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**Analysing the low adoption of water
conservation technologies by smallholder
farmers in Southern Africa**

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Abstract

Natural resource degradation and water scarcity are a global concern, which typically threatens the sustainability of smallholder farmers' livelihoods in semi-arid developing areas. As part of research efforts, a number of water-conservation technologies (WCT) have been developed, yet with low adoption rates in smallholder farming environments. This paper discusses the concepts of adoption and innovation, comparing the perspectives of research operators to the ones of smallholder farmers. Discrepancies are highlighted and ultimately explain low uptake of technologies by farmer. Then it addresses socio-economic factors affecting such adoption. It is argued that WCT show specific traits: (1) diversity and applicability to different time and spatial scales; (2) hence, the dependency upon a context. These traits influence dissemination and adoption of WCT, and should not be ignored, from the early stage of technology development. It is shown that adoption does not only depend on individual farmers willingness, but also upon the role of property rights on resources, and collective action at community level. Other specific issues and factors like the demand for WCT, the role of public sector and research, and related biases are also discussed. It finally draws some recommendations towards rural livelihoods that are more sustainable. Farmers' participation in technology development, taking account of local indigenous knowledge and sound institutional arrangements are among others the pathways that are suggested towards a better integration of technology development and innovation processes.

Key-words: adoption, innovation, water conservation technologies, collective action, property rights, sustainability, livelihoods

1. Introduction

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 the 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, globalization and liberalization, climatic disturbances, and traditional practices that are no longer adapted to a quickly changing socio-economic environment.

At local level, the smallholder farmers' livelihoods are at stake, in dire need for sustainability, especially in sub-Saharan Africa (DFID, 1999). In semi-arid areas, the

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challenge is to develop Water Conservation Technologies (WCT) and related management methods, and to promote innovation by smallholder farmers. Although many promising technologies have been developed and made available, the field application of these is limited (Knox & Meinzen-Dick, 1999).

This discussion will not dwell on the biophysical or technical merits of any WCT *per se*, (although those merits indeed influence the adoption process), but rather try to contextualize these technologies within the socio-economic, decisional and policy framework of smallholder farming in developing areas.

2. WCT adoption faces heavy odds and some misunderstandings

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

Sustainable resource-conserving technologies are defined as technologies that enable a farmer to produce her/his desired output, while using the available resources –land, water, labour, energy, inputs, etc.- more efficiently, and while maintaining the productive capacity for the future (Whiteside, 1998, Uphoff, 2002)

2.1. A critic of the linear, positivist paradigm

WCT are by essence based on the following principles. For dryland crop production purposes in semi-arid environments, it is critical to harvest, conserve, concentrate, 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 evapo-transpire more (hence an increased simultaneous demand in 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 rational, along with proved, clear and well publicized results is sufficient to close the deal of adoption by smallholder farmers. The usual format of these results consists of promising yields per unit of land used (ha), but hardly provide any insights about the nature of the technology (e.g. is it labour-intensive, capital-intensive, what kind of farm organization and management changes it supposes, does it require more inputs, can it be fragmented, implemented in modules, or is it a package, etc. 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, agendas, time and scale perspectives (Bosc & Jamin, 1995). For example, in line with prevailing policy frameworks or mottos (e.g. “more crop per drop”, “sustainability”), researchers may be prone to develop resource-conserving technologies *per se*, whereas farmers' immediate agenda is short-term production for survival. Such disconnection also originates from long embedded perspective that researcher and research organization have about research professionalism and the contribution of research to human societies (Pretty & Chambers, 1993, Boehmer-Christiansen, 1994). Such perspective does not accommodate exchanges, dialogue and negotiation between stakeholders, co-construction of common research objectives and objects, or multidisciplinary.

As poor adoption rates repeatedly show (Knox & Meinzen-Dick, 1999), such linear, reductionist and positivist perspective (also referred to as Transfer of Technology TOT) is

faulty (Roling, 1994, Norton, Nix & Williams, 1995). It hardly works in smallholder farming environments. But it is still amazingly very commonly applied (see proceedings of the International Symposium on Water Conservation Technologies for Sustainable Dryland Agriculture in Sub-Saharan Africa, 2003), in spite of about 20 years of active promotion of farming systems approaches, of farmer-centered research methodologies, yet with limited concrete implementation in Southern Africa (Whiteside, 1998).

There seems to be a need for re-formulating some basic principles of farmers' decision making and innovation processes, for a more successful match between research inputs and farmers' uptake of water conservation technologies.

2.2. Innovation from a farmer's perspective

Innovation is a key component of economic evolution, therefore of development (Nelson & Winter, 1982; Treillon, 1992, Dougherty, 1996). For millenniums, farmers have continuously domesticated, bred and used new crops, invented new implements, changed their ways to produce crops, re-combining the production factors (labour, assets, capital and cash, land) in order to improve production, food security and income. This process has long been mostly endogenous, or dependant on limited exchanges between close community members. Such form of innovation is slow and hardly matches the current requirements of a quickly changing socio-economic environment. It's only relatively since recently that agricultural research provides exogenous solutions (technologies) to farmers. Innovation can then take place at a much quicker pace, ever enhanced by improved access to information and communication technologies.

It seems however that the basic issues facing farmers when it comes to innovation still revolve around choices and trade-offs, since they are the ultimate decision-makers in a context of scarce resources and production factors, thus, of limited options.

From a farmer's perspective, innovation about resource-conserving technologies may involve (1) some form of immediate investment with long-term expected returns, (2) trade-offs between current yield and future yields, (3) trade-offs between one yield and its production costs, (4) trade-offs between yield and its related risk (Knox & Meinzen-Dick, 1999).

These trade-offs define a portfolio of choices that farmers are left with since they are the ones that have to take the risks. These risks and uncertainties mostly originate from the lack of information on the long-term benefits, impacts and returns attached to a technology, once it faces real-world climatic and economic variations.

Also, for the farmer, the innovation process does not only involve a given technology. It rather supposes turning it into a practice (see box 1), which most of the time supposes adaptation rather than mere adoption. The innovation process is not addressing the technology as such but rather the organizational and managerial changes that are required so that the technology slots into the farming system and becomes a practice among others (Milleville, 1991; Bosc & Jamin, 1995). Such process may even involve stakeholders beyond the farm boundaries if some form of collective action is required to implement the technology (e.g. mechanization, nurseries, watershed management) (Rasmussen & Meinzen-Dick, 1995). This emphasizes the complexity of farmers' decision-making with regard to innovation on resource conservation.

Such complexity may even increase when one considers certain specific traits of southern African smallholder farmers (Ellis, 1993; Low, 1986), and especially markets failures:

- Smallholder farmers are partially connected to markets that are imperfect anyway; besides product markets, credit markets, information markets, land markets and labour market are weak or even non-existent;
- They are risk-averse when exposed to a harsh and uncertain environment; subsistence remain the dominant farming strategy;
- Their farming systems are usually not capital- or technology intensive; they are even not much labour intensive, owing to the scarcity of male adult labour;
- They show a growing multi-activity character, since there are a number of off-farm, non farm, and non monetarized activities that take place (diversification of livelihoods, part-time farming);

The technology must not only fit into the existing farming system, but also fit into the whole livelihood systems, matching the strategy developed by the family. Failures and successes of the so-called Green Revolution give vivid examples of that reality.

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 formulated independent of farmers and relates to theory. Practices concern 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. Lastly, farming practices underlie the concepts of cropping system and livestock systems.

Researchers and extension agents must acknowledge that adoption refers to 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).

The following chapters present and discuss certain specific features and implications of WCT that should be considered as factors for innovation.

3. Diversity in nature and scales as first factors for innovation

3.1. Diversity and the spatial scales of WCT

The first key trait of WCT is their diversity in nature, although sharing many common goals. The diversity of available technologies is most striking in the literature and the majority will be discussed during the duration of this paper.

Furthermore resource-conserving technologies are applied at different spatial scales. Some technologies occur at plot level and only necessitate decision and involvement at the farm-level by an individual farmer. Such are the adoption of improved varieties of drought-resistant crops, water harvesting and storage at household level, or mixed cropping or increased planting density. Other technologies, although applying within a crop

management sequence by an individual farmer, at plot level, may involve coordination or collective action beyond the farm boundaries. These include for instance mulching, which supposes that livestock do not graze on crop residues, or reduced tillage, which may suppose some form of collective organization about mechanization. Above farm-level technologies will only make sense if implemented at larger scales, like for instance at mini watershed or community level. These include technologies like terracing, contour cultivation or conservation irrigation that can hardly apply and achieve some efficiency at the plot or farm level. A necessary condition for application of WCT at the above-farm level is that a platform for collective decision-making must be established to make coordination and grouping of farmers possible to manage resources (e.g. nurseries for agro forestry or contour planting, access to mechanization). The problem however is that in most places platforms for collective decision-making does not exist, and success is seldom achieved in isolation (Rasmussen & Meinzen-Dick, 1995; Knox & Meinzen-Dick, 1999).

The main consequence of such differences is that certain technologies require some form of co-ordination between farmers, which in turn requires a high degree of social capital among community members. This is also referred to as so-called 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 organizations.

3.2. Technologies with different time frames

Some technologies provide short-term returns to investment (the crop cycle being the time frame), such as irrigation or the choice of a drought-resistant crop variety. However many natural resource management technologies take years to provide a full and stable return. In an Ethiopian case study, Agnew (2000) reckons that it takes 2 to 6 years for farmers to fully benefit from soil and water conservation technologies.

If farmers do not have secured rights to natural resources, they lack incentives to adopt these technologies, since they are not assured of receiving the benefits (Knox & Meinzen-Dick, 1999). In India, Pender and Kerr (1996) demonstrated that greater investment about soil and water conservation technologies was made 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 well as their capacity to plan in the long run. A vicious spiral of increasing poverty, declining sustainability and degrading natural resources then occurs.

Several technologies are located in Figure 1, as examples. For a given technology, the larger the spatial scale of application, the higher the degree of collective action is required. The longer the temporal scale, the higher the degree of tenure security 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 often require some co-ordination as far as input supply, mechanization or resource management are concerned (e.g. seedlings for agro forestry, specific equipment for reduced tillage / direct planting, etc.) on above farm-level.

- Approximate position of figure 1. -

This framework 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 on 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 success of conservation technology not only depends on the appropriate technology and prices (Rasmussen & Meinzen-Dick, 1995), motivation, skills and knowledge of an individual farmer, but needs to be combined with supporting local institutions (e.g. strong social bonds, clear tenure rights) (Jagger & Pender, 2003) and an enabling external environment as will be discussed later in this paper (Röling, 1994; Whiteside, 1998).

4. Adoption of Water Conservation Technologies is context-dependant

The following discussion aims at identifying a number of key issues that affect adoption of conservation technologies (such list is not exhaustive). Researchers and development operators often lack to see the whole picture, and tend to overlook the inner household context and/or external environmental factors.

4.1. Taking account of the household context

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).

Labour

Labour bottlenecks resulting from relative higher labour requirements are also cited as a constraint to the adoption of conservation technology, especially if new technologies create seasonal peaks that overlap with other agricultural activities (Knox & Meinzen-Dick, 1999). Collective action and reciprocal arrangements may be employed as a means to overcome household labour shortages, particularly in cash-scarce economies, or in communities characterized with high levels of adult migration. Therefore labour requirements of a given technology must be seen as a key criterion for development.

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

Sustainable techniques, such as WCT, need, by definition, to work over the long term. For instance, mulching or a reduced tillage practice for water conservation must be better than existing practice when used over a long period. It may, however have extra cost implications in terms of increased labour or reduced yields, and these often fall in the early years. Experiments or demonstrations over one to three years are then often irrelevant. There's a need for much longer periods of experimentation (10 years or more, in order to consider the full range of climatic fluctuations).

Not many research institutions, extension services or projects have this type of time perspective. Furthermore, long-term on-farm experimentations on WCT are uneasy to undertake. The research station remains the most secured 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). Development and extension services should then emphasize information exchange between farmers on that basis.

Farmers also need support to take the long-term view. There may not be an incentive for farmers to adopt WCT until environmental damage or serious yield problems occur, and by then it may be too late since prevention is often cheaper and easier than cure. Key issues for the farmers are: 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? (see the issue of tenure security in chapter 3) How can farmers finance the investment? (see the importance of wealth and credit in chapter 4).

Diversity of farmers' strategies

The two previous points discussed highlighted the diversity that may exist at community level, among households. Farmers may have different ways, objectives and practices. Such diversity refers to the concept of strategy.

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.) develop purposively, and which aim at changing or transforming their social, economic and/or physical environment. Such processes combine resources and/or techniques, knowledge and know-how (Olivier de Sardan, 1995). Farmers develop strategies as a response to a changing and uncertain environment, in order for them to duplicate or reach or transform a given life style that corresponds to an objective, as groups and/or as individuals. The crops, crop management sequences, cropping systems, animals and animal production systems, farming systems, off-farm activities, and so on, that the farmers combine and mobilize reflect such strategies (Yung & Zaslavsky, 1992). For example, the common association of stock 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, embedded within a livelihood strategies at individual as well as collective levels. Such practice can hardly accommodate mulching or any changes in the crop management timeframe without major alterations in other practices at farm and community levels.

Within a community, diverse strategies may develop, depending on each household's history, composition and objectives. On the one hand, it is impossible to take account of each and every household's characteristics while on the other hand it is irrelevant to consider the community to be homogeneous; hence the introduction of typological approaches that group households with similar strategies and characteristics with regard to a specific objective (Perret, 1999). Such an objective may be the identification of the needs for WCT and the current water conserving practices as applied by farmers.

Social and cultural factors

Despite the dominance of family farms in the adoption literature, the family is rarely examined as a context for the adoption process (Salamon et al., 1997). These authors stress that recent studies persist in focusing on a single male farmer as the actor 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. Furthermore, the transition from conventional to alternative farming systems ignores literature relevant social barriers to adoption other than profitability.

Also, certain taboos, norms and practices on soil and water management do exist in various socio-cultural settings in Africa. Indigenous knowledge and local traditional practices may be considered part of this social and cultural framework.

They are often strong, and inescapable, and can undermine the adoption of any technology. This militates in favour of locally centered technology development. Researchers and extension services need to acquaint themselves with the different cultural norms and

practices of their farmers, and also take them into consideration and avoid any hasty judgment in their development planning (Kirsten *et al.*, 2002).

Although on the surface cultural norms that hinder technology adoption may appear to have equity, efficiency or environmental drawbacks, they also tend to have more profound implications. For instance, in many rural African societies, communities promote cohesion and lessen exposure to risks through kinship and marital practices, which have implications for the distribution of property rights (Knox & Meinzen-Dick, 1999).

The demand for WCT, the appropriateness of research

As already stated, it is important to recognize that farmers' need assessment does not necessarily prioritize long-term solutions. Smallholders however are often forced by external circumstances to prioritize short-term constraints. The adoption of conservation practices may not be perceived as a priority for farmers until evidence of deterioration of the environment or alarmingly declining yields are visible (Gillet *et al.*, 2003).

In theory, a way of facilitating technology adoption is to make sure that research priorities are in line with farmer's 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 supposes a strong encouragement of farmers participation in need identification (Whiteside, 1998; Kirsten *et al.*, 2002). However, amongst the poor and small-scale farmers an effective and co-ordinated request for appropriate research (thus adapted technologies) is often lacking. Moreover, needs are often very heterogeneous and relative diverse. Therefore the needs 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 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 set-backs (Whiteside, 1998).

Finally, pre-existing indigenous water conservation practices and skills do exist (Pretty, 1994; Pender & Kerr, 1996; Gandonou & Oostendorp, 2001). From an innovation viewpoint, research operators must definitely take these practices into account, since they form the inescapable platform for further innovation.

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

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

Most research is done on research stations, which are mainly located on favourable soils and climatic conditions, and are therefore not typical of farmers' conditions. Besides, efforts towards on-farm research are undermined by budget cuts (pressure on transport budgets).

Most experiments still have the objective of production or yield maximization, with little attention paid to other trade-offs. Relatively few experiments 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, etc.).

Despite widespread rhetoric and nominal adherence to Farming Systems principles, most research organizations remain organized along commodity or discipline lines, which does not favour multidisciplinary and intersectoral research on WCT definition and adoption.

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

The actual participation of the poorest and smaller scale smallholder is still an issue, since those farmers are underrepresented or less involved in trials, field-days or committees.

4.2. The need for an enabling external environment

Information

Farmers cannot adopt technologies if they do not have all relevant information about the technology and what scope of returns could be expected after adoption. This second condition is often overlooked. The former is often incomplete, focusing on the technical aspects and overlooking some key criteria from a farmer's point of view (e.g. labour requirements).

Different extension approaches have been implemented in order to inform and train farmers, aimed at the adoption of technologies. The different approaches to be found varied from Transfer of Technology (TOT) (inherited from the Green Revolution principles), the Farming Systems Research and Extension approach, Training and Visit approach up to the Farmer-First and participatory approaches (Kirsten *et al.*, 2002). Most research and extension organizations in Southern Africa still apply TOT principles, although with some inclusion of certain components of the farming systems approach (see Box 3). Actual participatory methodologies are still seldom used (Whiteside, 1998). Participation, if it is to become part of extension and research approaches, must be clearly interactive and empowering. Any pretence to participation will result with little change. Also the identification and inclusion of indigenous or local knowledge and practices for the development and training of farmers is much talked about, yet with limited actual implementation.

Environmental and price risk

African farmers are faced with a number of risks, in an uncertain world: weather, war, robbery, pests and diseases, illness and death, and price fluctuation. Risk-averse and low-wealth farmers are often reluctant to adopt technologies because they need a stable income and consumption streams, especially when the returns to adoption are themselves unclear or uncertain. Besides the clear need for local typologies of farmers, it is also necessary to include in technology development an analysis of the environmental and economic risks.

Collective action and farmers' organisation

As seen 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). Finally, farmers' organization should be identified as the main vehicles conveying farmers' needs for technology development and dissemination.

Rural finance

Credit can be a way of overcoming wealth constraints to investment on 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. Informal savings and credit groups at community level have long proved to be worthy and effective. They 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 credit and labour markets imperfections affect negatively conservation investments.

Infrastructure

Farmers cannot adopt technologies if roads and transport are inadequate and poor for them to acquire conservation technology-related inputs, or to market their produce. There's a clear need to put conservation technology development within the whole rural development picture, therefore an integrated approach. The infrastructure issue typically illustrates that the adoption process does not only depend on the farmers' willingness, but partakes to an overall sustainable rural development process.

Agricultural and rural development policies

Most successes in the adoption of WCT are still very localized. This is because the overarching element of a favourable policy environment is missing. Most policies still actively encourage farming that is dependent upon external inputs and technologies. Such policy framework forms 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. A need for renewed research-development design on WCT

Adoption of WCT 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). Adoption of WCT is recognized as one of the components of sustainable agriculture, contributing to sustainable livelihoods in rural environments.

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

-Approximate position of figure 2. -

The paper first highlights the complexity underlying WCT development and adoption in smallholder farming environments. The conceptual framework proposed makes use of the entangled spatial and temporal scales. Two major factors are first identified: the nature of property rights and the degree of collective action. It must be underlined that those two factors are typical issues in developing, resource-poor, smallholder farming environments, whereas they are hardly mentioned in commercial, industrial farming systems.

Property rights refer to the ways a community and its member's access and use natural resources, the rules that are set up, used and enforced. This does not necessarily refer to the

notions of private ownership or title deeds, since some communal natural resource management patterns have long proved sustainable. Yet, technology development should take account of the existing property rights on natural resource. 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 and implementation of certain technologies. From a research point of view, existing patterns of collective action should be investigated and identified, so that a given technology fits best to such a situation. In turn, certain technologies may trigger or initiate some form of collective action at local level. Yet again, farming systems oriented research is more likely to achieve this than sectoral research.

A number of other factors have been identified and discussed in the paper. These household-related factors and external factors clarify the different stakeholders' responsibilities and roles in the adoption process. What is shown here is that adoption does not only refer to a successful dialogue between a convincing extension officer and a willing and abiding farmer, but also the role that other stakeholders have to play (like for instance other members of the community, policy-makers, development agents, researchers as indicated in figure 2).

Furthermore, water conservation technology adoption refers explicitly to intensification, as a response to growing production need facing uncertain and scarce water resources. However, the term "technology" is misleading, since adoption implies more labour-based intensification than technology- or capital-based intensification.

Faced with the relative low rate of adoption of resource-conserving technologies, researchers and extensionists have no other choice than to close a "new deal" with their partners, to shift from a Transfer of Technology (TOT) paradigm to a more participatory, partnership. Such new paradigm should include the following principles and resolutions (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); understanding the local livelihood systems and farming systems;
- Promoting multidisciplinary and multi-sectoral approaches; using alternative criteria for evaluation (not only yield maximization, but also cost, labour, energy, resource, and input minimization);
- Promoting a long term perspective in research and partnership;
- Active creation of a mutual learning environment involving farmers, extension and research (Roling, 1994; Campbell, 1994);
- Acknowledging and analysing local practices and knowledge, enabling and publicizing research and innovation done by farmers;
- Providing options to choose from, rather than recommendations (since there's no such thing as a "single magic bullet", according to Whiteside, 1998).

Current trends in action research, bottom-up, and participatory approaches provide the framework for such principles to be implemented (Roling, 1994; Campbell, 1994; Kirsten *et al.*, 2002).

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Figure 1. A conceptual framework for analyzing 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.

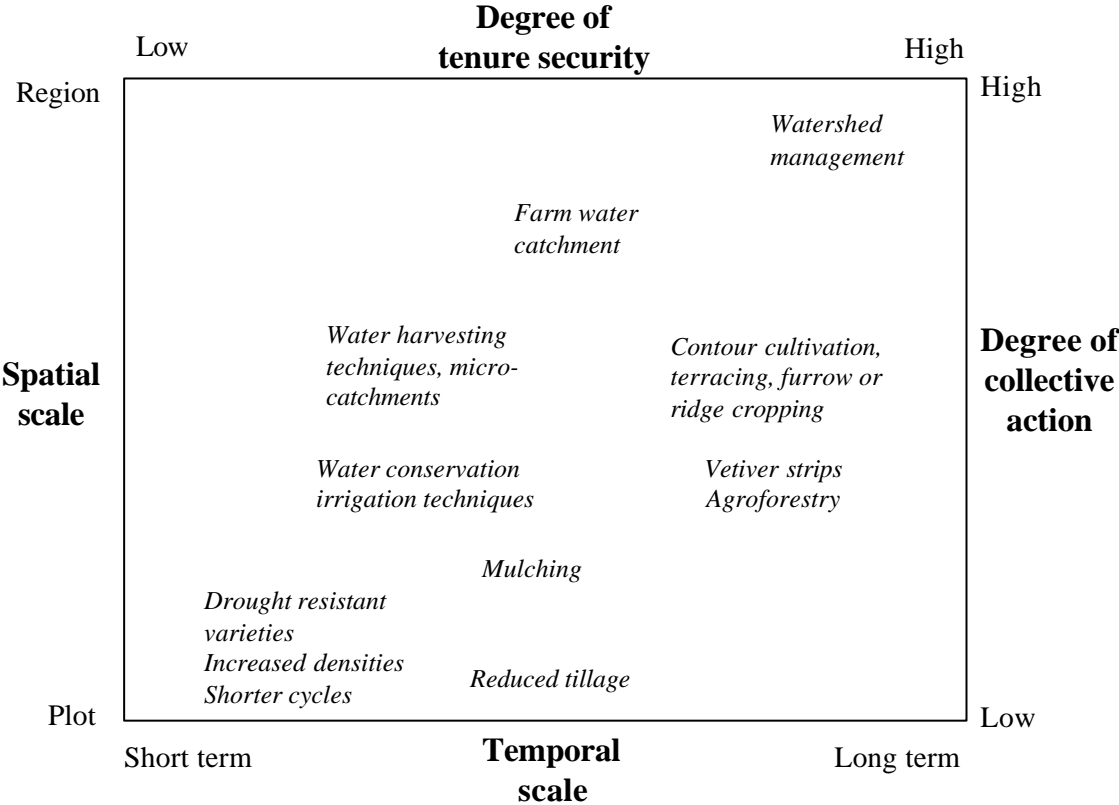


Figure 2. Conditions for technology adoption, towards sustainable farming systems and rural livelihoods (adapted from Pretty, 1995 and Whiteside, 1998).

