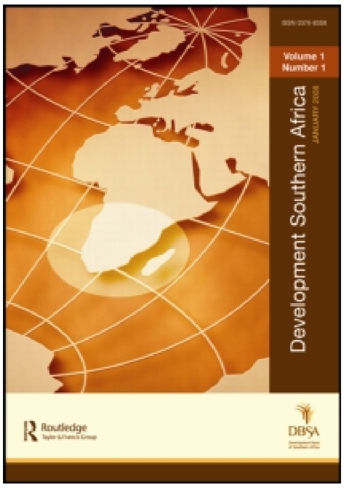

Development Southern Africa
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713413745

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To cite this Article Perret, Sylvain R. andStevens, Joe B.(2006) 'Socio-economic reasons for the low adoption of water conservation technologies by smallholder farmers in southern Africa: a review of the literature', Development Southern Africa, 23: 4, 461 — 476

To link to this Article: DOI: 10.1080/03768350600927193

URL: http://dx.doi.org/10.1080/03768350600927193

Development Southern Africa Vol. 23, No. 4, October 2006

Routledge
Taylor & Francis Group

Socio-economic reasons for the low adoption of water conservation technologies by smallholder farmers in southern Africa: a review of the literature

Sylvain R Perret & Joe B Stevens[1]

Natural resource degradation and water scarcity, which threaten the sustainability of smallholder farmers' livelihoods in semi-arid developing areas, are a global concern. Although researchers have developed water-conservation technologies (WCTs), adoption rates by smallholder farmers have been low. This article compares the perspectives of researchers and smallholder farmers, highlights the discrepancies which explain the farmers' low uptake of technologies and addresses the socio-economic factors affecting adoption. It argues that WCTs are diverse and applicable to different time and spatial scales and hence dependent upon context. These traits influence the dissemination and adoption of WCTs, and should not be ignored, from the early stage of technology development. It explains that adoption depends not only on individual farmers' willingness but also on property rights to resources and collective community action. The article discusses the demand for WCTs, the role of the public sector and research and related biases, and makes recommendations for achieving more sustainable rural livelihoods. Recent experiences in South Africa show that encouraging farmers to participate in technology development, taking account of local indigenous knowledge and making sound institutional arrangements are some ways to foster better integration of technology and innovation.

1. INTRODUCTION

The degradation of natural resources has become a global problem that threatens the livelihoods of millions of poor people. Sustainable and renewed resource management practices need to address widespread land degradation, declining soil fertility, unreliable rainfall and even desertification in a context of global climate change (FAO & World Bank, 2001). Gillet et al. (2003) list and discuss the major causes of such degradation in Africa, namely: demographic pressure, large-scale population moves owing to conflicts, deterioration of the general economic environment, globalisation and liberalisation, climatic disturbances and traditional practices that are no longer adapted to a rapidly changing socio-economic environment. Besides these problems, the majority of resource-poor smallholder farmers in South Africa are typically endowed with less favourable agro-ecological conditions – poor soils, and low and erratic rainfall (Kundhlande et al., 2004).

At local level, the smallholder farmers' livelihoods are at stake and they are in dire need of sustainability, especially in sub-Saharan Africa (DFID, 1999), and in South Africa

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ISSN 0376-835X print/ISSN 1470-3637 online/06/040461-16
DOI: 10.1080/03768350600927193

(Kundhlande et al., 2004). In semi-arid areas, the challenge is to develop water conservation technologies (WCTs), adapt management methods and promote innovation by smallholder farmers (Botha et al., 2003). Although many promising technologies have been developed and made available, the field application of these is still limited in developing environments (Knox & Meinzen-Dick, 1999), and especially in southern Africa (Whiteside, 1998; Twomlow & O'Neill, 2003; Stevens et al., 2005). Kundhlande et al. (2004) state that many water conservation projects have failed in South Africa, 'despite good techniques and design'.

This article does not dwell on the biophysical or technical merits of any WCT per se, (although those merits indeed influence the adoption process), but rather tries to contextualise these technologies within the socio-economic, decisional and policy framework of smallholder farming in developing areas, especially drawing examples and conclusions from South African experiences whenever possible.

2. THE ODDS AGAINST WCT ADOPTION

In order to understand the adoption of WCTs it is necessary to clearly define some specific WCT traits, and to identify some possible discrepancies between researchers' and farmers' perspectives on innovation.

Resource-conserving technologies are defined as technologies that enable a farmer to produce his or her desired output, while using the available resources – land, water, labour, energy, inputs, etc. – more efficiently and maintaining the productive capacity for the future (Whiteside, 1998). Therefore, sustainability is defined and used in this discussion as a property of the ecosystem as well as in terms of human activities and agreements (Pretty, 1994).

2.1 A critique of the linear, positivist paradigm

WCTs are essentially based on the following principles. For dryland crop production in semi-arid environments, it is critical to harvest, conserve, concentrate and store the scarce rainfall and the erratic runoff, and to limit direct evaporation from the soil. The plants benefit from such 'additional' water made available within the rooting zone: they evapotranspire more (and hence simultaneously increase their demand for nutrients) thus, ultimately, production increases. Soil and crop scientists develop and test technologies in line with these ideas. It is still commonly believed that such a rationale, along with proven, clear and well-publicised results, is sufficient to persuade smallholder farmers to adopt the technologies. The message usually consists of promising increased yields per unit of land used (hectares), but hardly provides any insight into the nature of the technology (e.g. is it labour-intensive? capital-intensive? what kind of farm organisation and management changes does it presuppose? does it require more inputs? can it be fragmented, implemented in modules? or is it a whole package? and so on – all questions that are critical from a farmer's point of view). The development agents (extension officers) are traditionally granted the role of translating and transmitting the message to farmers.

Such disconnection between the providers of a technology (researchers) and its potential users (farmers) probably originates from implicitly diverging interests and agendas, and time and scale perspectives (Bosc & Jamin, 1995). For example, in line with prevailing policy frameworks or mottos (such as 'sustainability' and 'more crop per drop'), researchers may be prone to develop resource-conserving technologies for the sake of conservation, whereas the farmers' immediate agenda is short-term production for survival. Disconnection also originates from long-embedded perceptions that researchers and research organisations have of research professionalism and the contribution of research to human societies (Pretty & Chambers, 1993). These perceptions do not accommodate exchanges, dialogue and negotiation between stakeholders, co-construction of common research objectives and objects or multidisciplinary approaches.

Disappointing figures for the adoption of WCTs (Whiteside, 1998; Knox & Meinzen-Dick, 1999; Kundhlande et al., 2004) demonstrate that following a linear transfer of technology (TOT) approach is a reductionist and positivist approach to research, with little or no feedback opportunities (Röling, 1994; Chamala, 1999). It hardly works in smallholder farming environments, with their unique requirements. Yet, amazingly, it is still commonly applied (see Beukes et al., 2003), and in spite of about 20 years of active promotion of farming systems approaches and farmer-centred research methodologies, actual implementation of these is limited in southern Africa (Whiteside, 1998).

There seems to be a need to identify some critical factors that play a role in farmers' decision making, to ensure farmers' uptake of WCTs.

2.2 Innovation from a farmer's perspective

Innovation is a key component of economic evolution, and therefore of development (Nelson & Winter, 1982; Treillon, 1992). For millennia, farmers have domesticated and cultivated new crops, invented new implements and changed their ways of producing crops, recombining the production factors (labour, assets, capital and cash, land) in order to improve production, food security and income. This process has long been mainly endogenous, or dependent on limited exchanges between close community members (consider the example in Venda, South Africa, documented by Simalenga & Mantsha, 2003). This kind of innovation is slow and hardly matches the current requirements of a rapidly changing socio-economic environment. It is only relatively recently that agricultural research has provided exogenous solutions (in the form of technologies) to farmers. Innovation can then take place much faster, ever enhanced by improved access to information and communication technologies.

The basic problems facing farmers when it comes to innovation are choices and trade-offs, since farmers are the ultimate decision-makers in a context of scarce resources and production factors, thus of limited options. From a farmer's perspective, innovation in the form of resource-conserving technologies may involve (1) some form of immediate investment with only long-term expected returns, (2) trade-offs between current yield and future yields, (3) trade-offs between a yield and its production costs and (4) trade-offs between a yield and its related risk (Knox & Meinzen-Dick, 1999). The farmers are the ones who have to face the uncertainties and take the risks, which are the result of lack of information about the long-term benefits, impacts and returns to be derived from a technology once it faces real-world climatic and economic variations.

For the farmer, the innovation process does not only involve accepting a technology; it involves turning it into a practice (see Box 1), which most of the time supposes adaptation rather than mere adoption. It involves accepting the institutional, managerial and social changes that are required to make the technology slot into the farming system and become a practice (Milleville, 1991; Bosc & Jamin, 1995). Such a process may even involve stakeholders beyond the farm boundaries if some form of collective action is required to implement the technology (e.g. mechanisation, nurseries, watershed management) (Rasmussen & Meinzen-Dick, 1995; Kundhlande et al., 2004). This emphasises the complexity of farmers' decision making with regard to innovation in resource conservation.

Such complexity may even increase when one considers certain specific traits of southern African smallholder farmers (Ellis, 1993; Low, 1986; Minkley, 2003), especially in the context of market failures:

- They are partly connected to product markets that are imperfect anyway, and credit markets, information markets, land markets and labour markets are weak or even non-existent.
- They are risk-averse when exposed to a harsh and uncertain environment, so subsistence remains the dominant farming strategy.
- Their farming systems are usually not capital- or technology-intensive, and they are not even particularly labour-intensive, owing to the scarcity of male adult labour.
- Increasingly, they are not just farmers but part-time farmers, who diversify their livelihoods into a variety of off-farm, non-farm, and non-monetarised activities.

To be accepted, the technology must not only fit into the existing farming system; it must also fit into the whole livelihood system, which includes the social, economic and institutional context of the household, the strategy developed by the family, and the constraints it faces (Kundhlande et al., 2004). The failures and successes of the so-called Green Revolution offer vivid examples of that reality, as has been acknowledged by a large number of authors globally (e.g. Mettrick, 1993; Mazoyer & Roudart, 2002; Dorward et al., 2003).

3. VARIETY, SCALE AND TIME FRAME IN WCT INNOVATION

3.1 Diversity and the spatial scales of WCTs

The first key trait of WCTs is their variety, although they share many common goals. The diversity of available technologies is most striking in the literature (Botha et al., 2003; Simalenga & Mantsha, 2003; Stevens et al., 2005). Furthermore, resource-conserving technologies are applied at different spatial scales. Some technologies are applied at

Box 1. A point of clarification: technologies are not yet practices

A technique or a technology is a way to produce or organise, out of any context (invention), whereas a practice is a technique, 'borrowed' by a social and economic context (innovation) (Ellis, 1993).

Techniques can be theories formulated independently of farmers. Practices, on the other hand, are the ways in which farmers work and are heavily influenced by the actual conditions in which technical operations are carried out (Milleville, 1987). They are assumed to be the result of a direct intention, which in turn depends on objectives set by the farmer in a context of constraints and effectiveness. Farming practices underlie the concepts of cropping systems and livestock systems.

Researchers and extension officers must acknowledge that adoption implies adaptation. Technologies are seldom adopted and implemented as such. Farmers tend to adapt them to their needs and to the constraints and limitations they face. Through such adaptation an invention (the technology) becomes an innovation (a practice).

plot level and only necessitate decision and involvement at the farm-level by an individual farmer. This will include the adoption of improved varieties of drought-resistant crops, water harvesting and storage at household level, mixed cropping and increased planting density. Others, although applied within a specific crop management system by an individual farmer, at plot level, may involve coordination or collective action beyond the farm boundaries. These technologies include for instance reduced tillage, which may require collectively organised mechanisation. Above-farm level technologies will only make sense if implemented on larger scales, for instance at mini-watershed or community level. A necessary condition for applying WCTs at the above-farm level is that a platform for collective decision-making must be established so that groups of farmers can cooperate in managing resources (e.g. setting up nurseries for agroforestry, or contour planting, or arranging access to mechanisation). The problem, however, is that in most places platforms for collective decision-making do not exist, and success is seldom achieved in isolation (Röling, 1994; Rasmussen & Meinzen-Dick, 1995; Knox & Meinzen-Dick, 1999).

The main consequence of such variety is that certain technologies require some form of coordination between farmers, which in turn requires a high degree of social capital among community members. Kundhlande et al. (2004) refer to this as the ‘organizational capacity of communities’, and as a key prerequisite to technology adoption and implementation. This is also referred to as ‘collective action’ (Knox & Meinzen-Dick, 1999). From empirical and theoretical literature, Rasmussen and Meinzen-Dick (1995) highlight that the characteristics of the group of users and the attributes of institutional arrangements are the key factors affecting the management capacity of local organisations.

3.2 Technologies with different time frames

Some technologies, such as irrigation or the choice of a drought-resistant crop variety, provide short-term returns on investment (the crop cycle being the time frame). However, many natural resource management technologies take years to provide a full and stable return. In an Ethiopian case study, Adnew (2000) estimates that it takes two to six years for farmers to fully benefit from soil and water conservation technologies. In South Africa, Kundhlande et al. (2004) observe that communities do not always immediately adjust to a technology and accept it; they can actually take decades to do this, and sometimes they never will.

If farmers do not have secure rights to natural resources, they generally lack the necessary incentives to adopt these conservation technologies, since they are not assured of receiving the benefits (Knox & Meinzen-Dick, 1999). In India, Pender and Kerr (1996) demonstrated that farmers were prepared to make a larger investment in soil and water conservation technologies on owner-operated plots. Furthermore, when smallholder farmers struggle for a daily meal and income derived from natural resource-based activities, their time frame for making decisions is limited, as is their capacity to plan in the long term. Increasing poverty, declining sustainability and degrading resources then drag them into a downward spiral. Owing to past dispensations and colonial history, southern Africa’s tenure system is skewed against black smallholder farmers (Lyne & Darroch, 2003). Furthermore, tenure arrangements in communal land are often gender-biased (Lahiff, 1999), although women are the main fieldworkers, the household’s decision-makers and the poorest members of rural communities (Perret et al., 2005). The absence of clear rights over land means less uptake of conservation technologies.

Figure 1 is an attempt to capture these time and space dimensions conceptually. Several technologies are located as examples in Figure 1. For a given technology, the larger the spatial scale of application, the higher the degree of collective action that is required. The longer the temporal scale, the higher the degree of tenure security that is required. Several technologies could be broken down into subgroups to more accurately reflect their spatial and temporal characteristics. Alternative cropping systems or technology may be implemented at plot level, but they often require some coordination as far as input supply, mechanisation and resource management are concerned (e.g. seedlings for agroforestry, specific equipment for reduced tillage).

The framework shown in Figure 1 highlights the fact that certain technologies will be more efficiently applied with collective adoption, whereas others will be more amenable to individual adoption. Some technologies require long-term and secured tenure of natural resources (the so-called property rights), while others can accommodate short-term cycles and uncertainty. Such diversity is indeed a very important factor affecting adoption and applicability of a given technology. Besides, what is highlighted here is that the success of conservation technology depends not only on the appropriate technology and prices (Rasmussen & Meinzen-Dick, 1995) or the motivation, skills and knowledge of an individual farmer, but also needs to be combined with supporting local institutions (e.g. strong social bonds, clear tenure rights – Jagger & Pender, 2003). This also challenges extension to demonstrate the relative benefits of practising WCT for the society as a whole (Stevens & Botha, 2001).

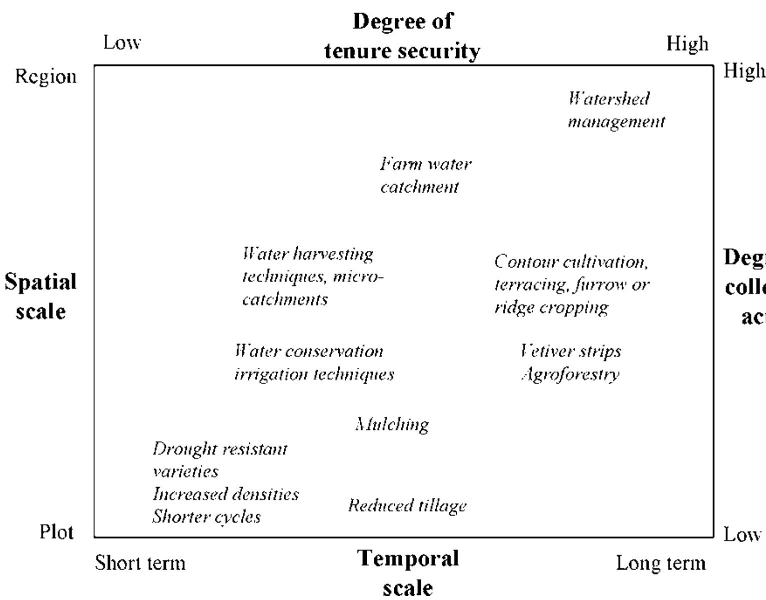

Figure 1: A conceptual framework for analysing the temporal and spatial scales of Water Conservation Technologies (adapted from Knox & Meinzen-Dick, 1999). *Note*: The technologies are just examples. Their location is approximate, for illustrative purposes

4. ADOPTION OF WCTS IS CONTEXT-DEPENDENT

There are a number of key factors that affect adoption of conservation technologies. Researchers and development operators often fail to perceive the whole picture, and tend to overlook the inner household context and/or external environmental factors that influence the adoption of innovations.

4.1 Taking account of the household context

4.1.1 Wealth

Wealth is intricately linked to power and property rights over natural resources, affecting people's options for adopting technology (Knox & Meinzen-Dick, 1999). The bundle of one's property rights and the security of those rights combined with one's level of assets, income and food security affect the degree to which one discounts possible future gains. Those who possess a higher quantity and quality of endowments will place a higher future value on medium- and long-term benefits produced by investment in conservation technologies. They are less constrained by food insecurity and risks than low-wealth farmers (see also Box 2).

4.1.2 Labour

Labour bottlenecks resulting from relatively high labour requirements are often cited as a possible constraint on the adoption of conservation technology, especially if new technologies create seasonal peaks that overlap with other agricultural activities (Knox & Meinzen-Dick, 1999; Kundhlande et al., 2004). Collective action and reciprocal arrangements may be employed as a means to overcome household labour shortages, particularly in cash-scarce economies, or in communities characterised by high levels of adult migration. Kundhlande et al. (2004) identify the labour requirements of certain tested technologies as key criteria for development and adoption.

4.1.3 Diversity of farmers' strategies

The two previous points have highlighted the diversity that may exist at community level among households. Farmers will adopt different approaches and practices to achieve their goals and objectives and these will be reflected in the specific strategy that is followed on the farm. A strategy may be defined as the combination of processes (plans, decisions and acts) that an individual or a group of individuals (a firm, a family, etc.) develops purposively, aimed at changing or transforming their social, economic and/or physical environment. Such processes usually combine various resources and/or techniques, knowledge and know-how (Olivier de Sardan, 1995).

Farmers develop strategies as a response to a changing and uncertain environment, so as to adopt a lifestyle that corresponds to the specific goals and objectives set by a group and/or individual. The specific strategy adopted by a farmer will be reflected in the selection of specific production and management systems as well as off-farm activities (Yung & Zaslavsky, 1992). For example, the common association of livestock-keeping with crop farming in semi-arid southern Africa is often merely overlooked by researchers promoting mulching or mixed cropping. Allowing community livestock to graze on crop residues is a common practice among smallholder farmers, embedded within livelihood strategies at individual as well as collective levels. Such a practice can hardly

Box 2. The problem of the long-term relative advantages in WCT adoption (adapted from Whiteside, 1998)

Sustainable techniques, such as WCTs, by definition imply that they work over the long term (Botha et al., 2003; Kundhlande et al., 2004), meaning that about five years or more are needed if full benefits and returns are to be reaped. For instance, mulching or a reduced tillage practice for water conservation must be better than the existing practice when used over a long period. These techniques may, however, have additional cost implications in terms of increased labour or reduced yields, which are experienced during the early years. Therefore, WCT experiments or demonstrations conducted over one to three years are often irrelevant. Much longer periods of experimentation are needed (Botha et al., 2003).

Not many research institutions, extension services or projects have this type of time perspective. Furthermore, long-term on-farm experiments with WCTs are not easy to undertake. The research station remains the most secure place, yet with numerous typical biases (see Box 3).

In some instances, indigenous technologies and farmers' local practices that have long proved successful might fill the gap (Gandonou & Oostendorp, 2001). The importance of harnessing local indigenous knowledge and social learning cannot be overemphasised.

Farmers also need to be helped to perceive the long-term implications of practising such conservation technologies. The necessary incentives to adopt WCTs are often not clear to farmers until environmental damage or serious yield problems have occurred, and by then it may be too late. Prevention is often cheaper and easier than cure. Key factors that farmers take into consideration when making decisions are the following: are the returns in the long term adequate to compensate for the short-term costs incurred by adoption? Will those investing reap the expected benefits (the issue of tenure security)? How can farmers finance the investment (the importance of wealth and credit)?

accommodate mulching or any changes in the crop management time frame without major alterations in other practices at farm and community levels.

Within a specific community diverse strategies can develop, depending on each household's specific history, composition and objectives. Although it is impossible to take the characteristics of every household into account when developing WCTs, it will also be a mistake to consider the community as being homogeneous; hence the introduction of typological approaches that group households with similar strategies and characteristics with regard to a specific objective. Such an objective may be the identification of the needs for WCTs and the current water-conserving practices as applied by farmers (Perret, 1999).

4.1.4 Social and cultural factors

Despite the dominance of family farms in the adoption literature, the family is rarely observed as an important factor that may play a role in the adoption process (Salamon et al., 1997). Salamon et al. emphasise that policies, if not research itself, persist in focusing on a single male farmer as the actor responsible for making adoption decisions. Such an approach is doomed with regard to the farming and decision-making profile of a majority of southern African households, where women are instrumental in decision-making (Low, 1986). Furthermore, the transition from conventional to alternative farming systems often ignores important social barriers to adoption other than profitability. Lasbennes (1999) identifies specific local norms and practices that are attached to natural resource management in the former Ciskei, for example likening mixed cropping or mulching to ill-weeding, or limiting the farming practices of pregnant women. These norms and practices will differ for the different socio-cultural settings. Indigenous knowledge and local traditional practices may be considered part of the social and cultural framework. They are often strong and inescapable, and can influence the adoption of any technology. This militates in favour of locally centred technology development. Researchers and extension services need to acquaint themselves with the farmers' cultural norms and practices, take them into consideration and avoid any hasty judgement in their development planning (Kirsten et al., 2002).

In South Africa, Kundhlande et al. (2004) emphasise that new technologies, as tangible creations, should not only improve financial wellbeing but also fit into the culture, which include intangible elements such as beliefs, norms and values.

4.1.5 The need for WCTs and the appropriateness of research

As already indicated, it is important to recognise that farmers' need assessment does not necessarily prioritise long-term solutions. Smallholders are often forced by external circumstances to prioritise short-term constraints (Stevens et al., 2005). The adoption of conservation practices may not be perceived as a priority for farmers until they see deterioration of the environment or alarmingly declining yields (Gillet et al., 2003).

To facilitate technology adoption it is important to ensure that research priorities are in line with farmers' needs and expectations. Although many resource-conserving technologies and practices have been widely proven on research stations to be productive and sustainable, the total number of farmers using them is still small (Stevens & Botha, 2001). If a bottom-up paradigm is favoured, this presupposes that farmers will be strongly encouraged to participate in identifying needs (Whiteside, 1998; Kirsten et al., 2002). However, an effective and coordinated request for appropriate research (thus adapted technologies) does not often come from the poor and smallholder farmers. Their needs are often heterogeneous and cannot be defined in generic terms but should rather be location or situation specific.

This constitutes a radical reversal of the normal modes of research and technology generation, because it requires participation and effective dialogue between professionals and farmers. However, with regard to smallholders' needs and characteristics, more detailed research seems to be needed on the adoption (or lack of adoption) of potentially beneficial conservation technologies, on existing beneficial and innovative local practices, on low-input technologies and on technologies that strengthen sustainability and can weather severe setbacks (Whiteside, 1998). Recent action-research experiments carried out in central South Africa (Botha et al., 2003; Kundhlande et al., 2004) show that such a renewed, participatory, demand-driven approach is possible and can bear fruit.

Since indigenous water conservation practices and skills do exist (Pretty, 1994; Pender & Kerr, 1996; Gandonou & Oostendorp, 2001), research operators must take these practices into account, as they are the essential platform for further innovation. For example, Simalenga and Mantsha (2003) report on the indigenous soil and water conservation practices of smallholder farmers in Venda, South Africa (i.e. stone lines, terracing, ridging and intercropping).

4.2 The need for an enabling external environment

4.2.1 Information

Farmers cannot adopt technologies if they do not have access to all the relevant information, but the information they are given is often incomplete, focusing only on the technical aspects and overlooking some key criteria from a farmer's point of view (e.g. labour requirements). Nor can they adopt technologies if they do not clearly perceive what scope of returns could be expected after adoption, but this is often overlooked by extension officers.

Various extension approaches aimed at the adoption of technologies have been implemented in order to inform and train farmers, such as the TOT approach (inherited from the Green Revolution principles), the Farming Systems Research and Extension approach, the Training and Visit approach, the Farmer-First approach, and alternative participatory approaches (Kirsten et al., 2002). Most research and extension organisations in southern Africa still apply TOT principles, although with some inclusion of certain components of the farming systems approach and limited participation by farmers (see Box 3). Wider participation by all relevant stakeholders is still seldom used (Whiteside, 1998). Participation, if it is incorporated into the extension and research approaches being used, must be clearly interactive and empowering. Any pretence at encouraging participation will result in little change.

Identifying and including indigenous or local knowledge and practices to develop and train smallholder farmers is much talked about, yet with limited actual implementation. Simalenga and Mantsha (2003) have, however, indicated an improvement in participation by farmers and an increase in researchers' awareness and deliberation on traditional practices where local knowledge was used in training programmes on WCTs.

4.2.2 Risks

Smallholder farmers are faced with a variety of risks and uncertainty that include: weather patterns, pests and diseases, robbery and vandalism, illness and death, and price fluctuation. Therefore, risk-averse and low-wealth farmers are often reluctant to adopt conservation technologies because they need a stable income and consumption streams, especially where the returns on adoption of WCTs are not clear or uncertain. Besides the clear need for local typologies of farmers, it is also necessary to include an analysis of possible environmental and economic risks in technology development.

4.2.3 Collective action and farmer organisation

As mentioned earlier, collective action proves necessary to overcome technical problems that are faced at individual or farm-level. It may also prove useful for information dissemination and farmer-to-farmer exchanges. Differences in impact between the individual and group approaches have been well documented (Sen, 1993). Farmer organisations should be efficient and show they are able serve as the main vehicles conveying farmers' needs for technology development and dissemination. The experiences in South Africa of the non-governmental organisation (NGO) 'Water for Food Movement' show that groups of women can successfully adopt and apply water-harvesting technologies through experience sharing, mutual learning and mutual confidence build-up (De Lange & Penning de Vries, 2003).

4.2.4 Rural finance

Credit can be a way of overcoming wealth constraints on investment in new technologies. Individual title deeds may give the farmers access to formal financial services. However, this is not the only way, since such formal services remain rare in African rural environments. Other forms of collateral may prove more appropriate.

Box 3. Key public sector research biases, as factors for low adoption of WCTs (adapted from Whiteside, 1998)

Often experiments are run for a short time period and are designed to provide short-term recommendations (see also Box 2). Research organisations seldom use an approach in which the long-term sustainability of a given technology is considered a factor for implementation.

Furthermore, most research is conducted on research stations, which are mainly located where there are favourable soils and climatic condition, and are therefore not representative of farmers' conditions. Efforts towards an on-farm research approach are often undermined by budget cuts (pressure on transport budgets) and some misunderstanding of the nature of 'local or indigenous knowledge'.

Many experiments still have the objective of production or yield maximisation, with little attention being paid to other trade-offs. Relatively few are designed to find either financial or economic optimum combinations of inputs and yields. Even in land surplus areas, nearly all crop experiments are designed to reveal yield per hectare, rather than yield per unit of the scarcest or most constraining resource (e.g. water, labour, cash flow).

Despite widespread rhetoric and nominal adherence to farming systems principles, most research organisations remain organised along commodity or discipline lines, which do not favour multidisciplinary and inter-sectoral research on WCT definition and adoption.

Social sciences (e.g. agricultural economics and rural sociology) are under-represented (or non-existent) in most organisations in charge of WCT development. Also, there is still relatively little consideration of gender in research programmes on WCTs. Such bias undermines adoption efforts in most smallholder farming contexts.

The active participation of the poorest and smaller-scale smallholder farmers is still a constraint, since they are under-represented or less involved in trials, field days or committees.

Informal savings and credit groups at community level (known as *stokvels*) have long proved worthy and effective and may even enhance opportunities for collective action in natural resource management. The level of investment required should be an important criterion for WCT development, since it impacts much on further adoption features. A study by Pender & Kerr (1996) in India clearly demonstrates that the defects of credit and labour markets have a negative effect on investment in conservation.

4.2.5 Infrastructure

Farmers cannot adopt technologies if roads and transport are inadequate and too poor for them to acquire conservation technology-related inputs, or to market their produce. There is a clear need to put conservation technology development within the whole rural development picture, in other words, by an integrated approach. The adoption process depends not only on farmers' willingness but also on an overall sustainable rural development process, hence the need to emphasise the importance of infrastructure.

4.2.6 Agricultural and rural development policies

Most successes in the adoption of WCTs are still very localised. This is because the over-arching element of a favourable policy environment is missing. Most policies still actively encourage farming that depends on external inputs and technologies. Such a policy framework is one of the principal barriers to a more sustainable agriculture, and has encouraged unsustainable and high-risk smallholder farming, with detrimental consequences for poverty alleviation and the environment (Pretty, 1994; Whiteside, 1998).

5. CONCLUSIONS AND RECOMMENDATIONS

Adoption of WCTs is not an end in itself; rather, technological change should be evaluated in terms of its contribution to broader goals of human development and economic growth, poverty alleviation and environmental sustainability (Knox & Meinzen-Dick, 1999). The adoption of WCTs is recognised as one of the ways to ensure sustainable agriculture, contributing to sustainable livelihoods in rural environments (Kundhlande et al., 2004).

Figure 2 shows some factors affecting the core objective of sustainable development. The box on the left-hand side sums up what has been reviewed in the article, in terms of the conditions and factors influencing technology adoption. It highlights the interactions between the technologies, local organisations and the environment.

This article highlights the complexity of getting WCTs adopted in smallholder farming environments. It explains how a conceptual framework must take into account spatial and temporal scales. Two major factors are identified: property rights and collective action. It must be underlined that these two factors are important issues in developing, resource-poor, smallholder farming environments, whereas they are hardly mentioned in commercial, industrial farming systems.

Here, 'property rights' means the ways a community and its members access and use natural resources, and the rules that are set up, used and enforced. It does not necessarily refer to the notions of private ownership or title deeds, since some communal natural resource management patterns have long proved sustainable. Nevertheless, technology development should take existing property rights to natural resources into account. In turn, certain very promising technologies may need property rights adaptations. Such interaction advocates for integrated technology development.

Collective action at community level also plays a key role in the feasibility of implementing certain technologies. Researchers should identify and investigate existing patterns of collective action, so that a given technology will best fit a specific situation. In turn, certain technologies may trigger or initiate some form of collective action at local level where farming systems oriented research is more likely to achieve this than sectoral research.

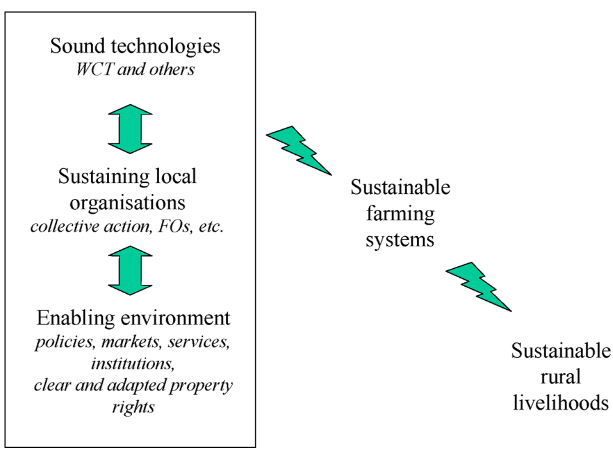

Figure 2: Conditions for technology adoption, towards sustainable farming systems and rural livelihoods (adapted from Pretty, 1995 and Whiteside, 1998)

A number of factors have been identified that will influence the adoption of WCT. The household-related factors and external factors clarify the various stakeholders' responsibilities and roles in the adoption process. What is shown here is that adoption depends not only on a successful dialogue between a persuasive extension officer and a willing and compliant farmer, but also on the role that other stakeholders (members of the community, policy-makers, development agents and researchers, as indicated in Figure 2) have to play in the adoption process.

Water conservation technology adoption explicitly means intensification, as a response to growing production needs being held back by uncertain and scarce water resources. However, the term 'technology' is perhaps misleading, since adoption of new technology may also imply labour-based or capital-based intensification.

Faced with the relative low rate of adoption of resource-conserving technologies, researchers and extension officers have no other choice than to close a 'new deal' with their partners, to shift from a TOT paradigm to a more participative approach where stakeholders are willing to share their learning experiences. Such a new paradigm should include the following principles and resolutions (Pretty, 1995; Whiteside, 1998; Piraux et al., 1999):

- Setting a clear priority in favour of smallholders and sustainability (a need for some form of 'affirmative action', according to Whiteside, 1998).
- Promoting adaptive, locally based research, responsive to diverse environments and to the farmers' actual demand, mixing station-based research with on-farm research.
- Taking account of farmers' actual demand in terms of alternative natural resource management, understanding their priorities and strategies (including those of women), and understanding the local livelihood systems and farming systems.
- Promoting multidisciplinary and multisectoral approaches, using alternative criteria for evaluation (not only yield maximisation, but also cost, labour, energy, resource and input minimisation).
- Promoting a long-term perspective on research and partnership.
- Active creation of a mutual learning environment involving farmers, extension and research (Röling, 1994; Campbell, 1994).
- Acknowledging and analysing local practices and knowledge, and enabling and publicising research and innovation done by farmers.
- Providing options to choose from, rather than recommendations (since there is no such thing as a 'single magic bullet', according to Whiteside, 1998).

Current trends in action research, bottom-up and participatory approaches have been illustrated by numerous studies (Campbell, 1994; Röling, 1994; Pretty, 1995; Kirsten et al., 2002) which provide the framework for such principles to be implemented.

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