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Development of the public release version of Smallholder ADOPT for developing countries

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Development of the public release version of Smallholder ADOPT for developing countries

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Foreword

The Australian Centre for International Agricultural Research (ACIAR) has a history of encouraging an adoption culture among researchers and next users of research outputs. The lack of adoption of new technologies and improved varieties in many developing countries is a significant obstacle to advancement in these countries' agricultural productivity. Thus, ACIAR has pioneered the development of innovative approaches to better understand the adoption process, and to find ways to break down barriers to uptake of new technologies and varieties.

The need for us to continue on this path has been reinforced by the recommendations arising from ACIAR's external review in 2013. The review panel noted that the research ACIAR has funded over many years on the adoption of its research outcomes showed its potential to be a world leader in further work. With this in mind, the panel recommended that ACIAR make improvement of adoption rates a focus of its research. This can be facilitated by ACIAR's engaging with a wider field of stakeholders, including businesses and non-government organisations, when designing projects and implementing their outcomes.

In accepting this recommendation, ACIAR has designated 'accelerating adoption' as a key research area. In taking this work forward, ACIAR research program managers and project staff have studied ADOPT, a tool originally designed for Australian agriculture, and adapted it to study smallholder scenarios in developing countries.

ADOPT was developed as an aid to project planning and implementation. It lists the well-known socioeconomic factors influencing producer decisions, and seeks to quantify the relative chance of new techniques and products being successfully adopted. ACIAR successfully tested ADOPT with potential end users, and from this work has developed a developing country version: Smallholder ADOPT.

This publication documents the development of Smallholder ADOPT, which started with a review of literature that gathered significant data on the factors influencing adoption in developing country settings. The development process was then progressed through a survey with users of the pilot version of Smallholder ADOPT, followed by workshops held in Ethiopia, Laos, India and Papua New Guinea.

Smallholder ADOPT is now ready for public release to those working in smallholder settings. The developers are seeking feedback as others start to use the package, to ensure ongoing refinements. It will be available through www.csiro.au/adopt.



Nick Austin
Chief Executive Officer, ACIAR

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADOPT	Adoption and Diffusion Outcome Prediction Tool
CA	conservation agriculture
CIMMYT	International Maize and Wheat Improvement Center
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
PNG	Papua New Guinea
SWC	soil and water conservation
TC	tissue culture

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1 Executive summary

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) was developed as a tool to encourage application in project planning and implementation of well-established understanding of the socioeconomic factors influencing adoption of agricultural innovations. It is designed to predict the likely level and rate of adoption, and to engage practitioners in considering factors influencing adoption. ADOPT was originally designed for Australian agriculture (the developed country version), but attracted considerable attention from many working in international agricultural research and development. It is clear that there is substantial demand and potential for a version of ADOPT adapted to international smallholder agriculture (called Smallholder ADOPT) to benefit project planning and implementation.

Smallholder ADOPT is designed to provide an understanding of the technology adoption process, as part of the wider processes of agricultural innovation. The World Bank defines innovation as the process by which individuals or organisations master and implement the design and production of goods and services that are new to them. In this context, innovation is the introduction of new ideas—these could be new technologies (new seed variety, new machinery etc) or new practices (changes to sowing times, changes to tillage practices etc). Smallholder ADOPT is designed to evaluate the adoption of these innovations by smallholder farming communities in developing countries.

Innovation can exist within a broader innovation system, which is the network of organisations, enterprises and individuals that focus on bringing new products, new processes and new forms of organisation into economic use, together with the institutions and policies that affect their behaviour and performance. Smallholder ADOPT can be used to

help inform innovation systems, but its real strength lies in evaluating agricultural innovations and practice changes.

A previous phase of investment by the Australian Centre for International Agricultural Research (ACIAR) successfully tested the concept of ADOPT with potential end user groups and developed a new set of questions relevant to smallholder scenarios. Building on this, further work was conducted on the developing country smallholder version of ADOPT. Work was targeted at improving some of the underlying formulas that calculate ‘peak adoption level’ and ‘time to peak adoption’; conducting case studies of the adoption of innovations in four developing countries (examining six innovations), linked with independent time-series adoption data to support calibration and validation of the model; and improving the usability and outputs from ADOPT, informed by feedback from a survey of existing users.

A review of the literature was conducted to consider the factors used in Smallholder ADOPT, particularly those relating to the innovation, the target population, relative advantage and learning of relative advantage. The review found evidence to support the existing factors used to predict peak adoption and time to reach it, with particular attention paid to the population-related factors rather than innovation-specific attributes. It also identified factors of less importance or relevance, along with other factors that have consistently been shown to influence adoption rates in the smallholder context and need to be considered for inclusion in any adoption prediction tool.

A survey of users of the previously available beta version of Smallholder ADOPT posed 19 questions to elicit feedback and comments on the usefulness of ADOPT, what it was used for, what was missing, its

weaknesses, and other comments and suggestions. There were 37 responses from 199 emailed invitations (19%). Some key findings were that 60% of respondents rated the beta version of Smallholder ADOPT as having a moderate ability or better to generate a realistic prediction (even though it is not calibrated for smallholder scenarios), and 73% rated the potential value of ADOPT as moderate or higher. Some valuable feedback was provided about suggested changes (more examples of questions, better explanations etc), and many suggestions about weaknesses and what was missing. These comments and suggestions were used in modifying Smallholder ADOPT.

To validate the revised Smallholder ADOPT, we conducted workshops and interviews in four case-study countries—Ethiopia, Laos, India and Papua New Guinea—representing six innovations. Case studies were identified that could be conducted in a short period of time and had good independent time-series data on adoption rates. The case studies relied on support and input from various in-country partners and institutions to access data, carry out ADOPT workshops and write reports. The case studies showed how the revised Smallholder ADOPT model performed against the beta version and against the independent time-series data on adoption. Limited by the availability of data on actual adoption, the case studies considered the introduction and adoption of new crops, varieties, herbicides and agricultural machinery. Almost all ended up reaching close to 100% adoption, which meant that the validation was more focused on time to peak adoption rather than peak adoption level. This case-study approach and validation was a very important component of the development of the Smallholder ADOPT tool.

A range of changes were made to Smallholder ADOPT. The text for each question was revised to make it more relevant for developing country smallholder contexts, including a focus on livelihoods, income generation and food production (rather than profit). Other changes include modifications to the formulas that govern peak adoption levels and time to peak adoption level, with a re-evaluation of the effect of relative advantage on those formulas.

Smallholder ADOPT remains a predictive tool and operates as a model based on user input. It therefore requires caution when results are produced. We modified the layout of the adoptability report that is produced, to make it more user friendly, and introduced sensitivity curves to the original S-curve that is used to show time to peak adoption and peak adoption level. These curves show the effects of one-step-up and one-step-down changes in the response to the questions with the highest sensitivity.

Smallholder ADOPT remains most suitable for introducing agricultural technologies that are capable of being conceptualised by users. These can include new crops, new varieties, new chemicals (fertiliser, herbicides, pesticides etc) and new equipment. In some situations, they can also include practice changes. Smallholder ADOPT can be used for a range of purposes—in particular:

- during the project design phase as an ex-ante impact predicting tool
- during project implementation
- during project evaluation or ex-post monitoring

- as a boundary object to discuss options with stakeholders
- as a tool to explore the systems that underpin innovation.

Recommendations for the implementation and further development of Smallholder ADOPT are as follows:

- Provide worked examples of scenarios within the tool to provide users with better guidance on how to use Smallholder ADOPT more consistently and effectively.
- Ensure that sufficient cautions are evident so that users do not focus excessively on the specific adoption predictions (e.g. the S-curve).
- Encourage consideration of the improved sensitivity analysis features of the tool.
- Continue to seek quality datasets of diffusion of well-understood innovations among well-characterised populations for the purposes of validation.
- Within the tool, encourage users to add additional text regarding the characteristics of the innovation and/or populations that may help to explain potential adoption rates, including variables that are not included in the Smallholder ADOPT model. Similarly, encourage users to add text providing their reasoning for choosing particular question responses.
- Make the new version of Smallholder ADOPT available for use by those working in smallholder settings, and collect feedback from these users (Smallholder ADOPT will be made available through www.csiro.au/adopt).

2 Introduction

2.1 Background

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) has been developed to assist those involved with agricultural research, development and extension to apply and understand factors that are likely to affect how innovations (agricultural technologies and ideas) are adopted. It predicts adoption¹ levels based on a structured application of well-established understanding of the socioeconomic factors influencing adoption of agricultural technology or practices.

ADOPT has been designed to achieve three aims:

- **Predict** the likely peak level of adoption of a technology and the time taken to reach peak adoption level.
- **Inform** users about the factors that affect adoption and diffusion,² and encourage them to consider these factors at the time that projects are designed, rather than once a technology has been developed.
- **Engage** users by making adoptability knowledge and considerations more transparent and understandable.

¹ Our definition of adoption is based on Rogers (2003): Adoption is the decision to make full use of an innovation as the best course of action available. In other words, it is an individual process detailing the series of stages one undergoes from first hearing about a technology/process to finally adopting it.

² Our definition of diffusion is based on Rogers (2003): Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social system (or population) and how it spreads.

ADOPT generates a prediction of the proportion of a defined farmer population that will adopt a specified innovation and the time it will take for the peak level of adoption to occur. The expected adoption outcome is presented in the form of an S-shaped diffusion curve. It does this based on input relating to four categories of influences on adoption:

- characteristics of the technology
- characteristics of the target population
- relative advantage of using the technology
- ability to learn about relative advantage of the technology.

The first version of the tool was developed and validated using Australian cropping and crop–livestock farming systems (Australian broadacre agriculture version of ADOPT). The Future Farm Industries Cooperative Research Centre (FFICRC) provided the initial 2.5-year investment for the development of ADOPT from 2009 to 2011, led by CSIRO and supported by contributions from FFICRC partners: the University of Western Australia, the Victorian Department of Primary Industries, and the Department of Agriculture and Food Western Australia.

A beta version developed primarily for modern Australian broadacre agriculture has been available since late 2011 (www.csiro.au/adopt). Although not adapted for the purpose, the original beta version attracted considerable interest from researchers and practitioners working in an international smallholder context. In 2012, the Australian Centre for International Agricultural Research (ACIAR) funded a 1-year project to explore the potential for the ADOPT tool and approach to be adapted for international smallholder application and use as part of development projects.

A subsequent investment by ACIAR in 2014–15 was designed to validate the model for smallholder farmers in developing countries.

The aim of this report is to describe the modifications and validation of the revised model for the developing country version of ADOPT for smallholder farmers (Smallholder ADOPT).

2.2 Assessment activities and methods

The main aim of the current work was to validate and test the revised Smallholder ADOPT. The following activities were conducted:

1. Conducted initial user survey of existing users of the smallholder version of ADOPT to obtain critical feedback, suggested improvements and perceptions of relevance to their context. This included discussions with research program managers at ACIAR to identify suitable projects.
2. Visited the International Crops Research Institute for the Semi-Arid Tropics (India); Laos; the National Agricultural Research Institute (Papua New Guinea); and Ethiopia to
 - a. identify available adoption data, its form and its suitability for use in ADOPT validation
 - b. develop a contextual understanding of the identified technologies
 - c. conduct retrospective user testing of Smallholder ADOPT with key research and extension staff who were familiar with the previously identified innovations at the time they were first available for adoption, and record reactions and reflections of staff.
3. Linked with other ACIAR-funded projects (identified in 1), and undertook visits for two or three relevant projects to follow the activities outlined in 2.
4. Revised the ADOPT algorithms and made some revisions to the output of ADOPT.
5. Provided a validated public release developing country version of ADOPT on the CSIRO website.
6. Produced a document describing the smallholder version of ADOPT, suitable for publication in the ACIAR Impact Assessment Series (this report).

This report is set out as follows:

- Chapter 3 summarises a literature review of influences on the adoption and diffusion of innovations for smallholders in developing countries. This chapter is based on the review undertaken by Rick Llewellyn, Geoff Kuehne, Peter R. Brown, Jackie Ouzman, Roger Wilkinson, David Pannell and Olive Mungai that was submitted to ACIAR in June 2013.
- Chapter 4 presents background information on the structure of ADOPT and the variables.
- Chapter 5 summarises the results from a survey of registered users of the developing country version of ADOPT and describes how this information was used to modify ADOPT.
- Chapter 6 summarises the case studies from four countries that were used to validate Smallholder ADOPT (six innovations were tested).
- Chapter 7 summarises the changes that were made to Smallholder ADOPT.
- Chapter 8 presents the conclusions from this project.

3 Summary of influences on the adoption and diffusion of innovations in developing countries in relation to ADOPT categories

The adoption of innovations and the process of innovation in agriculture continue to attract extensive research effort. In this review, we focus on literature aimed at increasing the understanding of adoption of new practices by smallholder farmers in a developing agriculture context. Effort has been made to review the most recent literature. The review is structured around the factors used in the Adoption and Diffusion Outcome Prediction Tool (ADOPT), which was developed with adoption by broadacre farmers in Australia as the primary context. These comprise factors relating to the innovation, the target population, the relative advantage of the technology and learning of the relative advantage. The review identifies supporting evidence for existing factors used to predict the peak adoption level and the time to peak adoption, with particular attention paid to population-related factors, rather than innovation-specific attributes. It also identifies factors of less importance or relevance, along with other factors that have consistently been shown to be associated with adoption rates in the smallholder context, and that need to be considered for inclusion in any adoption prediction tool.

Some of the differences between the existing ADOPT factors and the factors shown to influence adoption in smallholder developing country contexts include:

- relative advantage
 - importance of the population’s ‘market orientation’ versus subsistence and ‘traditional/cultural’ influences on change (related to current profit orientation)
- in the smallholder context, greater consideration of land tenure and property rights security, particularly as it might relate to innovations with longer term impacts
- in the smallholder context, a need to consider farmer ‘awareness of relevance’ of the innovation, not just awareness of the innovation
- the potential importance of advantages and disadvantages at the collective and village level
- in the smallholder context, a lower weighting for environmental orientation
- in the smallholder context, higher future discount rates to reflect greater value attributed to meeting short-term needs
- differences in availability of cheap labour between populations (associated with relative advantage of labour-demanding or labour-saving innovations)
- role of access to credit
- learning of relative advantage
 - the importance of extension and/or participation in development programs in influencing adoption
 - the potential importance of information networks, cooperatives and collective actions, where they exist

- in the smallholder context, potentially longer awareness phases than what is now assumed, possibly relating to education levels.

The high level of diversity within and between populations also has implications for ADOPT. This diversity is related to key variables such as education level, information exchange, social capital (networks, farmer typologies), market and risk orientation, and labour availability and requirements. It will be important to consider a range of populations and population segments, and how the high diversity of populations and their characteristics affect adoption levels and rates. Greater emphasis on characterising target subpopulations and segments is likely to be needed in the smallholder developing country context.

3.1 Learnability—population characteristics

3.1.1 Innovation awareness

Farmer-to-farmer information exchange, learning, extension and training play important roles in the acceptance phase, especially where there are inadequacies in extension services, as highlighted by De Graaff et al. (2008) and Mariano et al. (2012). Farmer-to-farmer extension and training have a greater effect when coupled with workshops on related training activities, as a participatory technique and form of farmer engagement in the process. Training sessions were identified as a significant determinant of adoption of modern rice technology and good management practices (Mariano et al. 2012). Research work in many developing countries, especially in Africa, reports findings of weak linkages between researchers, extension workers and farmers, compared with stronger influences of farmer-to-farmer contact on adoption and diffusion of agricultural innovations and practices. A related factor for the density and quality of networks in which farmers are embedded is ‘group involvement’ (see below).

Adaptive on-farm research, demonstrations and trials, and consistently assessing farmers’ needs boosts acceptability of innovations. Farmers are involved in data generation and evaluation, as well as assessment of technologies. A range of solutions are identified,

and best local-fit alternatives are selected. The basic premise is to increase farmers’ capacity to learn and apply innovations, and increase the likelihood of actual adoption. This type of action research facilitates participation of farmers in iterative technology development, co-learning and co-innovation, which has a significant effect on adoption of these technologies, as illustrated by a number of studies (Giller et al. 2011; Hounkonnou et al. 2012; Mariano et al. 2012). Numerous studies have reported the positive effect of participation by farmers in on-farm tests of agricultural practices and technologies. Relevant examples include the analysis of improved sorghum varieties in Burkina Faso and improved mangrove rice varieties in Guinea, which showed that adaptive on-farm research, demonstrations and trials were the most highly significant variable in explaining adoption decisions. Furthermore, a Peruvian study of soil and water conservation (SWC) measures found that participation in programs was the most important determinant of acceptance, particularly programs that offered incentives (Adesina and Baidu-Forson 1995; De Graaf et al. 2008), indicating the importance of both awareness of innovations and knowledge dissemination. This is related to the way research is organised and particularly the way it is designed to take into account the needs and knowledge of farmers themselves. It also relates to the ADOPT variable of trialability of innovations.

Social capital also serves to augment or hinder diffusion of innovations, through the practice of cultural traditions such as kinship and land inheritance. These relationships and interconnectedness in society may be considered an asset in influencing adoption. Studies in Peru and Paraguay, for example, have indicated a positive and significant correlation between diffusion of conservation agriculture (CA) practices, and high levels of social capital as a catalyst. This relates to the density and quality of networks. Observability of the innovation can be considered an additional boost if it characterises coordinated group activities. These have the potential to simultaneously reduce the cost of implementing technologies and practices (Knowler et al. 2001; Jara-Rojas et al. 2012).

- Recommendation for improving the Smallholder ADOPT model: Consider the importance of participation in development programs and other extension-related variables (discussed below) in influencing adoption.

3.1.2 Relevant existing skills and knowledge

Awareness and perception of problems, and awareness of the relevance of innovations are commonly found to correlate with adoption (Knowler and Bradshaw 2007; De Graaff et al. 2008). Conversely, lack of knowledge about problems or lack of exposure to measures that have been applied by other farmers have a negative correlation with the acceptance phase of innovation adoption. This correlation was also identified by Fujisaka (1993) in a study in the Philippines on introduction of agroforestry practices to improve sustainability of upland agriculture, and in Burkina Faso and Guinea by Adesina and Baidu-Forson (1995). Information on profitability, performance, correct implementation and adoption, and spread of technology determines the level and rate of uptake, particularly in populations with a limited risk capacity. The higher the degree of innovation complexity, the greater the importance of information and knowledge of associated practices in determining the adoption rate. This complexity can be considered in terms of management intensity (time, effort), learning difficulty, and economic impacts related to social attitudes, which ultimately translate into an increased need for information (Jack 2011).

It is essential to distinguish knowledge exposure from innovation awareness, especially when dealing with knowledge-intensive technologies and those requiring substantial changes in practices or farming system changes (e.g. conservation and precision agriculture, and natural resource management practices). This distinction is critical for successful implementation of technologies—that is, actual adoption. Knowledge exposure entails obtaining information on the performance and attributes of technologies. It involves heterogeneous information flow, a function of population-specific influences on the ability to learn. Kabunga et al. (2012) conducted a study on the role of heterogeneous knowledge exposure in estimating adoption parameters of tissue culture (TC) bananas at individual and population levels. Based on application of the average treatment effect approach, they found that adoption parameters are very different when accounting for heterogeneous knowledge exposure, compared with the classic adoption model.

Knowledge exposure is systematic, and related marginal effects vary. Results from the above studies

indicated positive and significant coefficients for several socioeconomic factors, including experience, group involvement and social networks, land holding size, and location in relation to input suppliers. However, awareness exposure is determined mainly by education and infrastructural accessibility (e.g. access to roads and markets). Inclusion of a gender factor (female-headed households) in terms of knowledge exposure was also identified. In the TC adoption study, when heterogeneous knowledge exposure was corrected for in the average treatment effect model, the predicted adoption rate almost doubled the 15% rate predicted using the classic adoption model. Consequently, it can be concluded that better understanding of technologies among farmers can substantially increase adoption rates. Additionally, predicted adoption rates in the subpopulation that was exposed to knowledge and in the unexposed subpopulation were 32% and 25%, respectively (Kabunga et al. 2012).

Making use of multiple sources of information and innovations by mapping the linkages and networks in the knowledge system, to establish information exchange mechanisms, is positively correlated with adoption and diffusion. These commonly provide avenues for farmer self-experimentation and exchange, and the resulting function of technology transfer agents. In practice, the role of participant farmers in enhancing an endogenous process of diffusion is highly significant, as other farmers in their networks become involved in testing and evaluating the innovations (Avila and Jabbar 1992; Collinson 2001). These sources of information mainly include farmer peers, cooperatives, group meetings, media, training workshops and extension officers.

External sources of information are more effective in the acceptance phase and the early stage of adoption, particularly in increasing innovation awareness and improving precise implementation (especially of complex innovations or technologies). Low levels of adoption can be predicted where, for a variety of reasons, there is a lack of information. This might be the result of inadequate incentives for those distributing information, high costs of acquiring information, and the design of provision of information (e.g. content and presentation). In this respect, the public and private sectors have different roles, which are suitable in different circumstances. The emphasis on information (as a determinant of adoption) is on its sources,

accuracy, quantity, detail, presentation form and content, and a multistakeholder learning process (Jack 2011).

As Bekele and Drake (2003) noted in their study on soil and conservation adoption in Ethiopia, variation is evident among farmers regarding the relative importance of the problem and understanding of the need for the technology. Integral aspects of information provision for improving adoption outcomes in the target population, in addition to those discussed above, include information on returns specific to the targeted beneficiaries, simplicity, appropriate sources, and level of specificity to preferences of subgroups. Both marketing and technical information are also essential, as is knowledge exposure.

- Recommendation for improving the Smallholder ADOPT model: Consider farmer ‘awareness of relevance’ of an innovation, not just awareness of the innovation. This can also be termed as perception of the problem.

3.1.3 Group involvement

According to Collinson (2001), participatory techniques that identify the needs of the local population, from its perspective, translate to relevance and greater uptake. Participatory techniques differ from top-down approaches, which provide commodities, products or technology that may not be needed or appropriate. Participatory technology development ensures effective technologies that are appropriate to the context, needs and circumstances of smallholders, and hence motivation for adoption. For example, according to Kabunga et al. (2012), research institutions in Kenya establish TC banana nurseries that are managed by farmer groups and others to provide subsidised plantlets to the groups via private companies. Early adopters within these groups are selected as champions who further facilitate adoption by setting up demonstration plots. Kabunga et al. (2012) also reported that adopters were mostly members of associations or community-based groups, and had significantly more contact with extension agents. Early adopters’ experience, however, had a negative effect on TC adoption within these social networks, as a result of information flow bias and misconceptions about the performance of, and perceived need for, the technology.

Observability of the innovation and adoption process among peers increases accurate assessment and efficient decision making on acceptance and actual adoption by farmers. Homogeneity in agroecological conditions—in population, land area size and other characteristics that affect technology benefits—positively affects the adoption levels attained through the participatory process of learning. Characteristics of the technology affect learning in this participatory approach, which influences adoption rates (Jack 2011; Kabunga et al. 2012). Possible linkage with trialability and observability concepts in ADOPT can be considered as a major aspect of this variable.

Information exchange networks develop from interaction between agricultural actors. Their structure is a critical attribute of the success of the broader innovation system and improvement of agrarian management. The main actors of social networks can be categorised as either formal or informal—they include individual producers, representatives of individual organisations (such as community-based organisations and non-government organisations), farmer field schools and extension agents. Actor, network and structure attributes determine the efficiency of information exchange, thereby influencing the rate of diffusion (Isaac 2012).

- Recommendation for improving the Smallholder ADOPT model: Consider the potential importance of information networks, cooperatives and collective actions, where they exist.

3.1.4 Advisory support

Facilitation and training are key approaches that can be employed for a positive impact on adoption and diffusion, particularly by way of research and development extension, and support from farmer non-government organisations, private interests and government incentives. This is particularly important in countries whose agricultural systems are characterised by inadequate and/or ineffective applied research extension (Roling 2004; Lybbert and Sumner 2012). It builds on agricultural knowledge and information systems as a theoretical framework (Roling 2004).

Identification of dominant networks and incorporation of collaborative actors fosters multistakeholder learning (Roling 2004). Farmers’ cooperative societies are common, especially in Africa and some Asian countries,

and have the potential to make significant contributions to building networks if they are coordinated with local growers' associations, input providers and local public institutions. Such networks of cooperation are influential in creating awareness of innovations by disseminating information, and hence in decision making, acceptance and adoption. Farmers within these networks learn about key issues, such as innovation profitability, and correct use and implementation, from personal and peers' experiences. Similarly, farmers can learn about the disadvantages of particular innovations through these networks, leading to low or no adoption. However, information delivery can be disconnected from beneficiary needs, and inconsistencies in service among various farmer types (e.g. women, poor) can be limiting (Jack 2011).

The availability of skilled personnel for training in new management skills is necessary to support the implementation of the innovation or practices. Mariano et al. (2012) identified the potential of extension systems that ensure improvement of technical and managerial capabilities to promote sustained peak adoption levels. Their study on adoption of modern rice technologies in the Philippines also noted the positive and significant impact of effective extension services on adoption rates. Adequate visits by extension officers have traditionally been identified as another variable that is positively related to the probability of adoption by the exposure of farmers to new information; however, it is not always a significant determinant of adoption levels (Adesina and Baidu-Forson 1995). As such, advisory support can be considered an integral part of the dynamic process of spread of information within social networks.

- Recommendation for improving the Smallholder ADOPT model: Consideration of the density and efficiency of extension networks would be useful in predicting adoption and diffusion rates of innovations; however, the impact on levels of adoption may often depend on other factors.

3.1.5 Institutional linkages—organisation (coordination) of institutions

Applied research institutions currently focus on investing in agricultural research as the source of innovation. This results in a tendency towards a prescriptive technology transfer scenario, in which allegiance to the product (technology) and research

discipline prevails. Also influential, albeit negatively, is the weak financial and management status of these public institutions (Collinson 2001).

High-level institutions (e.g. research institutions) play a major role in enabling access to, and adoption of, productive technologies. Opportunities that can enhance provision of interlinked services include extension, credit, inputs, training and marketing. Input and output market sectors are interrelated with these services, and also depend on development of infrastructure (Giller et al. 2011; Hounkonnou et al. 2012; Lybbert and Sumner 2012). Government support is crucial in strengthening these institutional and localised ties, thereby resulting in higher diffusion through improved communication networks and providing incentives for adoption.

The presence of two-way linkages (vertical and horizontal) has a positive effect on adoption, as opposed to a linear, top-down approach. These linkages mainly include research institutions, technology transfer workers, policy makers (at local and regional levels), input and credit suppliers, and educational institutions (Avila and Jabbar 1992). Bridging ties that connect farmers to organisations are critical to the agency of the actors within social networks and to information dissemination, which are major factors influencing decision making. This is evident in the findings of Isaac's (2012) investigation of network typology in management of agrodiversity in cocoa-growing regions of rural Ghana. He reported bi-directional information flow between producers, local opinion leaders and relevant organisations. In addition, the long-term effectiveness of farmer field schools in adoption of agrarian practices, as a result of the government's promotion of external agency linkages, was also evident. Increased network diversity is another outcome of interorganisational ties; the potential to augment effective information exchange is positively correlated with adoption levels and diffusion of innovation systems. 'The interactions of a variety of agrarian actors and the subsequent emergent networks of information exchange may be fundamental to adoption of innovative ... practices ...' (Isaac 2012, p. 9).

- Recommendation for improving the Smallholder ADOPT model: Consider including a variable in newer versions of Smallholder ADOPT that

accounts for the role that institutions can play to support or hinder adoption of innovations.

3.1.6 Education levels

The level of education of farmers positively correlates with adoption, on the basis of farmers' information and knowledge about the innovation in question. Reference to education may be specific or general (Knowler et al. 2001). Lack of education has been found to influence farmers' perception of the problems that the new technologies are introduced to solve (e.g. soil erosion). Farmers may be unaware of the potential effects of the problems or not recognise them as serious, particularly if negative impacts are not easy to perceive or are longer term. Heterogeneous agroecological conditions affect the perceived need of an innovation. For instance, adoption levels of TC banana technology were significantly lower in high-potential regions of Kenya and Uganda than in low-potential areas (Kabunga et al. 2012). This was due to greater need and perception bias of the attributes of the technology. Gine and Yang (2009) report findings in southern Malawi that technology adoption increases levels of education, income and other indicators of household socioeconomic status among maize farmers who take up use of hybrid maize varieties.

Relevant existing knowledge and higher education levels among farmers result in more time being invested in SWC measures, as evidenced in a Bolivian study; Adesina and Baidu-Forson (1995) and De Graaff et al. (2008) demonstrated that education level was correlated with a positive attitude to conservation. Thus, a higher probability of these variables determines actual adoption levels. However, this differs at an individual country level—in Peru, higher opportunity costs of labour have a strong negative influence on labour investment (De Graaff et al. 2008). Education levels determine farmers' information processing and innovative ability, and participation by observation of early adopters. Education can therefore facilitate uptake of innovation, and ultimately influence adoption and diffusion rates.

A survey of Ethiopian farmers found that 50% and 33% of farmers obtain information from extension workers and from other farmers, respectively (Jack 2011). Under conditions of technological change, the benefits of higher education levels increase. It is important to note that experience is also a determinant of adoption

rate, and its related returns may be higher than those of education under conditions of technological stagnation (Lestrelin et al. 2012).

Recommendations for improving the Smallholder ADOPT model:

- Consider potentially longer awareness phases, possibly relating to education levels.
- Consider the significance of progressive attitudes, or characteristics of sociocultural dynamism in target population households.

3.2 Learnability—innovation characteristics

3.2.1 Compatibility with local practices

The compatibility of innovations with local practices, and with policy and institutional frameworks influences uptake and the time to peak adoption. It also influences the continued use of the innovation. Innovations that include the transfer of indigenous knowledge in the process of developing and implementing technologies are more widely acceptable, and positively affect adoption levels and diffusion. Knowler et al. (2001) also noted that local traditions may match the overall concepts of innovations, despite lack of knowledge of specific technologies, as seen in some regions of South America, where commercial crop innovating traditions motivated adoption and diffusion of CA. Some practices are undertaken as part of tradition and culture that align with common ethics and in the interest of public goods. Agroforestry innovations for management of upland agriculture in the Philippines did not match farmer practice, which, in some instances, worked even better (Fujisaka 1993).

3.3 Relative advantage—population characteristics

3.3.1 Role of land tenure and ownership

A lack of adequate tenure hinders investment in agricultural innovations—including fallowing, planting

and irrigation—especially over the long term. This is exacerbated by dependence of smallholder farmers, for the most part, on credit facilities that require security of land ownership as collateral. If farmers are tenants, benefits of capital investments accrue to the land owners instead—hence farmers’ reluctance to participate (Fujisaka 1993; Knowler et al. 2001). In Malawi, several studies and national-level survey data from 2004–05 have shown that adoption of hybrid maize is higher among households in the highest quintile of land ownership than in the lowest quintile. Increase in plot size is also positively correlated with a rise in adoption of these high-yield maize varieties (Gine and Yang 2009).

According to in-depth research conducted by Jack (2011), various institutions exist in developing countries for the transfer of use and production rights of farmers, including tenancy and rental arrangements. These forms of contract farming inherently trade off incentives and risk sharing. Therefore, tenancy engagements, such as share tenancy, create disincentives for investment in technologies that improve productivity, as a result of outputs sharing. Share tenancy involves reduced risk but less incentive to invest, while rental contracts generate greater investment incentive, even though all risk is borne by either the tenant or the landlord (as is the case in wage contracts). Monitoring costs that landlords bear in share tenancy hinder adoption of some technologies, especially those that require information certainty and are not easily observable. Oostendorp and Zaal (2012) argue that land ownership change and transfer also has a significant and direct impact on adoption behaviour.

The state of insecure tenure is associated with lower investment in innovations for increased agricultural productivity (especially those with long payback periods) and also reduces the value of long-term profits. The spinoff is the need for strategies geared towards increasing incentives for landholder investment, such as allocation of all the increased productivity benefits to the renters. To improve adoption incentives, well-functioning land markets that ensure improved efficiency among productive farmers are required (Knowler and Bradshaw 2007; Jack 2011). This may also be linked to the management horizon and family succession variable. Notwithstanding, caution should be exercised in assuming that land privatisation or tenure security is an incentive to increased investment in improved land management, since it is not a guarantee

of the anticipated land management changes. As exemplified in empirical studies conducted in Africa, farmers may accept titling but not the required change of practices. This is due to the flexibility of customary tenure (Knowler et al. 2001).

Traditional property rights also play a role in providing incentives for investment. Formal titling and complete land markets do not guarantee tenure security, but they do allow easier access to credit. The influence of customary tenure can potentially result in a negative outcome for less powerful groups, such as women. Under circumstances of insecure formal or informal tenure, certain practices potentially reduce land security, which poses an expropriation threat. Institutions that govern land allocations—whether customary or formal titling processes—determine gender balance in land rights and ownership issues. The resulting social inequalities have a negative or positive correlation with adoption levels. For example, in Ghana, it has been shown that adoption levels of practices related to increasing land productivity are higher among farmers in regions where issues such as land insecurity, expropriation threats, extreme land pressure, and social or political influence are dominant (Bekele and Drake 2003; Jack 2011).

- Recommendation for improving the Smallholder ADOPT model: Give greater consideration to land tenure and property rights security, particularly as it might relate to innovations with longer term impacts.

3.3.2 Labour availability in the population

Farmers are interested in improved labour and capital productivity to achieve higher yields (Collinson 2001). The availability of affordable hired labour is important; however, it is correlated with other social and demographic variables. The availability of family labour increases with larger family size. Where incentives to adopt innovations are received, farmers can spread their investments in SWC over larger areas so that they benefit from more incentives, as found in a Peru case study (De Graaff et al. 2008). In central Chile, the positive correlation of larger family size with higher peak adoption levels was considered one of the significant determinants influencing adoption (Jara-Rojas et al. 2012).

The dynamics of labour allocation have a direct impact on the incentive to adopt agricultural innovations. An example is where increased labour productivity results in increased off-farm labour income; diminished incentive to adopt labour-saving technologies is also common where local labour markets are seasonal. According to Bekele and Drake (2003), and Jack (2011), where labour allocations are inefficient as a result of problems in the labour market—for instance, low population density and underdeveloped rural infrastructure—the effect on peak adoption level is negative. However, in the longer term, the time to peak adoption is longer, and lower rates of adoption are experienced because of a lack of investment incentives. Labour availability and allocation call for an understanding of the target population, as specific requirements of labour determine peak adoption levels and the choice of technologies—in particular, those that are labour intensive versus labour saving. The relevant characteristics include off-farm employment, limited household labour and involuntary unemployment. Bekele and Drake (2003) found that availability of household labour had a significant negative correlation with adoption of soil conservation structures in Ethiopia, as a result of the factors discussed above. Labour scarcity during planting hinders investment in new technologies and practices, particularly for poorer farmers lacking access to credit facilities. An example is the negative and significant effect of reliance on off-farm employment by poorer population segments. Higher opportunity costs of household labour are realised with increased availability of off-farm work (Jara-Rojas et al. 2012; Giller et al. 2011). The relationship between labour aspects (in terms of intensity) and input and output markets is another determinant. Spatial patterns—for example, distance to urban centres—have been observed to influence relationships between infrastructure, information and labour markets in Nepal (Jack 2011).

3.4 Relative advantage—innovation characteristics

3.4.1 Agroecological conditions

The performance of technologies in the context of seasonal climatic variations is unpredictable;

therefore, prior establishment of reliability and regularity is important. New varieties, crops and so on must be suitable to local conditions. As a result, a location-specific, downstream stage of research is needed, mostly accompanied by considerable investments. Long-term research approaches are required to provide explanations for these seasonal variations. Most developing countries lack adequate local research capacity that would enable benefit from upstream international research. Such countries can overcome these constraints to adoption if they have similar agroecological zones to countries that are highly advanced in research and development. Africa is particularly disadvantaged in this respect, as a result of its diversity of agroecological zones that require adaptation of transferred technologies, practices and varieties. This has the potential to limit diffusion of innovations—for instance, to prevent soil and nutrient deficiencies (Giller et al. 2011; Lybbert and Sumner 2012; Mariano et al. 2012).

Conditions that permit intensive and profitable use of small-scale agriculture increase acceptability of innovations, thereby positively influencing both the peak adoption level and the time to peak adoption. Impact studies have shown a poor level of continued use of technologies that depend for their adoption on production conditions (such as drought) over which farmers have no control. These include non-biophysical conditions (Hounkonnou et al. 2012). Mixed results—positive, negative and even insignificant correlations—have been found for the impact of rainfall, specifically in CA (Knowler and Bradshaw 2007). Accessibility to rainfed land, and soils of low agricultural potential were identified as factors positively correlated with adoption of CA in Laos (Lestrelin et al. 2012). Other physical conditions, such as topography, soil characteristics, farm size, and land quality and fertility, determine the actual adoption of innovations that increase productivity and relative financial attractiveness. This is due to increasing benefits of net returns, as evidenced by studies in Latin America (Bekele and Drake 2003), and in Ethiopia and Laos (Lestrelin et al. 2012). Some of these conditions that permit intensive and profitable use of small-scale agriculture can also arguably be considered as ultimately translating into ease and convenience determinants. Specific innovations, such as water conservation practices of CA, lead to a high correlation between the agroecological zone variable and adoption. Additionally,

higher costs of natural capital, such as water rights, promote adoption of practices and techniques that reduce demand for that natural capital. These issues are common across a range of CA practices (Jara-Rojas et al. 2012). Higher investments in innovations are made with increasing farm size, mainly because of higher productivity, as exemplified by SWC practices in Bolivia and Peru, as well as a synthesised review of analyses of CA studies (Knowler et al. 2001; Knowler and Bradshaw 2007; De Graaff et al. 2008).

3.4.2 Environmental orientation and time for environmental benefits to be realised

Land tenure is predominantly communal or under ownership of extended families; hence, plots are viewed as 'public goods'. The need to uphold social security and equity may influence acceptability of technologies either positively or negatively. Stewardship is a cultural norm in some areas, requiring a compromise between individual interests and societal benefits in decision making. However, the main concerns or considerations do not focus on environmental benefits such as climate change mitigation and adaptation, regulation of watersheds, reduced sediment loads, carbon sequestration and biodiversity conservation. This is due to limited awareness of various aspects of environmental degradation, such as increased sediment load in surface water, destruction of ecosystem functioning and related indirect use values. Environmental factors may only be seen indirectly as responses to declining yields or productivity, or soil erosion and degradation, since they are often masked by other factors affecting production. In the case of CA, most benefits can be community wide, whereas costs accrue to the individual farmer; this emphasises the need for incentive programs to attract individual farmers' investment. Adoption levels have been considered to be a function of profitability perception. This may be backed by financial analyses that have indicated positive net financial impact at the farm scale. Other studies have reported a negative correlation between net returns and stewardship trade-offs, on the one hand, and actual and continued adoption and diffusion rates, on the other (Knowler et al. 2001; Knowler and Bradshaw 2007).

- Recommendation for improving the Smallholder ADOPT model: Give a lower weighting to environmental orientation and time for benefits,

but possibly a substantial weighting of benefit to the community, village or collective.

3.4.3 Profitability and discount rates

Smallholder agriculture is characterised by the goal of obtaining short- and medium-term benefits. Rapid paybacks and financial incentives have been key influences in Latin America, where adoption of CA has resulted in notable financial benefits in terms of net farm income, with higher success rates in medium to large farms (Knowler et al. 2001). Higher value is attributed to immediate costs and benefits than to those that accrue in the future. For farmers with short-term planning horizons, as is common among poor smallholders (Giller et al. 2011), longer periods for the materialisation of benefits of practices and innovations are a potential barrier to adoption, as discount rates influence the magnitude of future benefits.

A summary of an analysis of studies conducted in western Africa and Latin America (De Graaff et al. 2008) concluded that integration of income-generating rural development activities that may potentially improve future opportunities augments investments in innovations, especially by market-oriented farmers. The potential for future benefits in the form of increased productivity, and therefore future profit benefits, also increases the rate of participation in maintenance of practices, and the intrinsic motivation of adopters helps sustain continued use. In Mali, replication and spontaneous diffusion of SWC measures even among previous non-adopters were evident, despite the negative effects of investment costs and lack of availability of resources. Actual mid-term profitability is another positive determinant; although it is insufficient for longer term continued use, it may affect replication.

The impacts of technology on roles, priorities and opportunities for members of the household and community vary among the resource rich and resource poor; the latter may be termed as laggards by misconception (De Graaff et al. 2008). In settings where stewardship of land is a cultural norm, trade-offs are made between private net returns and collective utility. Collective implementation of technologies at regional levels and participation in farm management strategies of cooperative societies may be required of rural smallholders, in the case of both communal and private property. This relates particularly to innovations

whose efficacy is determined by collective action (higher adoption level can be achieved if dimensions of the innovation are compatible). The influence of culture also includes economic and business forces; however, solid systematic studies in this area are lacking (Collinson 2001; Steers et al. 2008).

Recommendations for improving the Smallholder ADOPT model:

- Consider the culturally influenced aspects of collective behaviour that may affect the relative importance of private profit and relative advantage.
- Consider the importance of the population's market or profit orientation versus subsistence and traditional/cultural influences on change.

3.4.4 Relative upfront costs, investment costs and access to credit

A need for large capital outlays and other financial requirements to take up innovations can restrict changes in farm practices. Government and other support programs, and credit and extension policies have a strong positive correlation with levels of adoption. In addition, they act as a means of providing necessary interventions, to some extent (Bekele and Drake 2003). However, high transaction costs associated with credit supply discourage adoption, and these interventions have been generally ineffective. Program incentives have been observed to be short-term benefits that may increase acceptability and uptake of innovations but are unsustainable for maintenance and replication in the long term (for instance, subsidised credit potentially leads to higher interest rates due to defaults). A study of smallholder livestock production in Cameroon reported that gross income (a proxy for initial capital and upfront costs) was statistically significant as a direct determinant of adoption decision making, whereas expected income potential or profit benefit in the future was statistically insignificant. Investments with high levels of risk negatively affect perceptions of expected returns from the adoption of improved technology. This contrasts, however, with Kessler's analysis of SWC investments in Bolivia, where improving future prospects of income generation were crucial as a significant positive influence on actual adoption, triggering investments by market-oriented farmers (Tambui 1989; Knowler and Bradshaw 2007; Hounkonnou et al. 2012). Wealthier farmers were able to take on greater levels of risk,

which gave them an advantage as adopters, according to studies in Chile (Jara-Rojas et al. 2012) and Ethiopia (Anley et al. 2007).

Being able to access credit is critical for smallholders in procuring basic farm input; this has been illustrated by numerous efforts to increase accessibility to affordable credit over many years and using many strategies in the Philippines. Farmers in typical smallholder developing contexts still rely on informal credit sources, including input suppliers, traders and relatives (Mariano et al. 2012).

Unavailability of credit is a widespread challenge, which is mainly caused by limited liability, fragmented rural financial markets, asymmetric information, and contracting and enforcement problems. Alternative options do exist, although they are not in widespread use, for innovative collateral substitutes to improve access to credit facilities and financial services; these include farm output supply contracts, standing crops and reputation. Financial products that allow commitment to future saving or investment by individuals during periods of cash availability have been found to improve adoption outcomes, according to some recent studies in Malawi and Kenya (Jack 2011).

Recommendations for improving the Smallholder ADOPT model:

- Consider the availability to the population of lending practices that result in a lower cost of borrowing.
- Consider higher future discount rates to reflect greater value attributed to meeting short-term needs for the adapted version of ADOPT.

3.4.5 Labour requirements

A potential for savings on labour inputs leads to reductions in production costs, thereby positively influencing adoption rates as a result of higher returns to labour. Examples are given by Knowler et al. (2001), in a comparative analysis of alley farming in western Africa and bush fallow with no-till technology, whose findings indicated substantial labour savings under the implementation of no-till technology. Higher returns to labour under CA were also realised in studies of smallholders in Latin America.

Management intensity demand is another determining factor, since it influences the time spent on the farm—for instance, in direct management of experiments on farmers' fields. Farmers are also concerned about the need for additional or incremental labour; labour-intensive technologies are often a challenge because of related opportunity costs (Knowler et al. 2001).

Some technologies affect the gender division of labour and may require changes in household labour responsibilities, which may exacerbate existing gender-based conflicts over distribution of labour. For instance, herbicide use creates additional labour demand among males that potentially acts as a barrier to CA adoption (Tambui 1989; Avila and Jabbar 1992; Giller et al. 2011). In places where labour is a limiting factor, innovations that are labour intensive have faced the challenge of low adoption levels. For example, in the case of mangrove rice farming in Guinea, high labour demand for manual threshing created incentives for uptake of easily threshed rice varieties (Adesina and Baidu-Forson 1995).

Transaction costs of hired labour hinder the uptake of technologies that demand more than household labour, rendering hired labour a poor substitute for the majority of smallholders (Fujisaka 1993). These transaction costs increase alongside uncertainty due to volatility in the labour market, especially during seasons when labour supply varies from surplus to limiting ('bottleneck'). Two other conditions of market failure limit farmers' ability to meet temporary changes in labour demand: inelastic labour supply, and liquidity constraints due to seasonal harvests and lack of credit access (White et al. 2005). Results from a study that contrasted adoption of higher yield and early-maturity upland rice varieties in a Peruvian bush fallow system (White et al. 2005) revealed that farm management trade-offs arise from the uptake of new technologies, as a result of implied demands on limited labour resources. These trade-offs, especially when opportunity costs are high, thereby influence acceptance and the adoption level for resource-poor farmers, as their decisions favour technologies that fit with their resource input constraints. Return on opportunity-costed labour (RTOCL) was identified as accounting for, and addressing, the values of seasonal labour, costs, and related financial and management trade-offs. The conclusion is that RTOCL is an accurate measure for quantifying the significant relationship between innovations, seasonally changing labour

demands and farm financial performance, which means that it is an effective decision criterion in ex-ante adoption and diffusion analyses.

Notwithstanding, management intensity and trialability of innovations (in terms of observability and complexity) determine the labour requirements. Since education levels and information processing interact with labour assets in influencing adoption of innovations, the loss of farmers' educational benefits serves as a disincentive in human capital investment. Hired labour generally drives up monitoring and transaction costs, as well as increasing the need for additional incentives—hence, it is a negative influence on adoption. However, higher off-farm wages induce peaks in adoption levels of labour-saving technologies (Jack 2011).

- Recommendation for improving the Smallholder ADOPT model: Consider differences in availability of cheap labour between populations (associated with the relative advantage of labour-demanding or labour-saving innovations).

3.4.6 Risk orientation and effect

Practices, technologies and innovations that improve on-farm profitability and significantly reduce risk have evidently higher peak adoption levels. This is based on cases of adoption of CA in several countries in Latin America (Brazil, Paraguay, Argentina), which has the highest rate of adoption of no-till practices in the world (FAO 1995). Perceived risk and level of risk aversion are highly dependent on farmers' perception and awareness of the problem or relevance of the innovation, as well as their subjective preferences for innovation characteristics. A constraint to the adoption of some innovations is a related complex process of evaluating the benefits of risk reduction or mitigation, and profitability for farmers (e.g. drought-tolerant crop varieties) (Adesina and Baidu-Forson 1995; Lybbert and Sumner 2012).

Some investigations on the role of risk in take-up of credit have been undertaken in developing countries in recent years to determine whether it is a hindering factor, and, if so, to what extent. In principle, provision of insured loans should lead to higher adoption levels. However experimental results from Gine and Yang (2009) in Malawi indicated a higher uptake of non-insured loans among risk-averse farmers than

among those to whom weather insurance was made available. Among the reasons cited are that the implicit insurance inherent in limited liability contracts is more attractive than the subsequent increased interest rate affected by stand-alone, formal insurance bundled with a loan. Other reasons are variations in market prices, the timing of insurance policies, and credit access within the cropping seasons. Notwithstanding, farmers' education, income and wealth (as a proxy for default costs) were positively correlated with adoption of hybrid crop varieties among those offered insured loans, whereas these characteristics did not matter when the loans offered were uninsured. This brings into play issues such as uncertainty about risk characteristics of innovations (since insurance on loans may be perceived as a signal of higher risk), basis risk and perceptions about default costs as plausible reasons for the differences (Gine and Yang 2009).

- Recommendation for improving the Smallholder ADOPT model: Consider the presence of insurance or guarantee schemes when evaluating risk characteristics and the influence of risk.

4 The ADOPT tool

4.1 Conceptual framework

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) was developed in response to the recognition that many significant investments in agricultural research, development and extension are made without strategies for understanding the adoption process or predicting likely levels of adoption. ADOPT is based on a conceptual framework that combines established adoption and diffusion principles (e.g. Lindner 1987; Feder and Umali 1993; Rogers 2003; Pannell et al. 2006).

ADOPT encourages a process of learning, promotes users' engagement with adoptability issues, and encourages users to think more critically about the definition and characterisation of both the innovation under consideration and the target population of potential adopters. It focuses on characterising and

predicting diffusion across populations, not individuals. ADOPT can be used across a range of scenarios and phases of project development:

- project design phase
- project implementation
- planning or implementing development and extension projects.

Users undertake a structured process of responding to 22 questions relating to a conceptual framework (Figure 1). Responses are then used in equations and functions that provide a numeric representation of how the conceptual framework variables relate to each other, and how they influence time to peak adoption and peak adoption level. The expected diffusion of the innovation is graphically represented using an S-shaped cumulative adoption curve (see Griliches 1957; Marsh et al. 2000).

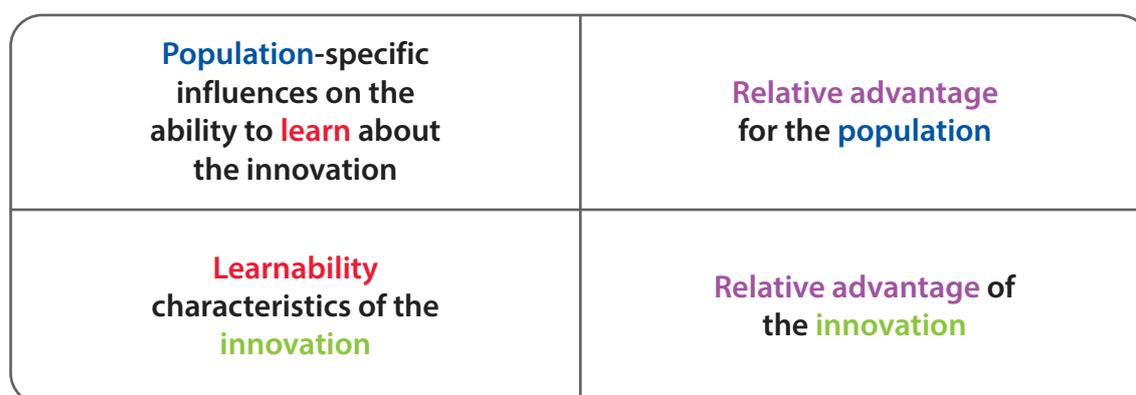


Figure 1. Conceptual framework of ADOPT. The two left-hand quadrants influence the time taken to reach peak adoption, and the two right-hand quadrants combine to influence both peak adoption level and the time taken to reach peak adoption

The literature shows that influences on adoption can be conceptualised as related to:

- learning about relative advantage, or
- the actual relative advantage.

Similarly, each influence can also be characterised as being related to:

- the population, or
- the innovation.

The conceptual framework can be represented across four quadrants (Figure 1). The two left-hand quadrants (population-specific influences on the ability to learn about the innovation, and learnability characteristics of the innovation) only influence the time taken to reach peak adoption; they do not influence the peak adoption level. The right-hand quadrants (relative advantage for the population and relative advantage of the innovation) combine to influence both the peak adoption level and the time taken to reach peak adoption. The variables that contribute to those quadrants are discussed in more detail below.

4.2 ADOPT variables

4.2.1 Population's ability to learn

This quadrant focuses on population-specific influences on the ability to learn about the innovation, in terms of both its existence and the potential relative advantage it may offer. This reflects the learning process of adoption, whereby farmers gather information, reassess their beliefs about the innovation under consideration and review their decision about whether or not adoption will be of net benefit. The four variables contributing to this quadrant are:

- *group involvement*, which is aimed at the extent to which the target population is involved with peer-learning networks
- *advisory support*, which aims to uncover how much the target population uses advisers for advice relevant to the innovation

- *relevant existing skills and knowledge*, which captures whether potential adopters will need to spend time developing new skills and knowledge before they can adopt the innovation
- *awareness*, which captures the target population's existing awareness of the innovation.

4.2.2 Learnability characteristics of the innovation

This quadrant is about innovation-specific influences on the ability to learn about the innovation. It has three main variables:

- *trialability*, which ascertains whether small-scale trials with the innovation are possible
- *innovation complexity*, which identifies whether the effect from the use of the innovation is able to be evaluated simply
- *observability*, which focuses on whether any use of the innovation in a local district is easily observed by others, such as neighbours.

4.2.3 Relative advantage for the population

This quadrant is about characterising the population in terms of factors that will influence which innovation characteristics are likely to lead to the greatest relative advantage from a particular innovation. The six variables are:

- *enterprise scale*, which focuses on the relative importance of the particular enterprise that will be affected by the innovation to the farm household
- *management horizon*
- *profit/productivity orientation*
- *local community benefit orientation*
- *risk orientation*
- *short-term constraints* that may slow adoption as a result of transient resource issues (e.g. caused by drought).

4.2.4 Relative advantage of the innovation

This quadrant deals with the relative advantage of the innovation that is derived from the innovation's

characteristics. Characteristics represented in this quadrant can sometimes be improved upon at the project design and development stage. The nine variables are:

- relative up-front cost of the innovation
- reversibility of the innovation
- profit/productivity benefit in years that the innovation is used
- future profit/productivity benefit; future benefits are discounted based on the expected time to future benefits
- time until any future profit/productivity benefits are likely to be realised
- risk effect
- costs and benefits for the local village or community
- time until costs and benefits for the local village or community are realised
- ease and convenience.

4.3 Smallholder ADOPT as a framework

Smallholder ADOPT should be seen as part of a larger adoption framework (Figure 2). Smallholder ADOPT was designed to use sufficient variables from existing adoption theory to make a realistic prediction without requiring exhaustive levels of detail. The 22 questions in ADOPT can assist users in thinking about aspects of adoption, or enable a more informed discussion about adoption. We recognise that ADOPT may not cover all aspects of adoption because not all influences on adoption are consistent or easily measured. The questions in ADOPT are designed to encourage users to think broadly about the innovation process and the influences on adoption of innovations. There are other influences on adoption, but including them would come at a cost to the usefulness that Smallholder ADOPT achieves by balancing simplicity and exhaustiveness.

The process of responding to the 22 questions requires reflection on the concepts underpinning the questions, and can be as important as the prediction produced

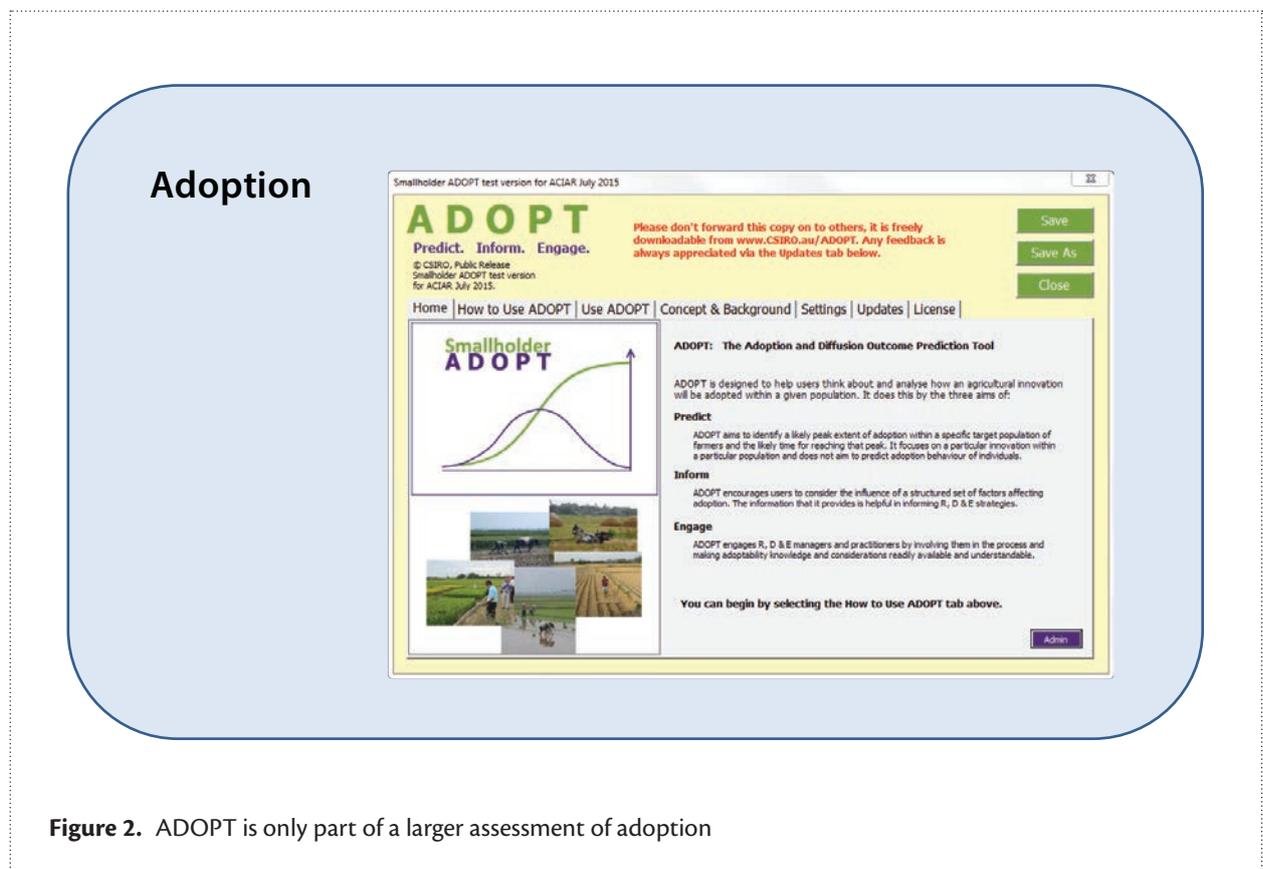


Figure 2. ADOPT is only part of a larger assessment of adoption

at the end. In line with the initial aims of Smallholder ADOPT to ‘predict, inform and engage’, the use of Smallholder ADOPT should be seen as a process of thinking, and developing understandings, about adoption, which includes a numeric prediction and S-curve.

Smallholder ADOPT can be used in a variety of ways, including (Figure 3):

- in the project design phase as an ex-ante impact predicting tool
- during project implementation
- during project evaluation or ex-post monitoring

- as a boundary object to discuss options with stakeholders
- as a tool to explore the systems that underpin innovation.

4.4 Structure of ADOPT

Figure 4 presents a simplified version of the Smallholder ADOPT model structure. The numbers in the boxes represent the 22 questions in ADOPT and are explained in Section 4.3.

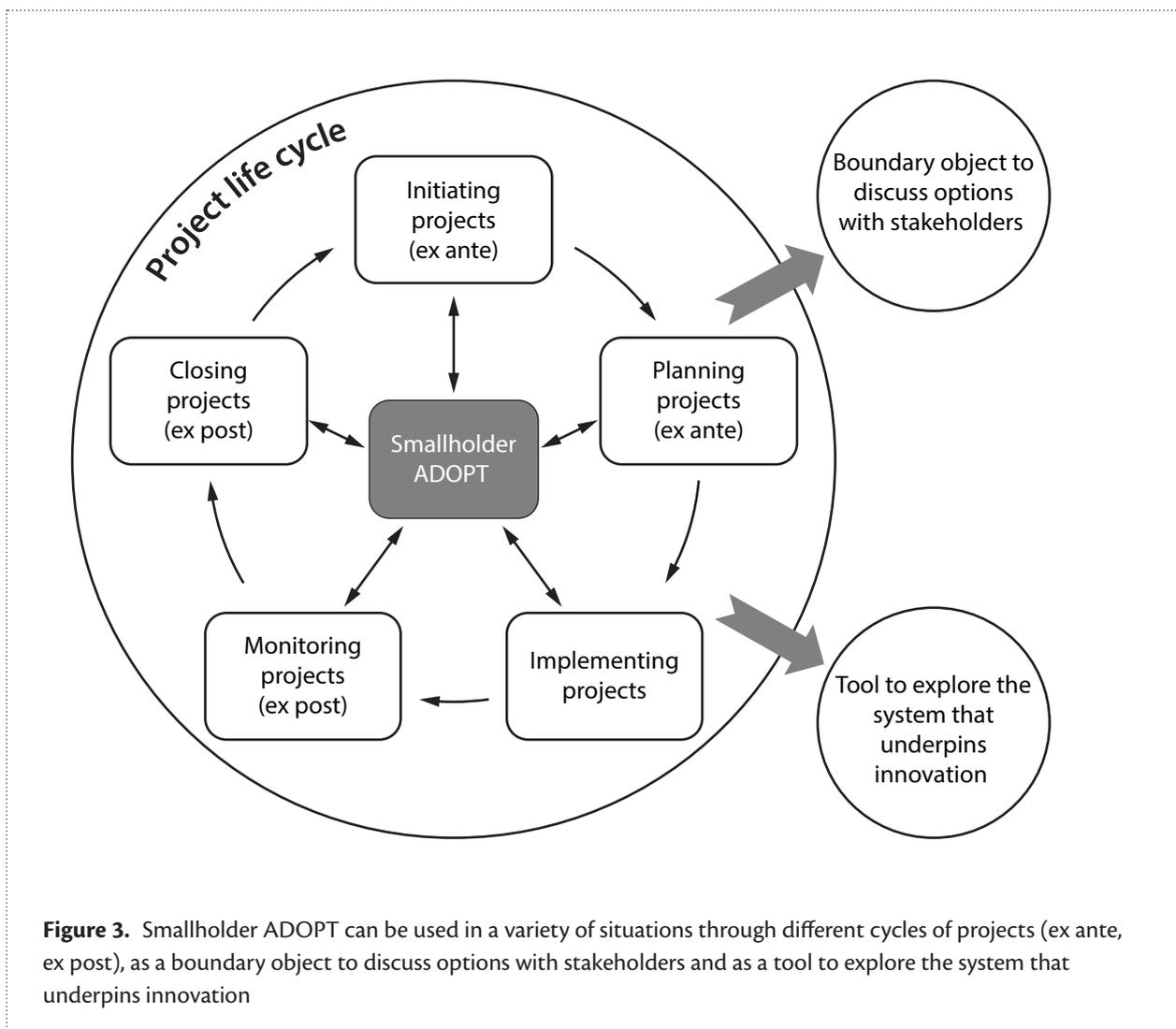


Figure 3. Smallholder ADOPT can be used in a variety of situations through different cycles of projects (ex ante, ex post), as a boundary object to discuss options with stakeholders and as a tool to explore the system that underpins innovation

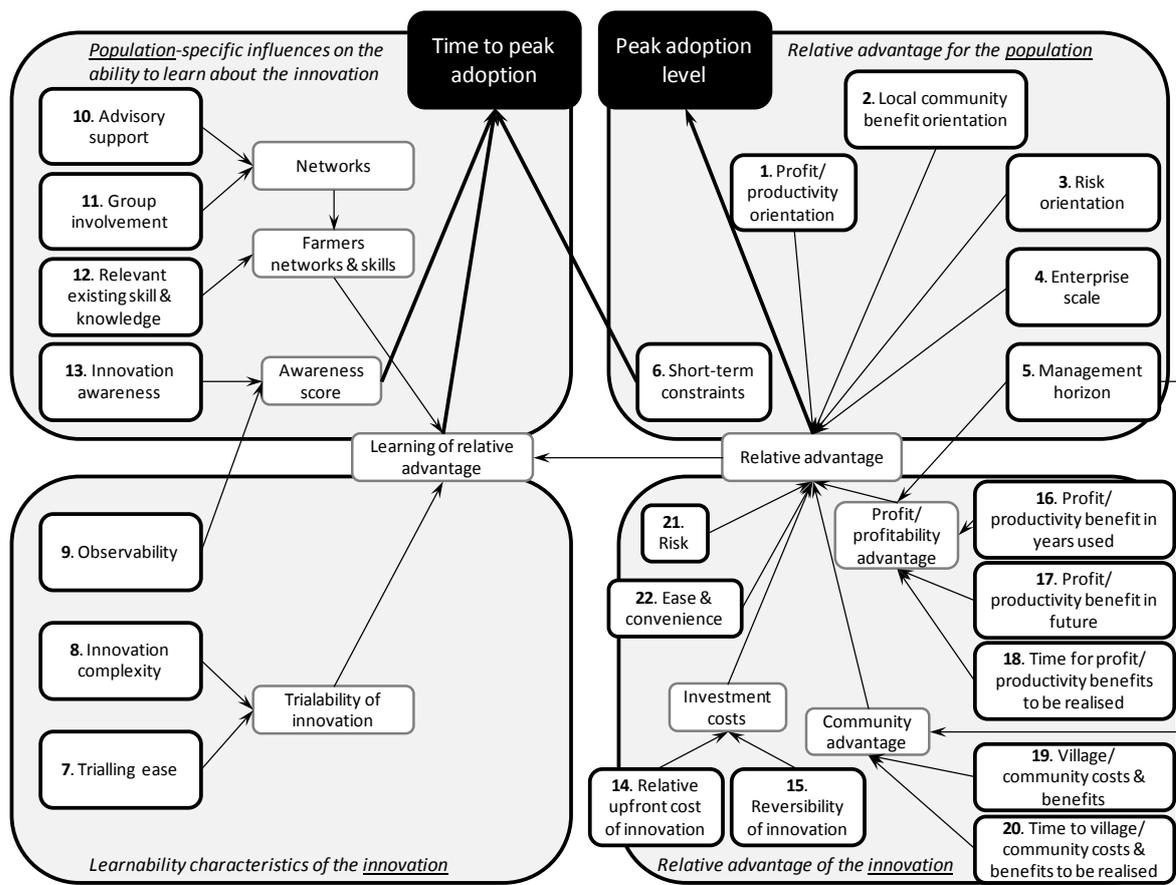


Figure 4. Simplified diagram of the Smallholder ADOPT variables by quadrant, and the interactions that produce the outputs of peak adoption level and time to peak adoption

5 Survey of ADOPT users

A survey of existing users of the Adoption and Diffusion Outcome Prediction Tool (ADOPT) was conducted in late 2014 and early 2015. The survey was run through SurveyMonkey. There were 37 respondents (19% of

the 199 emailed invitations). A summary of the main changes made for Smallholder ADOPT, based on user feedback, is shown in Table 1.

Table 1. Summary of changes made for Smallholder ADOPT

Issue	Suggested solution
<ul style="list-style-type: none"> ■ Adoptability report structure 	Updated the adoptability report: <ul style="list-style-type: none"> ■ Added link to further information (www.csiro.au/adopt) ■ Updated smallholder diagram (see below) ■ Consolidated all the questions, responses and reasons into a single table ■ Added some footnotes to the table of adoption values ■ Added 'time to near-peak adoption level' and value to summary table ■ Added a few words to the labels for the sensitivity analysis graphs ■ Added 'Use with caution' in the 'How to use' tab (and adoptability report) ■ Added new graph showing extra curves with one step up and one step down
<ul style="list-style-type: none"> ■ More questions 	Added additional questions
<ul style="list-style-type: none"> ■ Suggest solutions to speed up adoption/extension processes 	Provided additional information to look at what could be done to improve adoption
<ul style="list-style-type: none"> ■ Better explain the sensitivity analysis graph 	Provided a short description of what the sensitivity graph means on the graph, so that it is shown on the screen and in the adoptability report that is generated
<ul style="list-style-type: none"> ■ S-curve 	Included uncertainty in the generation of the S-curve through including one-step change for most variable questions (and a description of what this means)
<ul style="list-style-type: none"> ■ Simplify questions, provide more examples 	Updated additional information next to questions to provide more details. Used validation responses as examples (choose a rapid and high, and a slow and low as extremes)
<ul style="list-style-type: none"> ■ Fix relative advantage 	Adoption was too rapid and too high (from the developed country version), so revised influence of relative advantage and some associated factors (using case study examples)
<ul style="list-style-type: none"> ■ Run on alternative platform 	Maybe in the future?

6 Case studies for validation of ADOPT

6.1 Selection of case studies

The key criterion for validating the Smallholder Adoption and Diffusion Outcome Prediction Tool (Smallholder ADOPT) model was to find appropriate studies in which time-series data have been collected on the adoption rates of innovations. There were surprisingly few good examples of well-studied adoption rates over time. We used existing contacts and networks to identify good datasets, and established contact with relevant people to discuss access to the data and willingness to participate in a validation exercise. In summary, the criteria were:

- well-documented time-series data of adoption of innovations
- willingness to participate in a validation exercise for ADOPT
- willingness to share data
- willingness to participate in an ADOPT workshop to model adoption rates
- ability to undertake analysis before the end of June 2015.

A range of potential case studies were discussed with the Australian Centre for International Agricultural Research (ACIAR), and the following case studies were selected (Table 2). In total, six innovations were tested: one for the Adaptation to Climate Change in

Asia (ACCA) project (direct seeder technologies, in three locations), two related to International Maize and Wheat Improvement Centre (CIMMYT) projects, and three for the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) project. The Papua New Guinea (PNG) case study presented an opportunity for face validation of the model itself. A further case study for PNG was planned, but could not be completed in time for presentation in this report.

6.2 Process used to run ADOPT workshops and validate the model

Setting up and running the ADOPT workshops involved a series of steps. It was important that the key contacts were aware of what we were trying to do and what was involved. The process involved:

- contacting key personnel
- discussing data and time requirements
- agreeing on process
- obtaining data
- running the ADOPT workshop
- writing the workshop report, including validation with data for comments and feedback.

A summary of the main findings is presented below.

6.3 Summary of findings from case studies

The main results of the validation exercise are shown below. For each case study, we present a graph from the original run of Smallholder ADOPT with the workshop participants, then another graph containing the revised version of Smallholder ADOPT and a summary of what this means. We then discuss these findings.

6.3.1 Case study: CIMMYT in Ethiopia

Two innovations were examined that were linked to CIMMYT projects in Ethiopia:

- maize variety BH660
- introduction of glyphosate.

Case study: maize variety BH660 in Ethiopia

A new maize variety (BH660) was introduced to smallholder farmers in Ethiopia. An independent dataset on adoption rates of the new variety over time was available through CIMMYT. A focus group discussion was held with key researchers and extension workers about their experiences of the introduction and adoption of the new variety. BH660 is a long-duration, high-yielding variety that has been broadly adopted. After running ADOPT, a semi-structured discussion explored how similar the researchers' estimations of adoption were to ADOPT and the CIMMYT data.

The CIMMYT survey revealed that maize variety BH660 reached 93% adoption in 23 years (Figure 5). The original Smallholder ADOPT predicted 95% and a much shorter period, at 5.5 years. The revised Smallholder ADOPT predicted 97% in a slightly longer

Table 2. Case studies used for validation of ADOPT

Project and intervention	Opportunity for ADOPT	Timing
CIMMYT, Ethiopia <ul style="list-style-type: none"> ■ Adoption of maize variety BH660, West Oromia, Ethiopia ■ Adoption of glyphosate, West Oromia, Ethiopia 	PhD student Brendan Brown (University of Adelaide) identified these two innovations as worth considering for use in validation of the developing country version of ADOPT. The two innovations were linked to CIMMYT projects through the Bako agricultural research station. Local researchers were keen to be involved and had adoption data collected from independent CIMMYT survey data (covering 25 years of observations of adoption), making this ideal for validation. An ADOPT workshop was run with key local extension staff at the Bako agricultural research station in Ethiopia.	March 2015
ICRISAT, India <ul style="list-style-type: none"> ■ Chickpea variety JG-11 ■ Pigeonpea—ICP 8863 (Maruthi) ■ Sorghum 	Conducted a workshop with 15 researchers from ICRISAT (Hyderabad, India). They have good adoption data over time, to allow comparison of the ADOPT model with independent survey data.	April 2015
ACIAR, PNG <ul style="list-style-type: none"> ■ Various NARI projects 	Facilitated a workshop to test the face validity of Smallholder ADOPT with NARI.	April 2015
ACIAR, ACCA, Laos <ul style="list-style-type: none"> ■ Introduction of direct seeders in three villages in Savannakhet Province, Laos 	Conducted an evaluation of issues affecting adoption of direct seeders by smallholders after 3–5 years of farmer trials (ACCA project, 'Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Laos, Bangladesh and India', LWR/2008/019). The ACCA project is winding up soon. Project leader of ACCA (Christian Roth) was very interested in linking with the further development of ADOPT. Some good background materials were provided, but on-ground evaluations and farmer focus group discussions were required to obtain requisite adoption data.	May 2015

ACCA = Adaptation to Climate Change in Asia; ACIAR = Australian Centre for International Agricultural Research; ADOPT = Adoption and Diffusion Outcome Prediction Tool; CIMMYT = International Maize and Wheat Improvement Center; NARI = National Agricultural Research Institute, Papua New Guinea

period: 6.5 years. The participants in the ADOPT workshop estimated peak adoption (100%) to be achieved in 10 years, which was closest to the revised version of Smallholder ADOPT.

Both the original version and the revised version of ADOPT overestimated the time to peak adoption (too rapid), but the revised version of Smallholder ADOPT was slightly slower. It was considered that adoption would reach close to 100% at some point. The researchers and extension workers involved in the focus group discussions also overestimated the time to peak adoption, perhaps reflecting their expectations during the ADOPT workshop and responses used in calculating adoption levels.

Case study: glyphosate in Ethiopia

The herbicide glyphosate was also introduced to smallholder farmers in Ethiopia, and survey data were collected by CIMMYT projects to examine adoption over time; however, only a few measurements were available. A focus group discussion was held with key researchers and extension workers about their

experiences of the introduction and adoption of glyphosate. After running ADOPT, a semi-structured discussion explored how similar the researchers' estimations of adoption were to ADOPT and some CIMMYT data.

The CIMMYT survey data showed that adoption of glyphosate reached 63% after only 4 years (Figure 6; note, only one data point above zero). The beta version of Smallholder ADOPT estimated 95% in just over 9 years, and the revised version of Smallholder ADOPT estimated 98% in just over 11.5 years. It is interesting to note that the focus group discussion estimated adoption to be slower than that observed or predicted by ADOPT. We are hoping to obtain a more recent measurement of adoption of glyphosate to finalise this assessment.

The revised Smallholder ADOPT predicted adoption of glyphosate reasonably well, although more adoption data are required to see if the trend (currently based on only one data point) continues. This gives us reasonably high confidence that the revised model is estimating peak adoption a little slower than the original version.

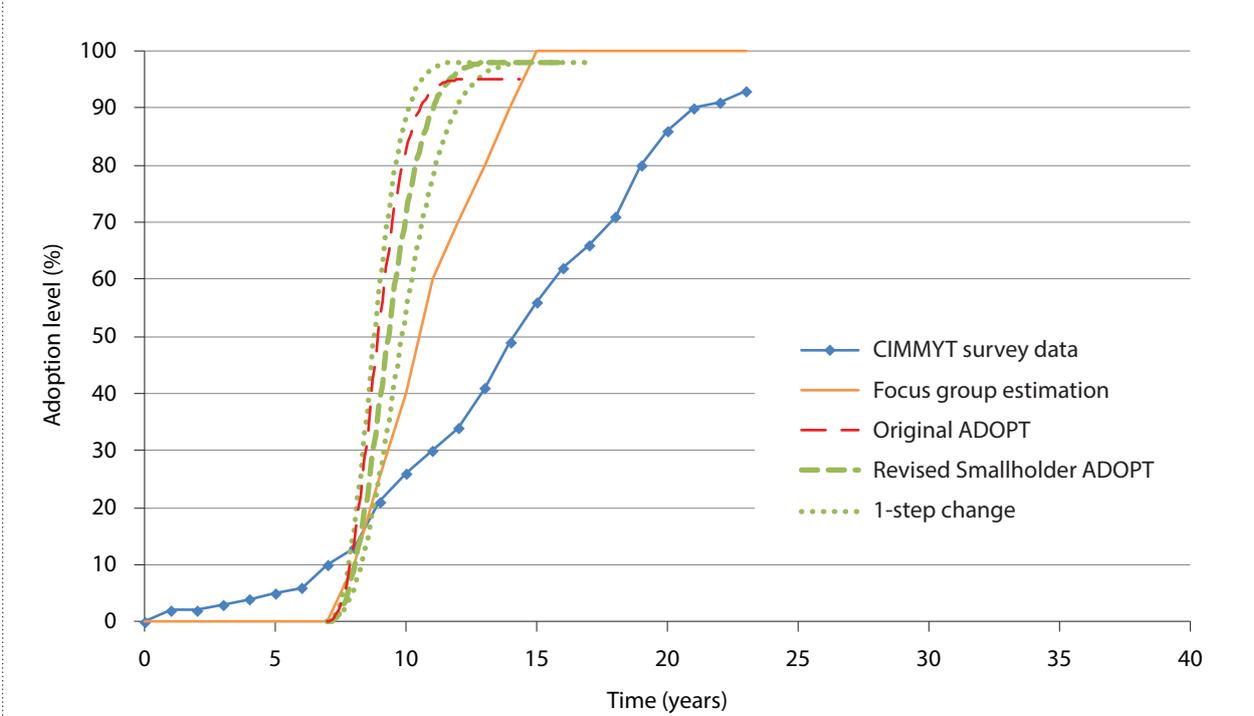


Figure 5. Adoption curves for maize variety BH660 in Ethiopia generated from the CIMMYT dataset, focus group discussions with researchers and extension workers, and a run of ADOPT

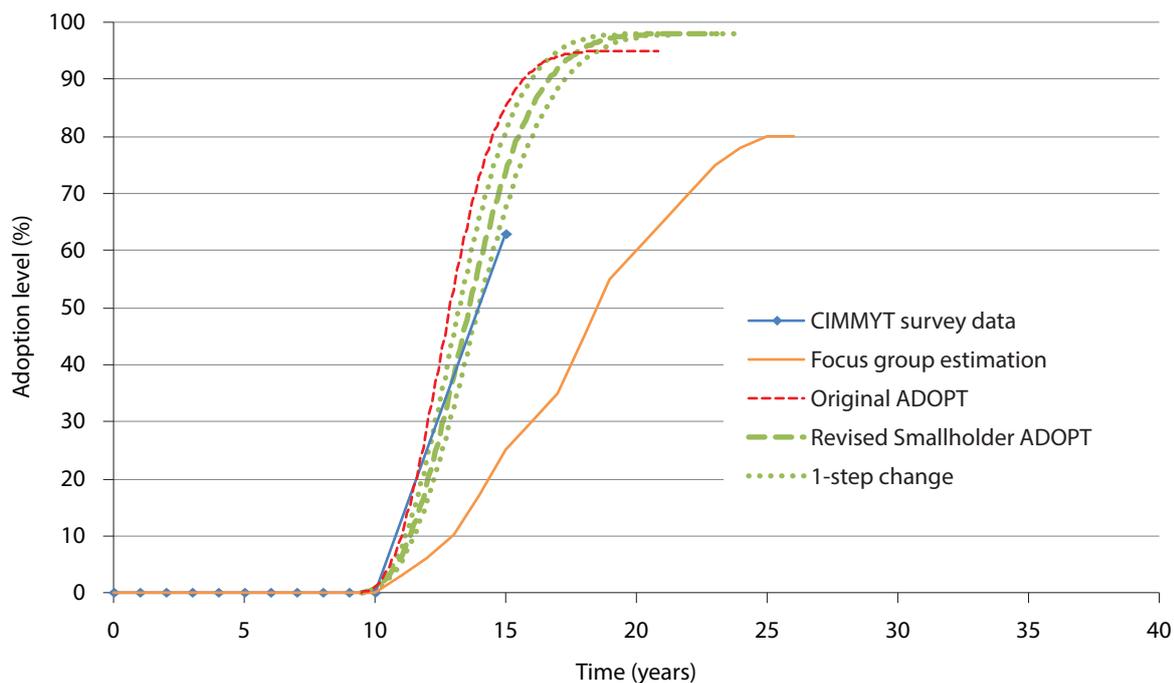


Figure 6. Adoption curves for glyphosate in Ethiopia generated from CIMMYT dataset, focus group discussions with researchers and extension workers, and a run of ADOPT

6.3.2 Case study: direct seeders in Laos

This small adoption study was designed to obtain relevant information on adoption of direct seeder machines by farmers in Savannakhet Province, Lao People's Democratic Republic. These machines were introduced through the ACIAR-funded ACCA project 'Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Laos, Bangladesh and India' (LWR/2008/019). Over the course of a 2-day field visit, we obtained information from researchers and extension workers about adoption through using ADOPT in a facilitated workshop. We then collected information from farmers who were involved in the trials 4–5 years ago to determine adoption rates, essentially to see to what extent ADOPT could predict adoption rates based on observations (to validate the tool).

An initial run of ADOPT generated both high and rapid adoption rates (95% in 9 years), which were considered too high and rapid (Figure 7). The initial model was re-run with researchers and extension workers in the workshop by carefully examining the response to each question, leading to lower adoption rates and a longer

period until peak adoption. The model was run for two districts, and there were small differences between the two revised models (Outhomphone—22% in 17.7 years; Champhone—26% in 17.3 years) (Figure 7).

Discussions were held with 16 farmers from three villages (Outhomphone District: Phin Tai; Champhone District: Toad and Alan Wattanay). The direct seeders were introduced through the ACCA project in 2011–12 through a number of trials. After 4–5 years of using the direct seeder machines, adoption rates were less than 10%, but are forecast to be 20–80% in 5 years and 50–100% in 10 years (Figure 7). Farmers identified labour saving as the main benefit, but they need more training to solve some issues, particularly with weeds. Farmers wanted more projects to provide the machines or government subsidies. They thought that the time for the return on investment would be 1–2 years. It was not clear why the farmers had not been investing in the machines themselves. The machines cost 4 million kip (~A\$650), but the farmers seem reluctant to invest, particularly since they do not have spare cash to invest and are still waiting to see that the benefits are long term (thus, time to peak adoption will be slow). Farmers have adopted hand tractors during the past 10 years or so

(which cost 20 million kip; ~A\$3,250), so farmers felt that they would also eventually adopt the direct seeders.

Given the disparity between results from the initial beta version ADOPT model (95% in 9 years—too high and too rapid) and the re-run of models (22% in 18 years and 26% in 17 years—too low but probably the right time to peak; responses too conservative), another run of the ADOPT model was made to try to estimate a more ‘realistic’ adoption curve based on input from all ADOPT workshops with researchers and extension workers, and what the farmers were saying (Figure 8). This shows the ‘realistic’ curve achieving 92% adoption in about 25 years. This seems more appropriate, given the potentially long time to peak adoption, and estimated high adoption rates.

The revised version of Smallholder ADOPT was then run for each of these ADOPT scenarios (Figure 9). The original run of ADOPT was similar, but the revised models for Outhomphone and Champhone were much lower and longer (down to 3% in about 29 years for both), which is probably too low. The ‘realistic’ model showed lower adoption (76%) and a slightly longer time to peak adoption (29 years).

Some of the very low model runs were removed; the remaining runs and the 1-step change to show uncertainty are provided in Figure 10 to show that the revised Smallholder ADOPT appears to be successfully estimating adoption of direct seeders. Adoption was likely to be slower than estimated by farmers, so we feel that this revised version of Smallholder ADOPT is doing a reasonably good job in estimating adoption of direct seeders. It is likely that adoption will reach close to 100% at some stage. This occurred with hand tractors, which are five times more expensive than direct seeders (20 million kip versus 4 million kip). Because farmers were waiting to see which type of machine is best, they held off buying them, and they also need to be adequately convinced during a few years of trialling. The peak adoption level will reach close to 100%, but the time to peak adoption is probably more critical and likely to be relatively long.

The revised ADOPT was able to estimate potential adoption rates reasonably well after close examination of the responses to the questions provided. Most extension workers and farmers agreed that adoption would reach almost 100% at some point in the future, but it certainly would not happen quickly.

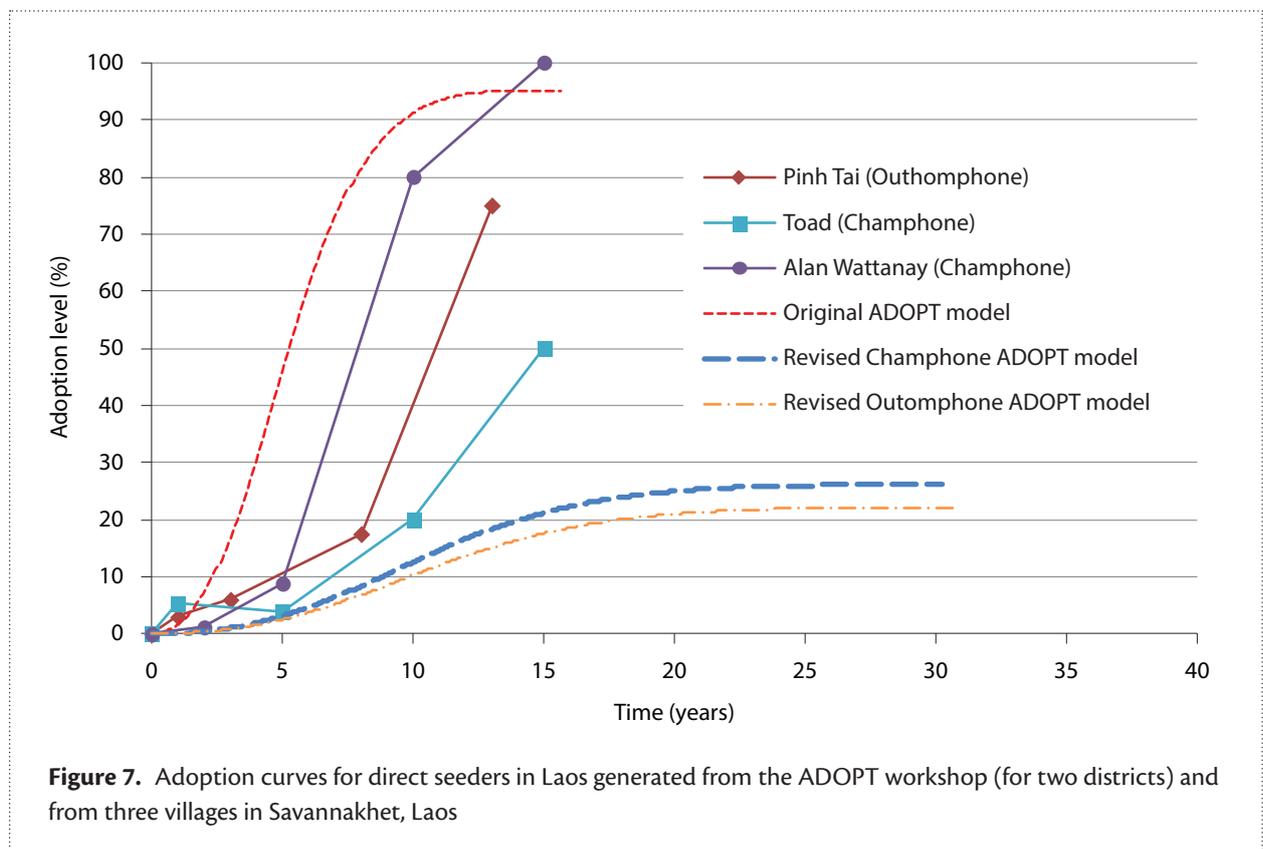


Figure 7. Adoption curves for direct seeders in Laos generated from the ADOPT workshop (for two districts) and from three villages in Savannakhet, Laos

The key findings from this validation were as follows:

- Good time-series data on adoption rates are required to adequately validate the ADOPT model. The direct seeder exercise from Laos was still very useful, because we were able to more deeply understand the issues at play for adoption of a

technology from both researchers and extension workers, and farmers.

- Adequate time is required to run the ADOPT workshops to ensure that all questions are examined closely and that responses are not unrealistically optimistic. Each response needs to be reviewed carefully.

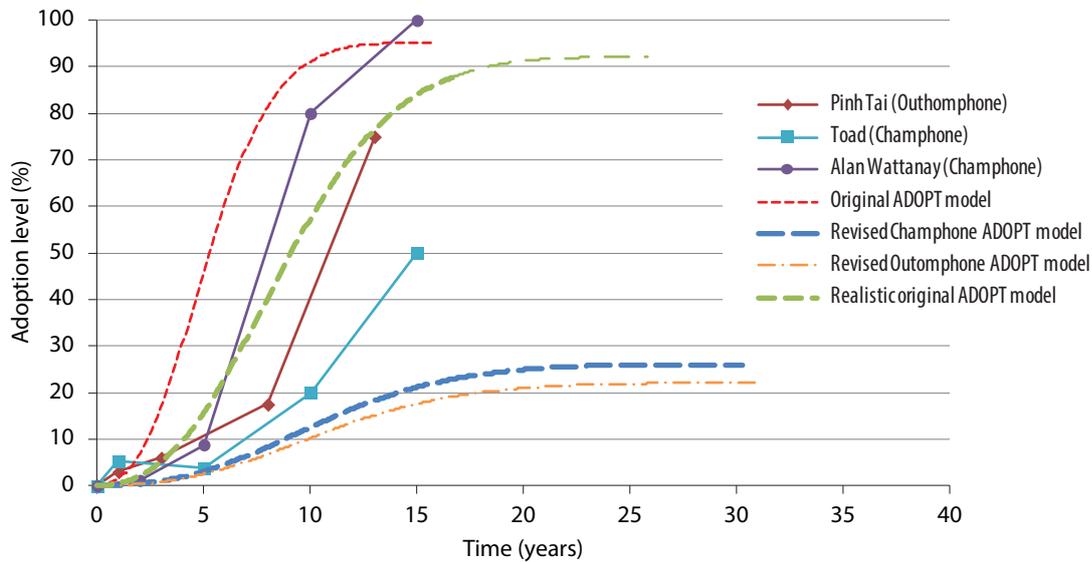


Figure 8. Adoption curves for direct seeders in Laos generated from ADOPT workshops and farmer discussions in three villages in Savannakhet, Laos, plus a curve from a more likely (realistic) ADOPT run

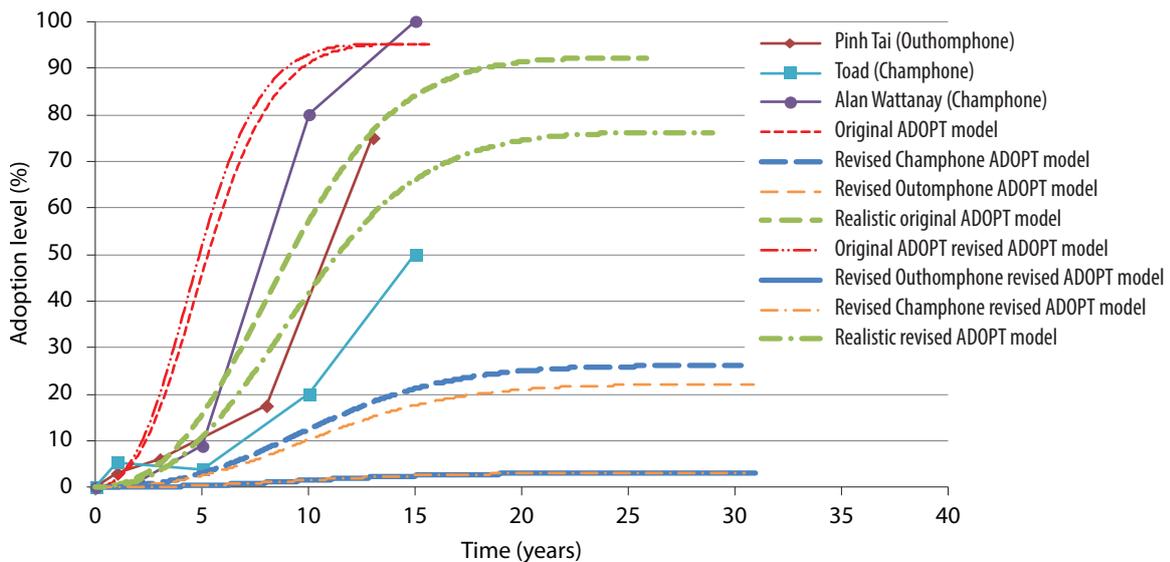


Figure 9. Adoption curves for direct seeders in Laos from all ADOPT scenarios (original and revised versions), for three villages

- It is important to have a mindset for thinking about potential future adoption, rather than relying on perfect knowledge after the fact, because changes can occur. This means that issues that were thought to be important early in the adoption phase might turn out to be less important; alternatively, issues that were not considered important become important later, or other issues arise that were not thought of at all. Either way, it is important to not become too fixated on the predictions from ADOPT without taking the opportunity to think about the issues as the 22 questions are answered.

6.3.3 Case study: ICRISAT varieties in India

This evaluation of three varieties was designed to compare independent published rates of adoption with the predictions from the use of Smallholder ADOPT at a workshop with ICRISAT researchers, in Hyderabad, Telangana State. The three varieties tested were chickpea JG-11, pigeonpea ICP 8863 (Maruthi) and sorghum. Three quite different adoption curves were presented with each of these ICRISAT datasets.

Case study: chickpeas in India

According to ICRISAT data, chickpeas were adopted relatively rapidly by farmers, to 95% after 15 years

(Figure 11); however, there was 93% adoption after 10 years. The original Smallholder ADOPT predicted 92% very rapidly (8 years); the revised version reached only 53% adoption but was slower, at almost 10 years. The one-step change was very wide for chickpeas (from 30% to 75%).

Case study: pigeonpeas in India

The ICRISAT survey data for pigeonpea showed adoption at 59% after 7 years (Figure 12). After correcting for the same start year, the original ADOPT model showed adoption at 95% after 10 years, and the revised Smallholder ADOPT showed a slightly higher adoption of 97%, but slightly slower at 12 years. The revised smallholder version tracked very well the adoption rate of the ICRISAT data for the first 5 years or so, when adoption of pigeonpea started to plateau.

Case study: sorghum in India

The ICRISAT data for sorghum showed a high (94%) but slow (40 years) adoption (Figure 13). The original ADOPT model showed high (95%) and rapid (11 years) adoption, whereas the revised Smallholder ADOPT showed 84% over a longer time (13.5 years). The ICRISAT survey data we referred to for sorghum did not differentiate between the kharif (monsoon) and rabi

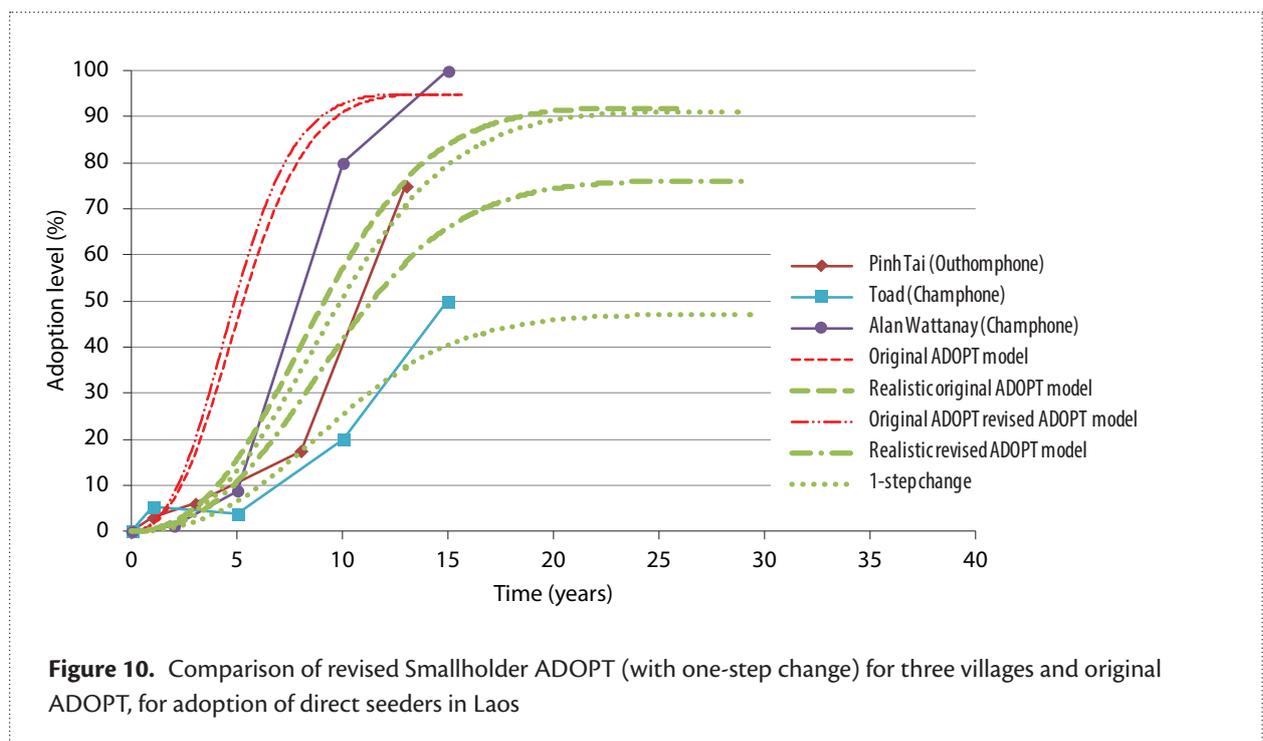


Figure 10. Comparison of revised Smallholder ADOPT (with one-step change) for three villages and original ADOPT, for adoption of direct seeders in Laos

(post-kharif) varieties. The research group that used ADOPT for this exercise seem to be in broad agreement with the output generated by the tool.

In general, the revised Smallholder ADOPT performed fairly well, in that adoption was slower than given by the original version of ADOPT. This is a good result because

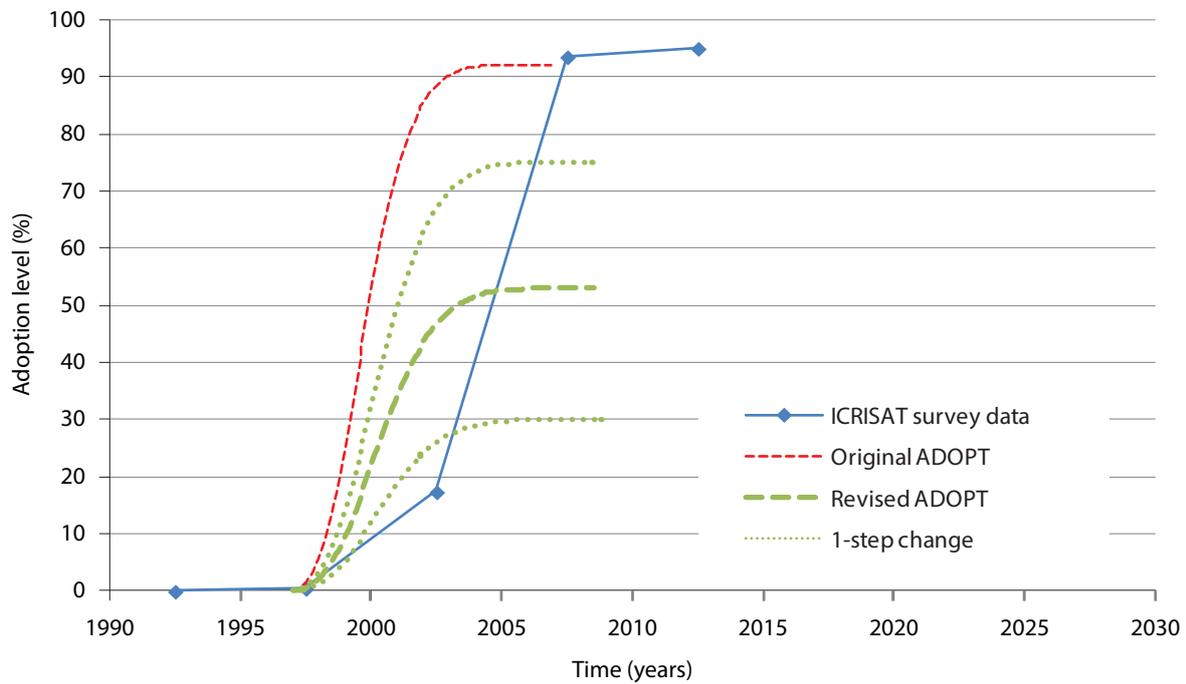


Figure 11. Comparison of original adoption curve for chickpea in India

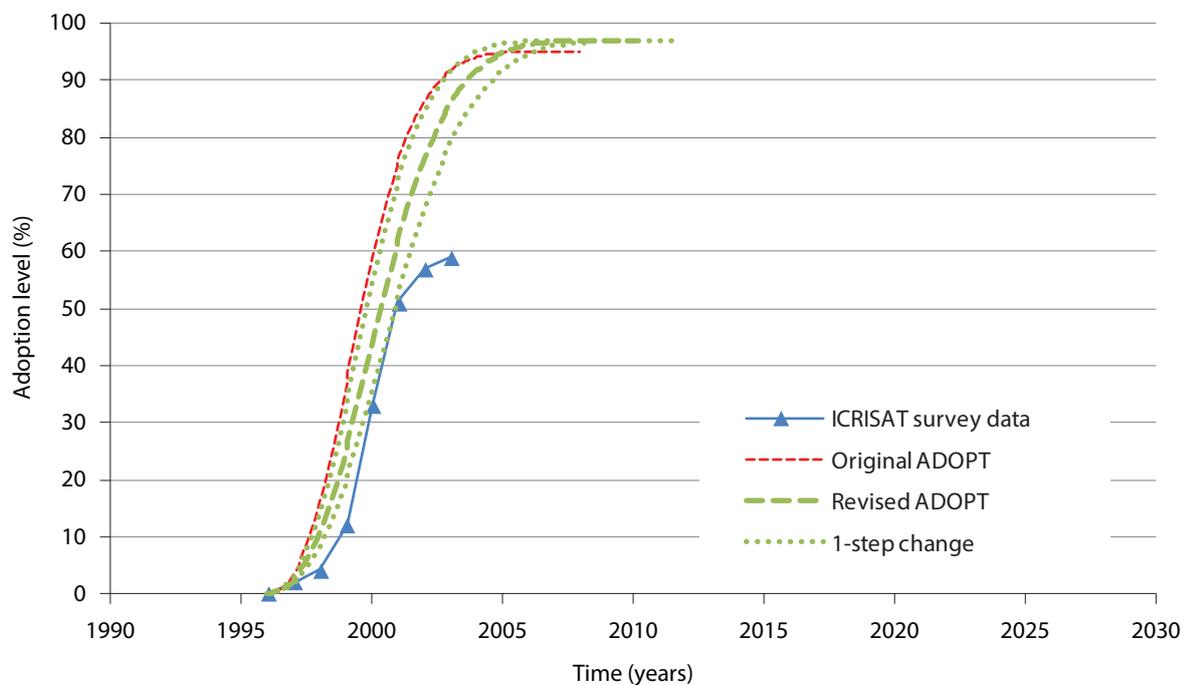


Figure 12. Comparison of original adoption curve for pigeonpeas in India with revised Smallholder ADOPT

it was felt that the adoption rate in the beta version of ADOPT was too high and too rapid. However, it appears that adoption may not be high enough in some circumstances (e.g. as shown for chickpeas in Figure 11).

6.3.4 Case study: Papua New Guinea

Where adoption data are unavailable or incomplete, as in PNG, it is not possible to validate ADOPT's numeric predictions of adoption outcomes against actual outcomes. In situations such as this, where the accuracy of the predictions cannot be measured, validation becomes a process of establishing 'face validity'. This is a subjective test that is more focused on establishing whether the tool achieves what it sets out to do. Although it is a subjective interpretation, it was more convincing in the PNG case study because it was carried out using the experience and judgement of two PNG extension agents who are representative of the potential users of ADOPT.

Their response to the PNG-specific version of ADOPT showed that adjusting the content of the tool to better recognise the social, cultural and economic issues

affecting farmers' decision making and management of risk has made the tool more acceptable to the intended users. They viewed the added supplementary questions as very important to the process of considering adoption. Their feedback suggested that this version of ADOPT, with changed and added questions, and key points that are more compatible with the PNG context, would be more likely to be influential in increasing users' acceptance of ADOPT in the first place. This would be expected to lead to a greater willingness to use ADOPT and, through this use, a greater likelihood of developing a fuller understanding of adoption issues and processes.

Further research in this area could investigate operationalising the PNG-specific supplementary questions in ADOPT so that they contribute to the numeric predictions, thereby providing a more comprehensive consideration of the complex issues found when considering adoption issues in PNG. This would allow project proponents and others to place a more deliberated emphasis on the social, cultural, gender and policy constraints found in the PNG context when considering and promoting adoption of beneficial innovations.

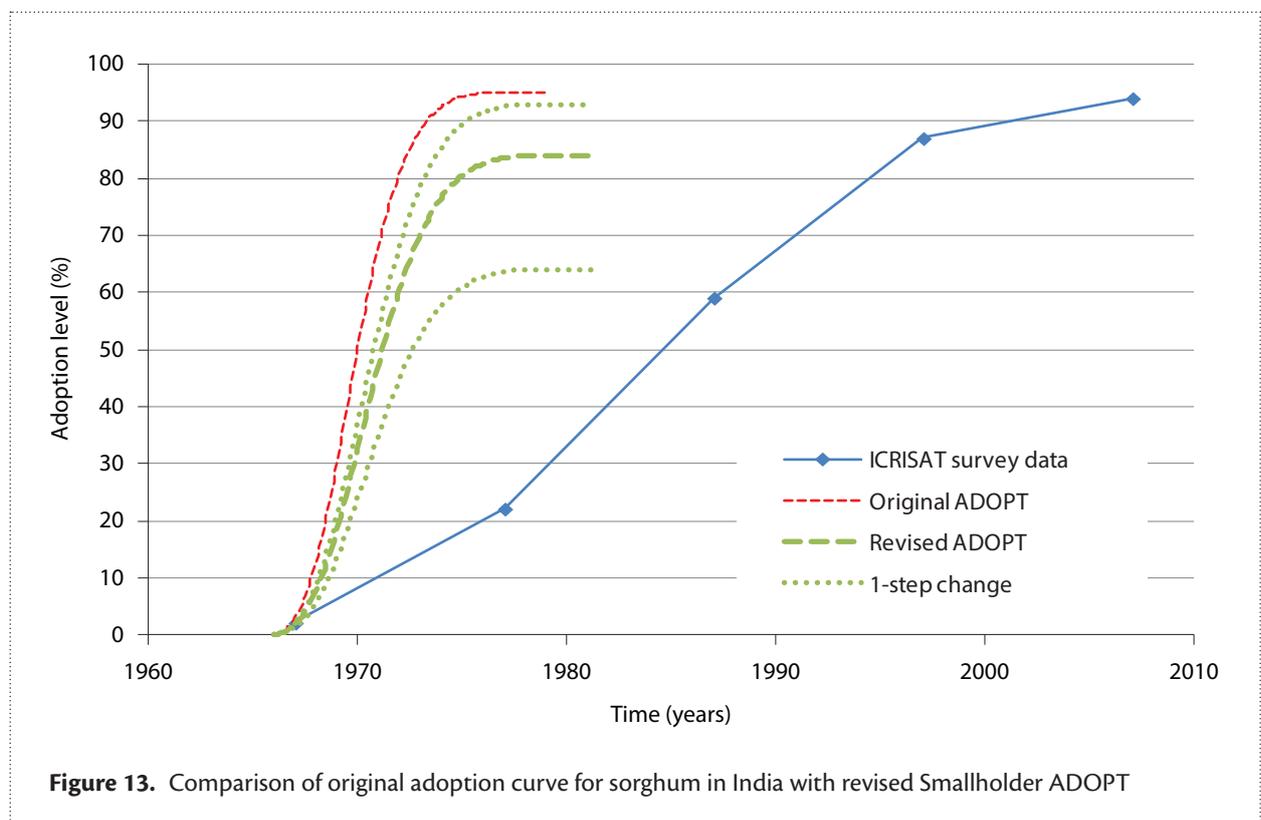


Figure 13. Comparison of original adoption curve for sorghum in India with revised Smallholder ADOPT

6.4 Summary of case studies

Each of the case studies offered something different, and they were thus considered a good set of studies with which to validate and test the Smallholder ADOPT model. The case studies covered a range of innovations (new crops, new varieties, fertilisers and new planting machinery) and locations (four countries: Ethiopia, India, Laos and PNG). Most case studies were of innovations that eventually reached close to 100% adoption, so the test of the model was more about the time to peak adoption than the level of peak adoption itself.

We found that the beta version of Smallholder ADOPT produced predictions of adoption that were too high and too rapid. The changes made to Smallholder ADOPT (in line with other changes being made to the developed country version of ADOPT; see Section 7), meant that the revised Smallholder ADOPT did a better job. The revised version of Smallholder ADOPT now more accurately predicts adoption across a wide range of scenarios.

Through involvement in discussions with researchers, extension workers and farmers while undertaking this validation exercise, we found the following:

- Sufficient time is required to run the ADOPT workshop, especially for going over all responses

to questions, and looking at the impact of changes to individual questions on peak adoption level and time to peak adoption. This is a key activity for better understanding of the processes of adoption. We have encouraged this by making modifications to the information in each question to provide better insights and to help ADOPT users make a more informed decision.

- Smallholder ADOPT is a model to help people consider the issues involved in adoption of innovations. We want users to use ADOPT as a guide in understanding more about the adoption process, rather than assuming that the numeric predictions from ADOPT are more than just an estimate. We have addressed this issue by introducing uncertainty in the model through showing one-step changes in model predictions for the most variable question.
- It was difficult for ADOPT workshop participants (researchers and extension workers) to think about the situation and conditions at the time the innovations were introduced, rather than using their accumulated knowledge and experience since the innovation was introduced. This undoubtedly has biased their responses to the questions, and resulted in more rapid and higher adoption levels.
- It would be useful to continue to search for other validation datasets to further refine the Smallholder ADOPT model.

7 Summary of changes made to ADOPT

The beta version of the Smallholder Adoption and Diffusion Outcome Prediction Tool (Smallholder ADOPT) had some underlying problems in that its predicted adoption outcomes were too high and too rapid in some situations, or showed large jumps in adoption. Investigation focused on the attribute of relative advantage, and how this influences overall calculation of the time to peak adoption and the peak adoption level. Modifications to the formula were made for the developed country version of ADOPT. As part of the validation process we considered whether these changes also made sense for Smallholder ADOPT.

7.1 Major modifications since original version (May–June 2015)

A range of modifications were made to both the developed country version of ADOPT and Smallholder ADOPT (Table 3). These underlying changes fix some bugs in the model to account for large jumps in adoption.

7.1.1 Testing relative advantage score and peak

The transformation function for converting relative advantage score to peak adoption percentage has not changed, but parameters have been adjusted slightly to accommodate the changed distribution caused by changes to the relative advantage function. A set of test cases can now be plotted on the relative advantage transformation curve to allow the effect of any changes to be more easily checked (Figure 14).

7.1.2 Main differences between Developed Country ADOPT and Smallholder ADOPT

The main difference between the revised Developed Country ADOPT and Smallholder ADOPT is in the calculations of two formulas (Table 4). Both of these changes were made because time to peak adoption was too rapid. There is much evidence to suggest that smallholder farmers in developing countries are more reluctant to adopt new technologies than their counterparts in developed countries, because of lack access to credit and a tendency to wait to see the benefits of innovations, among other factor (see literature review in Section 3). This is supported by evidence from our case studies used for validation (see Section 6). Other possible changes can be made to Smallholder ADOPT to influence time to peak adoption, but it is suggested that these small changes be evaluated first to determine whether further changes are necessary after further testing.

7.2 Other cosmetic changes to Smallholder ADOPT

7.2.1 Change to the S-curve

A new feature shows the uncertainty about the prediction of peak adoption. This was achieved through examining the question that has the highest effect on peak adoption level (it could be any of the 22 questions), and then using one step up and one step down to draw extra lines on the S-curve graph (Figure 15). The adoption S-curve now stops once it reaches a plateau.

Table 3. Main modifications to Smallholder ADOPT from previous versions

Issue	Modification made
Negative RA	RA characteristics (profit, risk, environment, ease and convenience) can now have negative (and positive) contributions to net RA. Factors that influence RA now always influence adoption in the correct direction.
No positive RA could lead to adoption	Previously, low or no Investment costs contributed positively to RA. This meant that it was possible for an innovation with no positive RA characteristics to achieve some adoption. Now, when investment costs are zero, there is zero addition (or subtraction) to RA. When there are some investment costs, a deduction is made from the RA score.
Enterprise scale multiplied investment costs	Enterprise scale is now a multiplier of the sum of only the main RA characteristics (profit, risk, environment, ease and convenience)—for example, good RA characteristics that can benefit more land (due to high enterprise scale) gain a higher overall RA score. Investment costs are deducted after this. In effect, this means that enterprise scale has less influence than before on innovations with only modest RA characteristics.
Variable weightings	All main variables can now potentially be weighted. This will be important when calibrating a smallholder version. The influence of the orientation questions on RA has not changed, but the weightings on these questions are now used in the RA formula to replace the previous 0.4 figures in the equation.
Ease and convenience	The ease and convenience weighting has been adjusted upwards so that its influence is similar to that of risk and environment.
Influence of RA on time to peak adoption	The positive influence of positive RA on learning and time to peak adoption has been adjusted upwards using a small weighting so that its influence is similar to that of the other variables, as originally intended.
Rescaling of RA to contribute to learning and time to peak adoption	A fixed set of 'worst case' and 'best case' inputs to the 22 questions is now included in the formulas page. They are used to provide a 'live' calculation of minimum and maximum RA scores. The relevant variables are also used to ensure that the maximum investment cost deduction from RA is also up to date. This ensures that there is zero deduction to RA for innovations with no investment costs.
Upfront costs	This now has the same input range as other similar variables (0–4 instead of the previous 0–3.2).
Other minor edits	A few other minor edits, mainly of redundancies from previous versions, have been made.

RA = relative advantage

Table 4. Main differences between Developed Country ADOPT and Smallholder ADOPT

Variable	Developed Country ADOPT	Smallholder ADOPT	Reason for change
Investment costs	Weighting = 0.333	Weighting = 0.667	To increase time to peak adoption
Rescaled relative advantage	Weighting = 1.2	Weighting = 0.8	To increase time to peak adoption

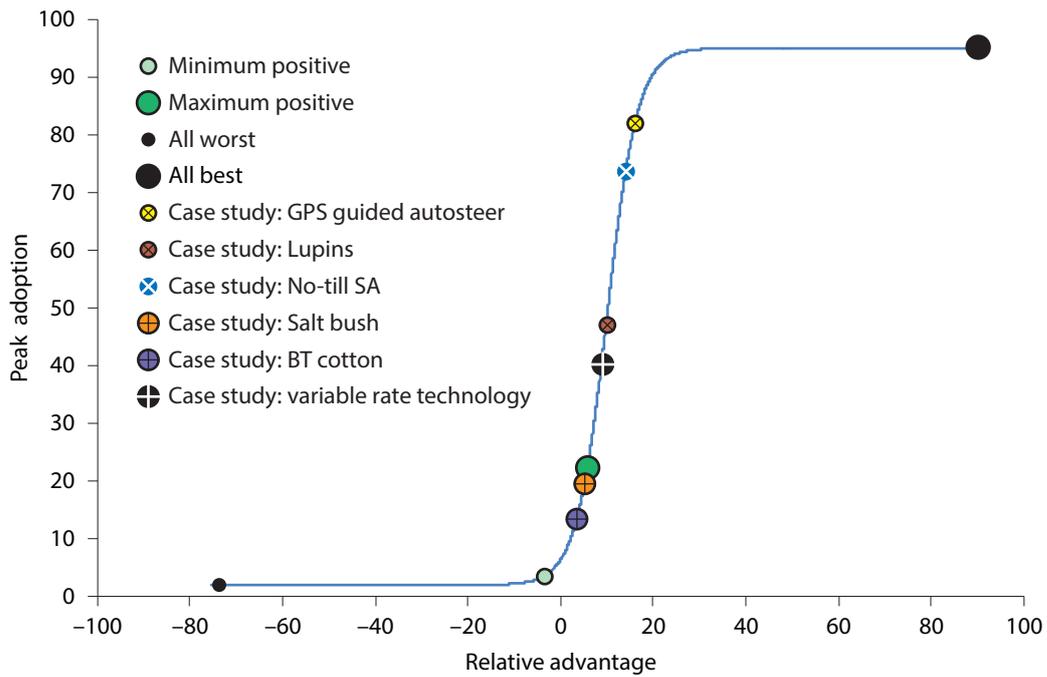


Figure 14. Relationship between peak adoption and relative advantage. 'Minimum positive' has profit at small profit; 'maximum positive' has profit at very large profit. All others are at neutral relative advantage or moderate settings.



Figure 15. Adoption curve showing uncertainty through the effect of a one-step change of the variable with the greatest impact on peak adoption level. Uncertainty is calculated using the largest sensitivity, then replotted with one step up and one step down.

7.2.2 Identification in the sensitivity analysis of items that can be changed

Users commented that they did not know which elements of extension could be used or modified to improve adoption. Most issues fall within the four quadrants of the ADOPT diagram as either needing improved extension effort or improved innovation design (Figures 16 and 17). These concepts have been applied to the sensitivity graphs generated in the model to assist with suggesting approaches to improve adoption.

7.2.3 Changes to the adoptability report

The structure of the adoptability report was changed so that the question number, question, response and reason are all listed together in a table; this makes it

easy to remember what the questions and responses were (they were listed separately in the printed report). This is useful when comparing different model runs for different smallholder communities.

7.2.4 Other minor changes

A series of other small changes were made to Smallholder ADOPT:

- Shifted the tab for entering 'supplementary information' to the top of the S-curve page.
- Fixed the merge function.
- Fixed visuals so that it is clear which sensitivity page is active (peak adoption level or time to peak adoption).

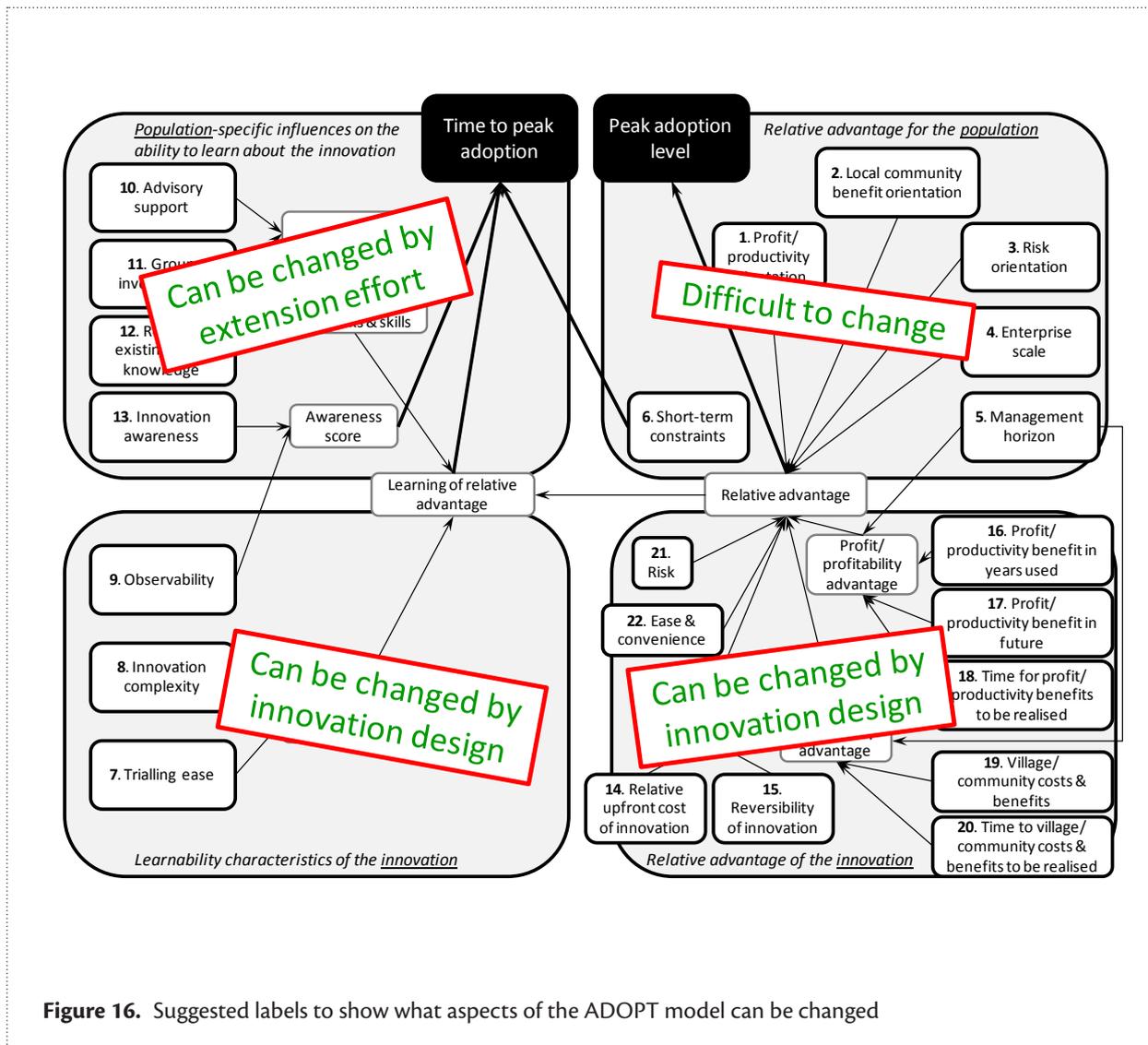


Figure 16. Suggested labels to show what aspects of the ADOPT model can be changed

- Added four extra questions. At this stage, these pages will not contribute to the calculations, but the responses and text that are entered will need to add to the report.
- Added 'Smallholder' to the title image.
- Added 'Use with caution' in the 'How to use' tab (and adoptability report).
- Added a new S-curve showing 'the effect of one-step change of the variable with the greatest impact on peak adoption level'.
- Updated licence: changed CSIRO Ecosystem Sciences to CSIRO Agriculture Flagship.
- Added some photos to the front screen and adoptability report to reflect smallholder agriculture and innovations (to differentiate from the developed country version).
- Updated the Smallholder ADOPT diagram.

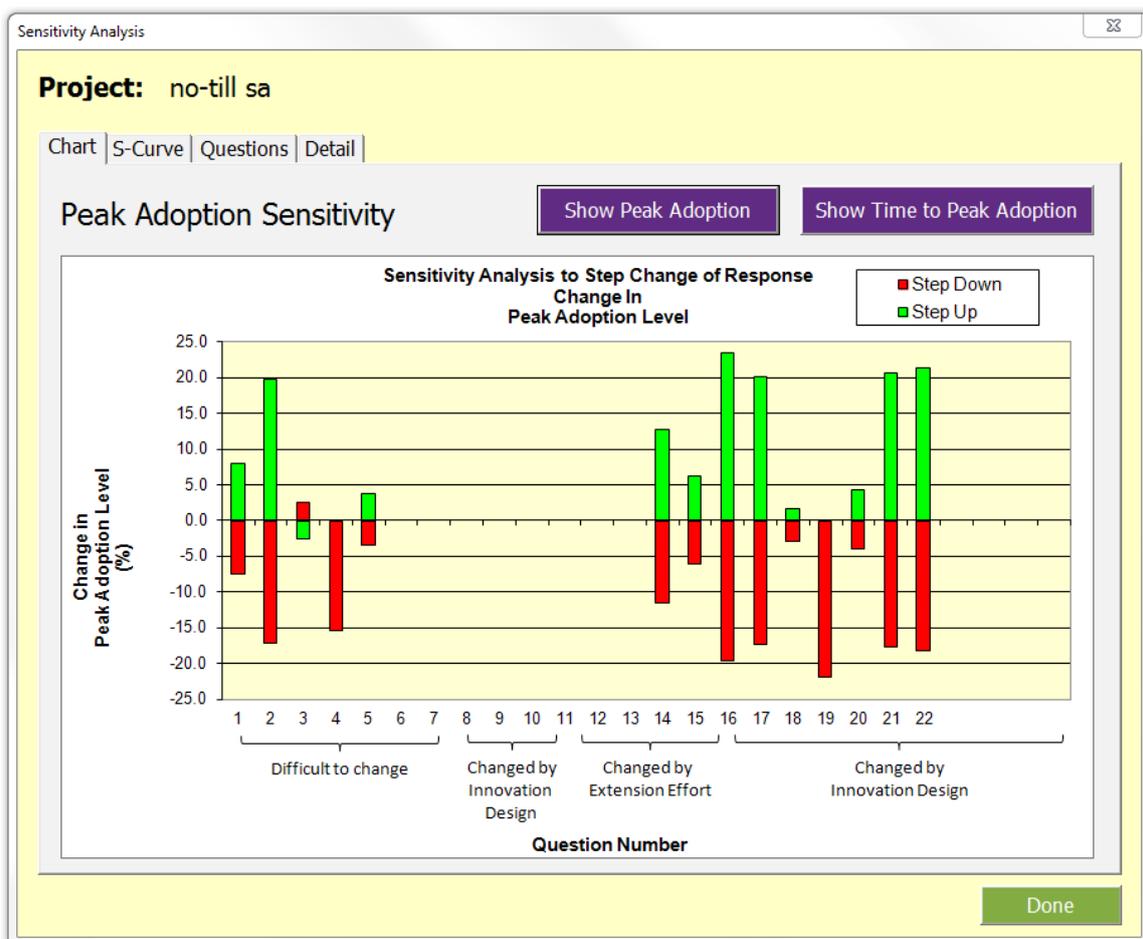


Figure 17. Display of the sensitivity graphs in Smallholder ADOPT. Approaches that could be considered to improve peak adoption, in terms of improved extension or improved innovation design, are shown.

8 Conclusions

This project gave us the opportunity to modify the Smallholder Adoption and Diffusion Outcome Prediction Tool (Smallholder ADOPT). We used:

- information gathered from a literature review
- feedback and suggestions from a survey of the beta version of Smallholder ADOPT users
- case study validations to make a series of changes and modifications to Smallholder ADOPT.

A survey of users was conducted to obtain their feedback on what was useful and applicable about ADOPT, and what could be improved. Comments and input were also sought from case study participants.

A series of case study workshops was undertaken to validate the revised version of ADOPT. The aim was to find examples of studies of adoption of innovations by smallholders where there were good independent datasets on adoption rates. These were used to try to validate the Smallholder ADOPT model to investigate whether there were any important attributes that the model was not predicting adequately. The validation showed that Smallholder ADOPT predicted slightly slower peak adoption rates and slightly lower levels of peak adoption than the beta version of Smallholder ADOPT. These changes were thought to better predict adoption for smallholders in developing countries. In addition to validating Smallholder ADOPT from a range of case studies from four countries, further examples are needed to more fully validate the model across a range of situations.

Some changes were made to the underlying structures and formulas of the model, in line with changes to the Australian version of ADOPT, to improve certain aspects of relative advantage and therefore the predictability of the ADOPT model. Two key changes were made to Smallholder ADOPT to effect a slowdown of adoption rates based on the literature review, comments from users and the case study validations:

reweighted investment costs and rescaled relative advantage. These changes meant that Smallholder ADOPT was predicting adoption rates better than the previous beta version of Smallholder ADOPT. We also included some uncertainty in the S-curve of adoption to show that it is a model output and that caution should be used in interpreting its predictions.

We took the opportunity to improve the layout of the model to make it easier to use and to improve the layout of the adoptability report that is generated from the ADOPT model. We also included some additional questions that were not linked to the model itself, but are likely to be important for adoption and are useful in terms of framing ADOPT in a broader consideration of adoption.

The predictions generated by Smallholder ADOPT are based on user input, and subject to the biases and misunderstandings of individuals. This means that its results should be interpreted with caution. It can be used in a range of circumstances—in particular, for adoption of agricultural technologies or other agricultural innovations. The questions in the tool are designed so that users have to think broadly about the different components that contribute to adoption. Furthermore, Smallholder ADOPT can be used for a range of purposes, particularly:

- during the project design phase as an ex-ante impact predicting tool
- during project implementation
- during project evaluation or ex-post monitoring
- as a boundary object to discuss options with stakeholders
- as a tool to explore the systems that underpin innovation.

Smallholder ADOPT will be made available through www.csiro.au/adopt.

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10	AACM International 1998.	Conservation tillage and controlled traffic	LWR2/1992/009
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53	Monck M. and Pearce D. 2008.	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
54	Monck M. and Pearce D. 2008.	Impact of improved management of white grubs in peanut-cropping systems in India	CS2/1994/050
55	Martin G. 2008.	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144
56	Lindner B. and McLeod P. 2008.	A review and impact assessment of ACIAR's fruit-fly research partnerships—1984–2007	CP/1997/079, CP/2001/027, CP/2002/086, CP/2007/002, CP/2007/187, CS2/1983/043, CS2/1989/019, CS2/1989/020, CS2/1994/003, CS2/1994/115, CS2/1996/225, CS2/1997/101, CS2/1998/005, CS2/2003/036, PHT/1990/051, PHT/1993/87 and PHT/1994/133
57	Montes N.D., Zapata Jr N.R., Alo A.M.P. and Mullen J.D. 2008.	Management of internal parasites in goats in the Philippines	AS1/1997/133
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64	Mullen J.D. 2010.	Reform of domestic grain markets in China: a reassessment of the contribution of ACIAR-funded economic policy research	ADP/1997/021 and ANRE1/1992/028
65	Martin G. 2010.	ACIAR investment in research on forages in Indonesia	AS2/2000/103, AS2/2000/124, AS2/2001/125, LPS/2004/005, SMAR/2006/061 and SMAR/2006/096
66	Harris D.N. 2010.	Extending low-cost fish farming in Thailand: an ACIAR–World Vision collaborative program	PLIA/2000/165
67	Fisher H. 2010.	The biology, socioeconomics and management of the barramundi fishery in Papua New Guinea's Western Province	FIS/1998/024
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69	Pearce D. 2010.	Lessons learned from past ACIAR impact assessments, adoption studies and experience	
70	Harris D.N. 2011.	Extending low-chill fruit in northern Thailand: an ACIAR–World Vision collaborative project	PLIA/2000/165
71	Lindner R. 2011.	The economic impact in Indonesia and Australia from ACIAR's investment in plantation forestry research, 1987–2009	FST/1986/013, FST/1990/043, FST/1993/118, FST/1995/110, FST/1995/124, FST/1996/182, FST/1997/035, FST/1998/096, FST/2000/122, FST/2000/123, FST/2003/048 and FST/2004/058
72	Lindner R. 2011.	Frameworks for assessing policy research and ACIAR's investment in policy-oriented projects in Indonesia	ADP/1994/049, ADP/2000/100, ADP/2000/126, AGB/2000/072, AGB/2004/028, ANRE1/1990/038, ANRE1/1993/023, ANRE1/1993/705, EFS/1983/062 and EFS/1988/022
73	Fisher H. 2011.	Forestry in Papua New Guinea: a review of ACIAR's program	FST/1994/033, FST/1995/123, FST/1998/118, FST/2002/010, FST/2004/050, FST/2004/055, FST/2004/061, FST/2006/048, FST/2006/088, FST/2006/120, FST/2007/078 and FST/2009/012
74	Brennan J.P. and Malabayabas A. 2011.	International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia	
75	Harris D.N. 2011.	Extending rice crop yield improvements in Lao PDR: an ACIAR–World Vision collaborative project	CIM/1999/048, CS1/1995/100 and PLIA/2000/165
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83	Palis F.G., Sumalde Z.M., Torres C.S., Contreras A.P. and Datar F.A. 2013	Impact pathway analysis of ACIAR’s investment in rodent control in Vietnam, Lao PDR and Cambodia	ADP/2000/007, ADP/2003/060, ADP/2004/016, AS1/1994/020, AS1/1996/079, AS1/1998/036, CARD 2000/024, PLIA/2000/165
84	Mayne J. and Stern E. 2013	Impact evaluation of natural resource management research programs: a broader view	
85	Jilani A., Pearce D. and Bailo F. 2013	ACIAR wheat and maize projects in Afghanistan	SMCN/2002/028, CIM/2004/002 and CIM/2007/065
86	Lindner B., McLeod P. and Mullen J. 2013	Returns to ACIAR’s investment in bilateral agricultural research	
87	Fisher H. 2014	Newcastle disease control in Africa	AS1/1995/040, AS1/1996/096
88	Clarke M. 2015	ACIAR-funded crop–livestock projects, Tibet Autonomous Region, People’s Republic of China	LPS/2002/104, CIM/2002/093, LPS/2005/018, LPS/2005/129, LPS/2006/119, LPS/2008/048, LPS/2010/028, C2012/228, C2013/017

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90	Pearce D. 2016	Impact of private sector involvement in ACIAR projects: a framework and cocoa case studies	PC/2006/114, ASEM/2006/127, SMAR/2005/074, HORT/2010/011
91	Brown P. R., Nidumolu U. B., Kuehne G., Llewellyn R., Mungai O., Brown B. and Ouzman J. 2016	Development of the public release version of Smallholder ADOPT for developing countries	



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