52.9	9.8
Zimbabwe			
PGR	12.8	8.8	91.2
SNM	5.3	50.0	50.0
SWM	9.1	87.5	12.5

Source: sample survey data; characteristics are as shown in Tables 2 and 3 and summarised in the following note.

Note: Tanzania: PGR - household grows grain for sale and has improved storage facilities
 SNM - household owns land, has cattle and/or sheep, and 3 or more full time labour; 9.3% are "adopters"
 SWM - household farms heavy soil, and grows maize and/or groundnuts; 37.3 use tillage for SWM on some but not all of their land
 Zimbabwe: all technologies - head of household has more than four years formal education, is between 30 and 70 years old, is a risk taker and a full time farmer
 SNM - as above, plus household has two or more cattle
 SWM - as for all technologies, plus household has at least one plough

On the basis of these figures, the estimate of the numbers of households in semi-arid areas in the two countries who represent the potential market for further promotion of existing technologies was calculated as shown in Table 5. The potential market for new technologies which address similar production constraints is assumed to be the total number of households with these characteristics and is shown in the final column of Table 5.

However, inspection of the data indicates that the variability of characteristics of those who adopt technologies is not captured adequately by the outputs from the qualitative study. For example in Tanzania, 27 households (11 percent) are growing modern varieties of maize primarily for the market, while 83 (32 percent) are growing them mainly for home consumption. Of the former, 14 (52 percent) have improved storage, compared to 33 of the latter (40 percent). A total of 34 households are growing at least one grain crop for the market of which 15 have improved storage. This shows that farmers without improved storage have been able to adopt new

varieties; and that farmers whose grain production is mainly for home consumption are not deterred from using modern varieties. Similarly, of the 98 respondents who prefer to eat traditional varieties (78 percent of those who said they could taste the difference), 24 (24 percent) are from households which grow new varieties.

Table 5 Estimate of potential size of market for NRM technologies (thousands of households)

	Number of farming households in semi-arid areas (1)	Number with adopter characteristics who have not adopted (est.)* (2)	Number with adopter characteristics who have adopted (est.)* (3)	Size of potential market for new NRM technologies (4) = (2) + (3)
Tanzania	1,690			
PGR		0	98	98 (50 to 146)
SNM		46	165	211 (142 to 279)
SWM		33	301	334 (252 to 417)
Zimbabwe	1,470			
PGR		172	17	188 (129 to 247)
SNM		39	39	78 (38 to 117)
SWM		17	117	134 (83 to 185)

Source: column 1, population data estimated from data in (Morse 1996) and World Bank website (African Development Indicators 2002); household size from survey data

columns 2 and 3, proportions from Table 4 applied to data in column (1) at 5% confidence level; range of the estimate at 5% confidence level is shown in parentheses; column 3 figures for Tanzania include "adapters"

The robustness of the estimates was tested by subjecting the survey data to further analysis, using a wider set of data than the distinguishing characteristics which emerged from the qualitative study. The purpose of the analysis was to see if the likelihood of being an adopter of the promoted technologies could be predicted from household and farm characteristics. The Zimbabwe data were subjected to logistical regression. In the case of the Tanzania data, most of which were recorded at nominal or ordinal levels, discriminant analysis (SPSS version 9.0) was used.

4.3.1 Demand for improved farm technology in semi-arid Zimbabwe

Logistical regression was used to examine the possibility of predicting whether households will adopt a technique by reference to independent characteristics of the farm household. The dependent variable was taken as the household's classification as either an adopter or a non-adopter of particular techniques. Independent variables included education and information, resources or assets owned, attitude to risk,

demography, income, commitment to farming, and the area surveyed — Chivi or Zimuto. Table 6 summarises the variables that were considered.

Table 6 Variables entering the logistical regressions, Zimbabwe

Dependent	Independent
Adopters vs Non-adopters ADOPTION	Area (Dummy): Chivi versus Zimuto
Vetiver grass VETADOPT	Education & Information: Years schooling of households head HED SCHOL
Fanja Juu JUUADOPT	Number of people per household with agricultural training AGRITRAN
Improved compost manure ICMADOPT	Membership of any one of 7 groups
Mulching MULADOPT	Resources: Total land owned by household LAND No of oxen OXENTOT No of ploughs PLOUGHNO No of hand hoes HHOENO
Stone terraces STOADOPT	Attitude to risk: Amount that respondent is prepared to forego a sure \$20 to have a 50:50 chance of winning the amount MONEY
Tillage TILADOPT	Household demography: Age of household head HEDAGE Sex of household head HEDSEX Size of household HHOLDSIZE
OPVs IPOADOPT	Income: Crop income CROPIN Total income TOTALIN Off-farm income
	Commitment to farming: Residence of head HEDRESID Occupation of household head HEDCOCCUP

Table 7 presents the results of the regressions, showing the results obtained from the best fit estimates — as seen through -2 Log Likelihood and the ability to predict correctly the households adopting.

Table 7 Zimbabwe adoption models: parameter estimates

	If scale data, mean value (SD)	If categorical data, scale used	Adoption	Tillage**	Stone**	Fanjaju	Vetadot	ICM	Muladot	IOPAdopt**
Percentage of adopters predicted			78.9%	60.8%	48.6%	38.9%	25.3%	15.4%	7.7%	33.3% (Heard but not used)
Area		1=Chivi 2=Zimuto	0.41 (p = 0.13)	(1) 17.76 (p = 0.00)	-18.43 ND (p = 0.00)	-2.56 ND (p = 0.00)	-1.72 (p = 0.00)	(1) -1.59 ND (p = 0.01)	-18.63 ND (p = 0.00)	
Headsex		1=Male 2=Female					-1.31 (p = 0.06)			
Hedschol	6.3 years (3.4)		0.12 (p = 0.00)					-0.20 ND (p = 0.03)	-0.20** (p = 0.21)	-0.57 (p = 0.08)
Headocc		0 = no other occupation than farming 1 = other occupation						1.09 (p = 0.14)	(0) 1.81 ND** (p = 0.13)	
Trainexp		0 = none 1 = a family member trained	-0.60 (p = 0.04)	-18.27 (p=0.00)	1.44 ND** (p = 0.08)	-2.15 (p = 0.01)		1.20 ND (p = 0.04)		
Cropin	Z\$5.81k a yr (Z\$8.1k)		3.49 E-05 (p = 0.05)				5.17 E-05 (p = 0.16)			
Totalin	Z\$22.53k a yr (Z\$27.0k)			-0.00 (p = 0.07)		-3.91 E-05 (p = 0.11)				-5.26 E-05 (p = 0.15)
RiskM	Z\$1.06k (Z\$2.4k)								-1.87E-04 ND** (p = 0.36)	
Oxentot	2.3 (3.2)									0.68 (p = 0.19)
Ploughno	0.77 (0.57)									
Land	5.68 acres (6.23)			-0.06 (p=0.09)						-0.15 (p = 0.20)

** The model is incomplete due to data quasi-complete separation.

*** The model explains 0% of adopters since there are only two observations.

Only two of the models were able to predict correctly more than half of the households adopting, those being the models explaining households that had adopted at least one of the technologies considered since 1980, and households that had adopted tillage. For the other techniques, attempts to model adoption were bedevilled

by the low numbers of adopters — often 20 or fewer households out of a sample of 265.

The models estimated and reported in Table 7 show that in almost all cases the area dummy was significant. Presumably this reflects differences in physical characteristics between the two areas (Chivi and Zimuto), as well as perhaps capturing those socio-economic variations between households that correlated with zone. The dummy may also capture differential histories of the introduction of ideas, their extension and promotion. The sign on the dummy, however, suggests that while having at least one adoption is more likely in Chivi, for particular techniques, living in Zimuto makes adoption more likely.

After this variable, education and training factors were most commonly significant — but the signs on these parameter estimates were neither always consistent nor expected. In some cases it seems that less education or experience actually increases the chance of adoption.

Income variables were also significant in some cases. Having greater crop income tended to raise the chances of adoption, whereas having more total income tended to depress the chances of adoption. Presumably the negative impact of higher incomes reflected the importance of non-farm activity, making households less interested in improved farming techniques.

Beyond these variables, others were almost always conspicuously insignificant — including household demography, access to resources and attitudes to risk.

Turning to the individual models, what may we learn from the two models that were able to predict correctly the majority of adopters?

(i) Adoption overall

In explaining whether a household had adopted one or more of the technologies since 1980, *years spent in school by household head* was the most powerful explanatory variable. For every additional education year achieved by the household head, the chance of adoption rose by 12 percent. *Training experience* was the next most important factor, with lack of training experience reducing the chance of adoption by 60 percent. *Crop income* was related to adoption: every additional Z\$10k of crop income increased the chances of adoption by 3.5 percent. Even though total household income could have predicted the adoption, it contributed less to the percentage of correctly predicted adopters. Finally, *area* was also important: Chivi households were 41 percent more likely to have adopted one of the technologies than those from Zimuto.

(ii) Adoption of tillage technology since 1980

The most powerful explanatory variable for tillage adoption was Area. Chivi households were 17.7 times more likely to use tillage compared to those from Zimuto — hardly surprising since all tillage users came from Chivi. Total household income was significantly related to adoption of tillage, but surprisingly negatively so, albeit with a very slight elasticity indeed. Similarly land size was negatively related, but by a low elasticity. Training experience was also likely to reduce adoption, although the number of people trained in the household did correlate with adoption.

Attempts to run this model for just the Chivi households did not produce notably different results.

4.3.2 Demand for improved farm technology in semi-arid Tanzania

The variables tested for Tanzania appear in Table 8.

Table 8 Variables entering the discriminant analysis for Tanzania

Dependent variables	Independent variables
<ul style="list-style-type: none"> • Adoption of new seeds SEEDS • Soil & water management through tillage FTILLAGE • Fertiliser use FERTAPPL • Use of manure SNUTRIENT 	Dummy: Hombolo versus Ilula, VILL
	Household characteristics: <ul style="list-style-type: none"> • Age of head AGE • Gender of head GENDER • Size of household FMLYSIZE
	Resources: <ul style="list-style-type: none"> • Household labour FLABOR • Land, own-farm OPSIZE • Land, rented in RPSIZE • Cattle NCATTLE
	Education and information: <ul style="list-style-type: none"> • Education of head of household EDU
	Commitment to farming: <ul style="list-style-type: none"> • OFFFARM — “1” for households with non-farm income, “0” for those who only had farm incomes.
	Access: <ul style="list-style-type: none"> • Distance from home to main road DMROAD • Distance from own fields to home OPDIST • Distance from rented fields to home RPDIST

Since all the variables for the Tanzanian villages had been recorded as nominal or ordinal data, discriminant analysis (SPSS version 9.0) was employed to classify a set of factors which maximally discriminate among groups. That is, the analysis predicts whether the farmers are adopter, adapter or non-adopter from a set of predictors.

The results from the Tanzania survey reveal levels of adoption over five technologies applied as shown in Table 9. Of the 13 factors listed in Table 8, only eight were found to be potential predictors of adoption, as shown in Table 10.

Two of the models show significant results: diversification of PGRs (cereal varieties) and soil nutrient management through manuring. The other models, for tillage and for fertiliser application, do not significantly discriminate between adopters and non-adopters.

Table 9 Adoption levels for four technologies

Levels	Seeds	Ftillage	Fertapply	Snutrient
Adopter (All)	53 (20.6%)	134 (52.1%)		83 (32.3%)
Adapter (Some)	79 (30.7%)	85 (33.1%)		8 (3.1%)
Non-Adopter (None)	125 (48.6%)	38 (14.8%)		166 (64.6%)
Yes			131 (51.0%)	
No			126 (49.0%)	

Table 8 Predictors of technology adoption, Tanzania

Parameters (with absolute correlation)	Seeds		Snutrient		Ftillage**		Fertapply**
	F1	F2	F1	F2	F1	F2	F1
% Variance explained	93.1	6.9	91.8	8.2	88.6	11.4	100
Functions at group centroids							
Adopter	7.35	2.58	-0.89	1.98	1.11	-0.41	0.45
Non-adopter	-8.05	.87	-4.12	-2.18	-1.16	1.67	-3.56
Adapter	1.82	-1.21	18.43	-1.28	-9.85	-1.38	
Loadings (Structure matrix)							
Size of own-farm (acre)	0.139			0.345			0.260
Size of rented-farm (acre)		0.362					0.213
Distance to village main road			0.111			0.355	
Distance to rented-farm						-0.357	
Village		0.356		-0.405			
Number of family member						0.513	
Full time family labour						0.464	0.279
Number of cattle		-0.385		0.191	-0.401		0.168

Notes: **The functions are not significant: relationship between group and predictors not reliable.

(i) Diversification of plant genetic resources (cereals)

Most of the variation in adoption is explained by the first function (Figure 5). In this, size of own-farm land is the most important parameter that separates the 'Non-adopter' group from 'Adopter' and 'Adapter' groups. The larger the farm is, the better chance to use this technique. Function two has little explanatory power, but suggests that adopters are likely to have more rented land and less cattle, and to belong to Ilula village.

(ii) Soil nutrient management through FYM techniques

The key parameters correlate most strongly on function two where adopters are separated from non-adopters (Figure 6). The bigger size of own-farm land and the more cattle owned, the more chance to be an adopter. It also appears the Hombolo villagers tend to be adopters more than those from Ilula.

On function one, it seems that there is weak and negative correlation between the distance from homestead to the main road and adoption.

(iii) Soil and water management through tillage

Function one plays an important role in discriminating between adoption on all and on none of the household's fields or plots (Figure 7). It seems that the less cattle a farmer has, the better his or her chance to be an adopter of tillage, whereas the higher the education of the household head and the bigger the size of rented farm land, the better chance to adopt this technology.

Number of people in the family and amount of full time family labour are moderately correlated to function two. They are ambiguous parameters in predicting adoption since the higher the number of people, the greater the chance of partial adoption of tillage technology (i.e. 'some'). Furthermore, according to function two where the 'some' adopters are discriminated, the nearer the distance to rented-farm land, the higher chance of taking 'some' adoption whereas the longer the distance to village main road, the better chance to adopt at 'some' level.

(iv) Fertilizer application

Fertilizer application seems to depend on the number of full time family labour, size of own-farm land, size of rented-farm land, age of the head household ($r=.204$) and number of cattle. But the model is not significantly defined by the discriminant function.

To sum up the Tanzania results, it seems that:

- New seeds are likely to be taken up by those with larger farms, those with fewer cattle and those from Ilula.
- The use of farm-yard manure is more likely for larger farmers, those with more cattle and those from Hombolo.
- Tillage and soil-water management are associated with having fewer cattle and more educated heads of household, but the results are barely significant.

- The fertiliser function is also insignificant, but suggests more labour, larger area farmed and more cattle are associated with use of fertiliser.

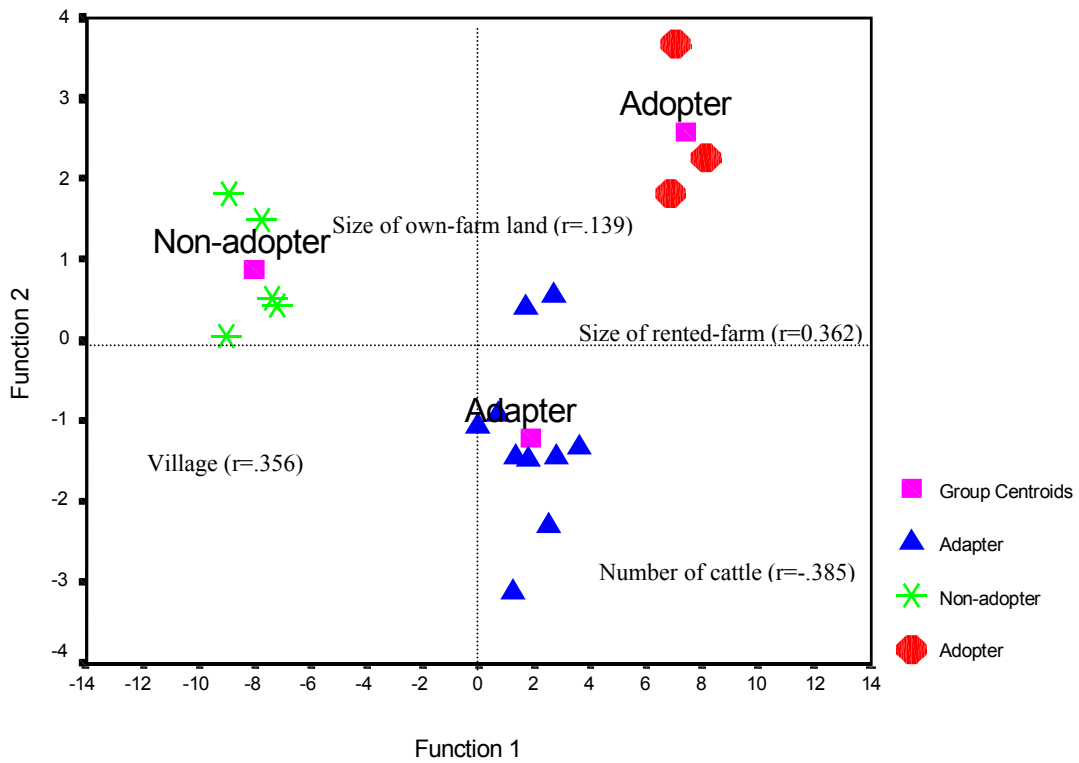


Figure 5 Canonical Discriminant Functions, PGR (Tanzania)

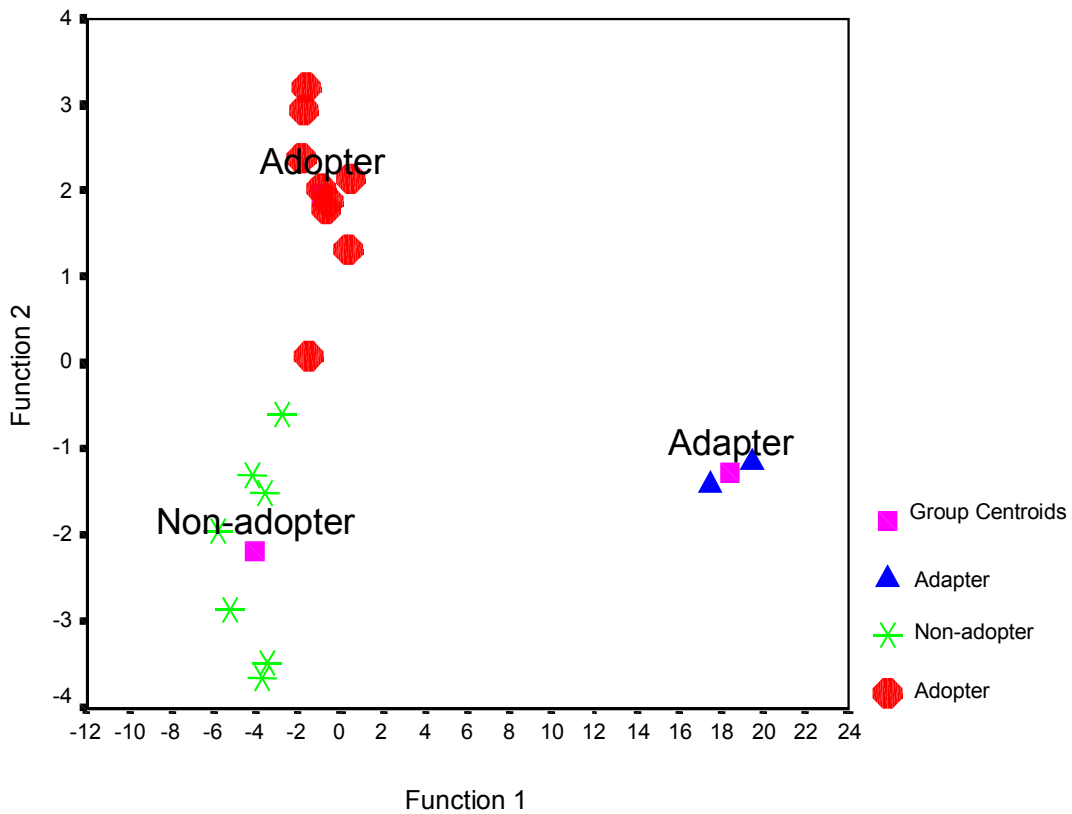


Figure 6 Canonical Discriminant Functions, SNM/manure (Tanzania)

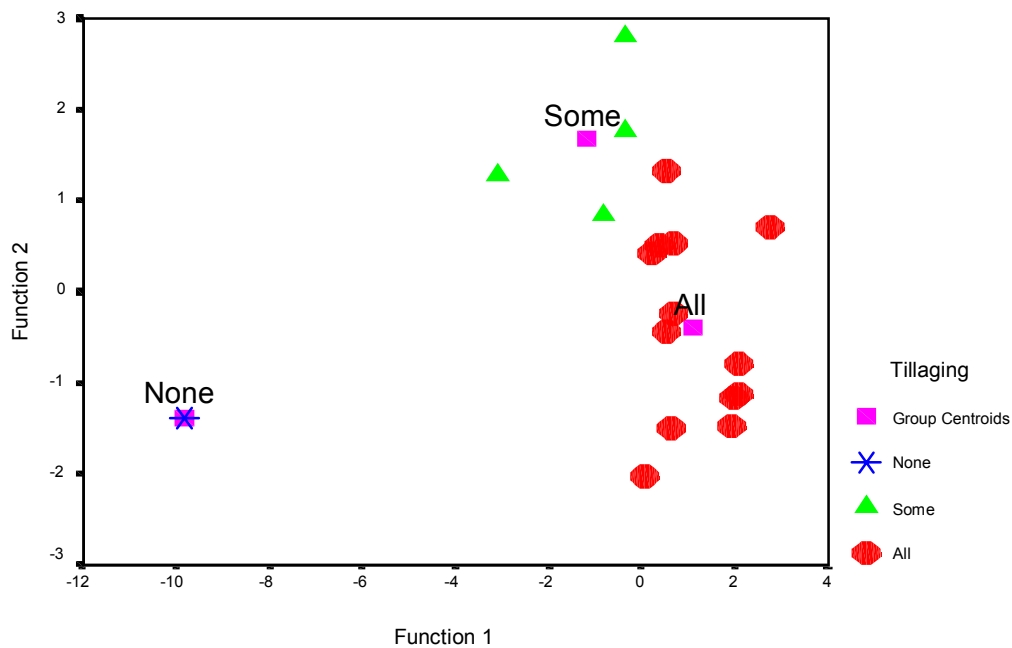


Figure 7 Canonical Discriminant Functions, tillage (Tanzania)

Even with these somewhat weak correlations, there must be questions about what the associations mean. For example, does having fewer cattle actually drive farmers to try some techniques, or does lack of cattle correspond with an unobserved variable that does have plausible explanatory power? Even the land variables may be proxies for wealth, access to working capital or ability to take risks.

Overall, therefore, the data simply do not reveal strong correlations between adoption and any of the household characteristics tested. While some factors may favour adoption, much of what makes people adopt techniques depends on other variables. Making predictions of the demand for technology, then, on the basis of who is using currently available new technologies at present does not seem possible.

5 Discussion

The levels of adoption by households of NRM technologies that have been developed and promoted in the study areas vary a great deal. Technologies within a particular category have also fared differently in the two countries, with new PGRS adopted by a large proportion of households in Tanzania but very few in Zimbabwe and SWM technologies more widely adopted in Zimbabwe than in Tanzania. This latter finding reflects the high number of separate SWM technologies promoted in Zimbabwe: most of these have been promoted only locally, in the context of small-scale development or participatory research projects. Several are not widely known beyond the villages where the project has been conducted. This suggests that there are potential returns to more widespread promotion and dissemination of technologies that have been taken up by farmers locally, and that farmers are more likely to benefit from a basket of options than from a single technology promoted by a development agency.

For some technologies, more households have adapted than have adopted them exactly as promoted, suggesting that technologies which are more readily adapted to local and individual circumstances are more likely to have widespread uptake and impact. This further suggests that the promotion of processes of adaptation, through farmer experimentation, as well as of technologies *per se* will be helpful. There are also variations in the proportions of households who have stopped using particular technologies after initially deciding to use them. Over a quarter of households using vetiver grass in the Zimbabwe survey sample subsequently stopped using it, compared with one in eight of the households who adopted improved compost manure.

Changes in the vulnerability context of small scale farmers in semi-arid zones of Tanzania and Zimbabwe since the late 1970s have affected the uptake of new PGRs. These include (Cromwell 2001) less reliable rainfall, declining soil nutrient status, closing of rural produce marketing infrastructure, deteriorating real prices for farm produce and less easy access to technical information on varieties. At the same time, the findings of several studies combine to suggest that farmers with larger cultivated areas, better quality land and more extension contact are more likely to be positive towards the enhancement of PGRs ((Friis-Hansen 1999; Cromwell and van Oosterhout 2000; ITDG 2001).

Some modern varieties, such as short season drought-tolerant varieties of sorghum and millet, have undoubtedly improved the livelihoods of some farmers. But many modern varieties released by the formal sector have characteristics which mean they cannot fulfill all the functions required of PGRs in the livelihood context of the majority of small farmers in semi-arid zones. Many modern varieties are yield maximisers rather than stabilizers; many require expensive external inputs to achieve full yield potential; many are labour intensive, less storable or lack preferred taste, processing or cooking qualities.

There is no doubt that SWM and SNM technologies are addressing production constraints which have a high priority for farmers. As one would expect, farmers are aware of long term changes in the natural resource base. They are also able to articulate reasoned explanations for them and to evaluate why available technologies do or do not enable them to overcome production constraints. Technologies which may seem self-evidently beneficial to those outside the farming and livelihood system may simply not be appropriate for large numbers of farming households, for a whole set of reasons:

- institutions which do not give incentives, or which create uncertainty or impose high transaction costs
- lack of access to a critical input (especially manure and livestock)
- lack of critical assets, including human and well as physical, financial or natural capital
- net benefits from a technology may be less than those expected by those promoting it.

The influence of policies and institutions was also highlighted among the reasons given for low uptake of PGRs in Zimbabwe in a 1996 ICRISAT survey (Rohrbach, Mutiro et al. 1997) - unfamiliarity with the varieties and lack of access to seed. This has implications for both promotion and seed supply.

The analysis does not allow an estimate of future demand for NRM technologies - in the sense of the size of the potential market - to be made with any confidence, even where the R&D process is careful to identify and then focus on production constraints articulated by farming households. Much depends on how the technology that emerges from an R&D process performs on farmers' fields, in terms of yield, risk and resource demands.

The design underlying the study was based on integrating data collected through qualitative and quantitative methods. The characteristics of households which have taken up NRM technologies were identified through participatory qualitative study; a sample survey was then used to estimate the proportion of households with these combinations of characteristics in the population as a whole. However, the survey data showed that the suggested characteristics do not distinguish between adopters and non-adopters with a sufficient degree of accuracy, either individually or in combination. Explanatory variables which show modest statistical significance in identifying adopters are those related to location, education and agricultural training, and resource ownership or access. This highlights the challenge of developing NRM technologies which resource poor households will feel able to take up. Variables relating primarily to livelihood strategy (such as agriculture as a full time occupation) show little association with adoption, despite their being identified by informants in the qualitative phase of the study.

6 Conclusions

The discussion above suggests the following conclusions.

- (a) The size of the market for new PGR, SNM and SWM technologies cannot be accurately estimated from the uptake history of previous technologies. There are sound reasons why some NRM technologies have triggered a wider uptake than others: these are not only related to the characteristics and performance of the technology itself but also to the institutional context in which it is promoted.
- (b) The study provides no conclusive evidence that livelihood strategies significantly affect household investment in NRM technologies. On the one hand, informants indicated that full time farmers were more likely to be adopters of NRM technologies. On the other hand, analysis of the survey data showed that while total household income was associated with adoption of several of the promoted technologies, having more than one occupation or source of income was not.
- (c) The process of R&D should continue to focus on production constraints identified by farmers. PFM methods can help to articulate those constraints and assess the potential impact on farming systems and livelihoods of emerging technologies. However, constraints are complex and interact: the actual performance in the field of new technologies in the face of this complexity will determine their potential for widespread uptake.
- (d) Adding to the "basket of options" available to farmers is more helpful than investing in the development of a "one size for all" technology.
- (e) Developing technologies to meet the needs and circumstances of poorer households remains a challenge. This is particularly the case for SNM and SWM which tend to require large amounts of labour and/or access to key natural resources whose short supply is part of the problem which NRM technologies

seek to address. It is also apparent for modern PGRs which require external inputs or fail to meet selection criteria which are important for resource poor households.

- (f) Investing in widespread promotion of technologies which have been successfully taken up by farmers locally, including practical demonstration and training for farmers, is likely to bring positive returns.
- (g) Further research on integrating the findings from qualitative and quantitative methods will inform future studies of uptake of technologies.

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