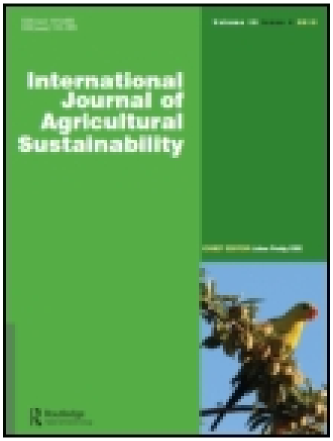

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The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa

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The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa

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Despite the great potential of agricultural innovations, the uptake by smallholder farmers in sub-Saharan Africa seems to be slow. We reviewed existing theories and frameworks for the uptake of agricultural innovations and found that these tend to emphasize the role of extrinsic factors such as the characteristics of the adopter and the external environment in the decision-making process. In this paper, we argue that intrinsic factors such as the knowledge, perceptions and attitudes of the potential adopter towards the innovation play a key role, but this has been less studied. We present an analytical framework that combines both extrinsic and intrinsic factors in farmers' decisions to adopt new agricultural technologies and apply the framework to agroforestry adoption as a case study. We review the literature on agroforestry adoption in sub-Saharan Africa and identify the extrinsic and intrinsic variables affecting the uptake of agroforestry technologies. We conclude that the uptake of agricultural technologies is a complex process influenced by both extrinsic and intrinsic variables, and recommend that future studies aiming to understand the adoption process of agricultural innovations take into account both sets of variables. A mechanistic understanding of how intrinsic and extrinsic factors interact and drive adoption can help in targeting technologies appropriately to ensure sustainability.

Keywords: agroforestry; adoption; agricultural innovation; sustainability; analytical framework; attitudes; knowledge; decision-making; sub-Saharan Africa

Introduction

One of the most widespread anthropogenic changes affecting the planet is forest conversion for alternative human use, resulting in environmental degradation and climate change. Farmers depending on subsistence agriculture are most vulnerable to the effects of environmental degradation and climate change, since their lack of economic resources restricts access to alternative livelihoods (Slingo *et al.* 2005). In sub-Saharan Africa, declining crop yields are exacerbated by depleting soil fertility (Sanchez 2002) and climate variability (Jones and Thornton 2003). Human population growth has resulted in more intensive agriculture and land use pressures.

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Traditional fallow periods that allow replenishment of soil fertility have been reduced, resulting in nutrient losses from the system (Sanchez 1999). Reduced soil fertility is leading to reductions in crop yield, which in turn compromises food security (Sanchez and Swaminathan 2005). As a result, per capita food output has declined in sub-Saharan Africa and the region has the highest proportion of undernourished people in the world, estimated to be 30% of the total population or 239 million people in 2010 (FAO 2010).

There is a serious need for sustainable agricultural practices that can address these issues. In recent decades, there has been an increased focus on sustainable intensification in African agriculture. Pretty *et al.* (2011) analysed 40 projects in 20 African countries and found that by early 2010, they had provided benefits for 10.39 million farmers and their families on roughly 12.75 million hectares of land. Despite the great potential of agricultural innovations, their uptake by smallholder farmers in Africa seems to be slow (Ndjeunga and Bantilan 2005).

The focus of this paper is on the factors influencing the adoption of agroforestry technologies in sub-Saharan Africa. Agroforestry has been demonstrated to offer a wide range of benefits to farmers including the positive effect on their livelihoods through increasing crop yield and increased food security (Sileshi *et al.* 2008a, Akinnifesi *et al.* 2010, Garrity *et al.* 2010) and income (Ajayi *et al*. 2009), as well as improving farmers' ability to deal with the effects of climate change through improved rain use efficiency and yield stability under rain-fed agriculture (Verchot *et al.* 2007, Sileshi *et al.* 2011). In addition, agroforestry is known for providing benefits to the environment by providing various ecosystem services (Sileshi *et al.* 2007, Bhagwat *et al.* 2008, Jose 2009, Nair *et al.* 2009). For example, Ajayi *et al.* (2011) have shown that fertilizer tree systems are inexpensive technologies that significantly raise crop yields, reduce food insecurity and enhance environmental services and resilience of agro-ecologies in southern Africa. Although the benefits of agroforestry are well known and various innovations are being used by farmers throughout the tropics, widespread adoption has not occurred. Even where some agroforestry technologies have been adopted, they have been abandoned after some time in several cases (Dahlquist *et al.* 2007, Kiptot *et al.* 2007). Despite the fact that several studies have looked into the challenges facing agroforestry adoption, the reasons for the relatively low adoption rates are still not fully understood.

This paper reviews the literature on farmer decision-making in relation to the uptake of agroforestry technologies and examines the variables which commonly explain adoption. The paper sets out by briefly exploring some general theories that can help explain the application and adaptation of innovative agricultural technologies. Technology uptake is a complicated process, and can involve both the adoption of a new technology as well as the adaptation of existing practices. Traditionally, theories dealing with decision-making processes have highlighted the role of extrinsic factors such as the characteristics of the technology and attributes of the external environment. Recently, researchers have started to pay more attention to the internal decision-making process and look beyond the mere characteristics of the innovation and the household to include psychological and motivational factors in technology uptake. Knowledge, attitude and practice studies looking at the uptake of innovations have been carried out since the 1980s; however, these surveys have rarely been applied to agroforestry adoption, especially in sub-Saharan Africa (Ajayi 2007). The theories reviewed here lead to the development of an analytical framework, which emphasizes the role of knowledge, attitudes and perceptions in the decision-making process of technology adoption. Using this analytical framework as a reference point, we review the literature on the uptake of agroforestry practices in sub-Saharan Africa to better understand the variables that most commonly explain agroforestry adoption. Application of the framework in adoption studies and design of agroforestry interventions are hoped to help in ensuring sustainability.

Theories of decision-making

There is a broad range of the literature with regard to theories about decision-making processes. The expected utility theory of Daniel Bernoulli predicts that the decision-maker chooses between risky and uncertain prospects by comparing the expected utility values of their outcomes to maximize profit (Schoemaker 1982). Theoretical and empirical literatures have shown that risk and uncertainty play an important role in the adoption of new agricultural technologies (Marra *et al.* 2003, Mercer 2004). This is especially true for marginal farmers in Africa, who have to manage risks on an everyday basis to secure their livelihoods. The expected utility theory has been used as a framework for studying farmer decision-making in various contexts (Oglethorpe 1995, Babcock and Hennessy 1996, Gomez-Limon *et al.* 2004) and to further develop the thinking about decision-making processes and development of alternative models.

Rogers (1995) described how innovations are adopted over time in his 'diffusion of innovations' theory. Diffusion refers to the process by which innovations are spread among the members of a social system over time. An innovation can be an idea or concept, technical information or an actual practice that is perceived as new by the individual. Rogers (1995) identified five characteristics that determine the rate of adoption of the innovation: the relative advantage, compatibility, complexity, trialability and observability. The decision to adopt an innovation is a mental process consisting of five stages: knowledge, persuasion, decision, implementation and confirmation. Rogers (1995) suggested that the innovativeness of an individual determines when the individual adopts the innovation and recognized five successive adopter categories: innovators, early adopters, early majority, late majority and laggards. The adoption process is also affected by the so-called receiver variables, such as personality characteristics, social characteristics and the perceived need for the innovation. The diffusion of innovations theory has guided many studies that try to understand the uptake of new agricultural technologies and it has been applied in the development of farmer decision-making models in the tropics (Mercer 2004, Edwards-Jones 2006, Pannell *et al.* 2006, Reed 2007).

There has been a shift in thinking away from looking at adoption as the delivery of an external, typically science-based innovation with farmers as potential end users towards a more complex learning process involving a wide range of actors (Röling and Jiggins 1998). Röling (1992) describes the emergence of knowledge systems thinking, in which an articulated set of actors, networks and organizations are expected or managed to work synergistically to support knowledge processes. Röling and Jiggins (1998) describe three types of knowledge systems: transfer of technology, farm management development and the ecological knowledge system. The most common and conventional knowledge system is the transfer of technology, which views desirable farming practice as using science-based component technologies, farmer learning as the adoption of external innovations and facilitation as the delivery of these innovations. Farm management development operates within strategic rationality and aims to support the practices of the farmer as an entrepreneur engaged in an economic enterprise focusing on the farm as a whole. The main purpose of the ecological knowledge system is to help land users to become experts at managing complex ecosystems in a sustainable manner. It assumes that farmers are experts on their own farm and take decisions based on knowledgeable interference from observation and analysis through social learning (Röling and Jiggins 1998).

Another way of looking at decision-making was developed by Fishbein and Ajzen (1975) and is called the 'theory of reasoned action'. It is an expectancy-value model with emphasis on attitudes, subjective norms, intentions and behaviours directed at a specific focus. Expectancy-value models provide a framework for understanding the relationship between a person's attitudes and their underlying beliefs. The theory of reasoned action has received considerable attention in the field of consumer behaviour and has been found to be a good predictor of intentions and behaviour (Sheppard *et al.* 1988) and in subsequent years, it has been revised and extended to the 'theory of planned behaviour' (Ajzen 1991). This theory includes a third component, the perceived behavioural control, which predicts the behavioural intention. Together, the attitude towards the behaviour, the subjective norms and the perception of behavioural control lead to the formation of a behavioural intention, which in turn leads to the performance of the behaviour (Ajzen 1991). Despite the fact that the theory is fairly reductionist and consequently has been the target of much criticism and debate over the years, it has become one of the most frequently cited models for the prediction of human behaviour (Ajzen 2011).

Explaining decision-making: an analytical framework

Given that technology uptake is a complex nonlinear process, influenced by multiple factors, the use of a single theory in analysing decision-making could not provide a full picture of the adoption process. A comprehensive framework which takes account of the interaction of various factors in decision-making is needed. Here, we present an analytical framework (Figure 1) which encompasses both extrinsic and intrinsic factors to technology uptake and highlights the interaction of both in decision-making on the application and adaptation of agricultural innovations.

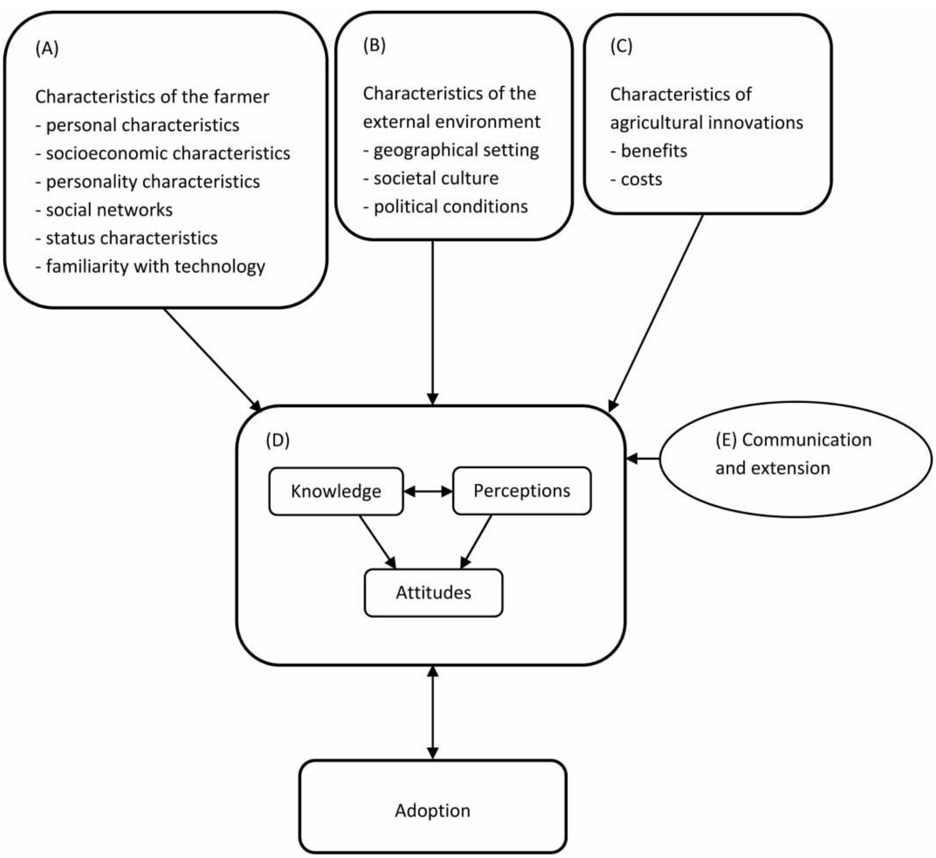

Figure 1. Conceptual framework showing the linkages and interaction between extrinsic variables (a–c) and intrinsic variables (d), and the influence of the intervening variable (e) in the decision-making process of adoption of agricultural innovations.

Intrinsic and extrinsic factors

The role of knowledge, perceptions and attitudes are at the centre of the analytical framework (Figure 1). The first phase in the decision-making process regarding adoption is the development of knowledge of the innovation, which corresponds to the model proposed by Rogers (1995). Farmers can have knowledge about the existence of a new technology, how to apply it, and what the outcomes are in terms of products, yield, potential environmental benefits, risks and costs. The information an individual has about a new technology then forms the basis of the perceptions and attitudes this individual develops towards the technology. Fishbein and Ajzen (1975) described three processes that underlie the formation of beliefs. First, a link between an object and an attribute can be established on the basis of direct observation, which is called a descriptive belief. Second, an attribute might be linked to an object through a process of inference from some other belief about the object, which is referred to as an inferential belief. Third, a link between an object and an attribute may be formed by accepting information from an external source, which is known as an informational belief.[1]

The perceptions farmers have about an innovation are very closely related to the knowledge they have about it. Whereas knowledge refers to factual information and understanding of how the new technology works and what it can achieve, perceptions relate to the views farmers hold about it based on their felt needs and prior experiences; and these do not necessarily align with reality. The knowledge and perceptions about an innovation then together determine the attitude towards it. In accordance with the theory of planned behaviour, the attitude component comprises not only the attitude towards the behaviour, but also the attitudes with regard to the subjective norms and perceived behavioural control. In this case, we expect that a positive attitude towards an agricultural innovation will increase the likelihood of adoption and a negative attitude to reduce the probability of adoption.

There are a large number of extrinsic variables which help shape the knowledge, attitudes and perceptions. The extrinsic variables can be grouped into three categories: characteristics of the farmer, characteristics of the external environment, and characteristics of the innovation (Figure 1). First, knowledge, attitudes and perceptions are influenced by the characteristics of the farmer, which include personal characteristics (gender, age, marital status, etc.), socio-economic characteristics (income, assets, education, etc.), personality characteristics (self-confidence, independence, etc.), position in social networks (network size, connectedness, frequency of interaction, etc.), status characteristics (control over political power or economic resources) and familiarity with the technology. Second, the characteristics of the external environment affect the development of knowledge, attitudes and perceptions as well, which include geographical settings (ecology, topology, soil conditions, climate, demography, proximity to markets, roads and forests, etc.), societal culture (language, tribal background, religion, ideologies, norms, values, etc.) and political conditions (land tenure and access rights, national policies, the structure of government, bureaucracies, the political character of a state and the existence of political freedoms and laws). Third, the characteristics of the new technology also shape the knowledge, attitudes and perceptions. In the case of agricultural innovations, it is the benefits and costs of the new practice, such as the contribution it can make to household income, food security, soil fertility improvement, health and nutrition, firewood and building materials and the costs such as purchasing inputs, equipment, managing pests and diseases, etc., which influence knowledge, perceptions and attitudes.

The role of communication and extension

The role of extension and training is crucial in the development of knowledge, perceptions and attitudes about agricultural innovations (Figure 1). Scherr (1992) described five basic models for extension for agroforestry practices: 'media-based extension', 'commodity-based extension', 'training and visit', 'farming systems research and extension' and 'community-based extension'. As agricultural production systems can vary considerably in nature and complexity in different settings, it is important to take these differences into account in tailoring extension interventions (Bernet *et al.* 2001). There has been a growing emphasis on farmer-led extension, in which farmers are the principal agents of change in their community and help disseminate the new technology to other farmers (Franzel *et al.* 2001, 2004, Kiptot *et al.* 2006). This was initiated by the 'farmer first' approach, which stressed the importance of local knowledge and farmer innovation to complement the traditional transfer of technology approaches to agricultural research and extension (Chambers *et al.* 1989). Although the approach has faced considerable criticism, the idea to link agricultural research to farmers' knowledge has been generally accepted (De Wolf 2010). Nevertheless, a factor that has often been neglected in adoption studies is the extent to which farmers themselves are involved in the development of and experimentation with the new technology. Often, a new technology is considered to be a 'finished product' and farmers are assumed to either adopt or not adopt the technology. However, often farmers experiment with different adaptations of the technology, which tends to be neglected by scientific research institutions (De Wolf 2010). When farmers are able to adapt the new technology themselves and apply it in their local context, the potential of successful and sustained adoption will increase (Versteeg *et al.* 1998, Douthwaite *et al.* 2001, Mekoya *et al.* 2008).

Case study: agroforestry adoption

An estimated 1.2 billion people in developing countries rely on agroforestry practices to sustain their agricultural productivity and income (FAO 2011). There are many different types of agroforestry worldwide and they consist of various practices (Sinclair 1999), which in turn consist of components such as fruit trees, fertilizer trees, fodder trees and firewood trees. A large body of the literature on the variables influencing the adoption of agroforestry practices exists, with a real explosion of research since the early 1990s (Mercer 2004). Traditionally, adoption studies have had a tendency to look at extrinsic variables when explaining the uptake of agroforestry. More recently, studies have also looked at socio-psychological factors, such as perceptions and attitudes, to explain adoption behaviour. Here, we review empirical agroforestry adoption studies from sub-Saharan Africa to illustrate the present state of knowledge about the adoption process. First, we discuss studies which mainly consider extrinsic factors, such as the characteristics of the adopter, the external environment and the innovation, as the main explanatory variables (Table 1). We then examine adoption studies which have attempted to explain agroforestry adoption behaviour by linking it to farmers' perceptions and attitudes (Table 2).

Studies focusing on extrinsic factors

In a global meta-analysis of agroforestry studies, Pattanayak *et al.* (2003) reviewed 120 cases of the adoption of agricultural and forestry technologies by smallholder farmers. Their study concluded that the factors which explain technology adoption within an economic framework can be grouped into five categories: preferences, resource endowments, market incentives, biophysical factors and risk and uncertainty. The study then selected 32 empirical studies, most of which took place in Asia and Africa, and performed a meta-analysis to evaluate the significance of the adoption categories. Although the results suggest that preferences and resource endowments are the most common factors included in the studies, they conclude that factors in the risk, biophysical and resource endowments categories are most likely to significantly influence adoption behaviour (Pattanayak *et al.* 2003).

Table 1. Empirical studies of extrinsic factors affecting agroforestry adoption in Africa.

Author(s)	Year	Country	Agroforestry innovation	Explanatory variables
Allen	1990	Swaziland	Homestead tree planting	Homestead size, wealth status and years of residence
Ayuk	1997	Burkina Faso	Live fence	Water availability and profitability of technology
Franzel	1999	Cameroon, Zambia and Kenya	Fertilizer trees	Population density, land availability and soil fertility
Adesina *et al.*	2000	Cameroon	Alley farming	Gender, extension, farmer group membership and population density
Adesina and Chianu	2002	Nigeria	Alley farming	Farmer characteristics and economic variables
Thangata *et al.*	2002	Malawi	Improved fallows	Availability of land and labour
Thangata and Alavalapati	2003	Malawi	Fertilizer trees	Age of farmer, extension contact, number of people contributing to farm work
Ajayi *et al.*	2003	Zambia	Fertilizer trees	Awareness of technology, membership of farmers' group, wealth status, size of land holding, the use of modern farm inputs, possession of oxen, cash crop production, labour constraints and short investment horizon of farmer
Phiri *et al.*	2004	Zambia	Improved fallows	Gender and wealth status
Krause *et al.*	2007	Ethiopia	Integration of woody plants	Resource-based factors and characteristics of the farmers
Matata *et al.*	2010	Tanzania	Improved fallows	Receiving information on improved farming, farmer participation in improved farming, membership in farm groups and contacts with extension
Wambugu et al.	2011	Kenya, Tanzania, Uganda and Rwanda	Fodder shrubs	Inherent attributes of fodder shrub technologies and landscape, collective action, pluralistic extension approach, involvement of large NGO promoters, dissemination facilitators, farmer-to-farmer dissemination, involvement of the private sector in inputs supply and marketing systems, facilitating seed flows, civil society campaigns, gender and equity 'inclusivity' in extension approaches and strategies, 'piggy-backing' of fodder innovations on other technologies preferred by the farmers and enabling political environment
Ndayambaje *et al.*	2012	Rwanda	Tree planting	Gender of head of household, number of salaried members of household, amount of on-farm fuelwood, number of meals per day, geographical location of household and selling of tree products
Gibreel	2013	Sudan	Gum Arabic agroforestry	Commercialization index, access to credit, land fragmentation, education level, gum Arabic gate price, distance to markets, years of experience in farming and working days for commercial sole crop production
Bullock *et al.*	2013	Tanzania	Cardamom agroforestry	Marital status, household size, remittances, credit access and tenure security
Jerneck and Olsson	2014	Kenya	Agroforestry	Food security and poverty and risk and uncertainty

Table 2. Empirical studies of intrinsic factors affecting agroforestry adoption.

Author(s)	Year	Country	Agroforestry innovation	Explanatory variables
Douthwaite *et al.*	2002	Nigeria and Benin	Alley farming *Mucuna* cover crops	Farmers' and researchers' perceptions of technology
Mekoya *et al.*	2008	Ethiopia	Exotic multipurpose fodder trees	Perceptions of use value, management practices and constraints to adoption
Sileshi *et al.*	2008b	Malawi, Mozambique and Zambia	Agroforestry	Perceptions of tree mortality, pests and pest management practices

The importance of risk and uncertainty in the adoption of agroforestry has also been demonstrated by Jerneck and Olsson (2014) for small-scale farmers in western Kenya. In this study, 'narrative walks' were employed to analyse reasons for adoption and non-adoption. Their findings showed that agroforestry fails to be taken up by the 'poorest of the poor', whose main priority is to get food on the table and who cannot afford taking risks by investing time and labour in new technologies which have uncertain benefits in the long term. In contrast, farmers who enjoy higher levels of food security are more likely to be 'opportunity seekers' and might be more inclined to venture into agroforestry (Jerneck and Olsson 2014).

Factors associated with resource endowments have been well studied in relation to agroforestry adoption (Pattanayak *et al.* (2003). For example, Franzel (1999) used the profitability–acceptability–feasibility framework to assess the adoption of improved fallows in different settings in sub-Saharan Africa. In southern Cameroon, where land is plentiful and natural fallows restore soil fertility, farmers are not inclined to invest in improved fallows; whereas in eastern Zambia, where the population density is higher and farmers experience a decrease in soil fertility, the potential for tree fallows is great. In the intensive systems in western Kenya, land is scarce and cropped continuously which makes certain fertilizer trees unattractive to farmers (Franzel 1999). Similarly, Adesina *et al.* (2000) used an econometric model to analyse the factors determining farmers' adoption of alley farming in southwest Cameroon. The analysis showed that adoption was higher for male farmers, farmers having contacts with extension agencies and farmers belonging to farmers' groups. In contrast to the findings by Franzel (1999), agroforestry adoption decreased in areas with very high population pressure, whereas it increased in areas with high fuelwood scarcity (Adesina *et al.* 2000).

The provision of direct economic benefits resulting from agroforestry has been mentioned as a key factor in determining adoption potential (Table 1). For example, a study on the adoption of agroforestry (live fence) technologies in Burkina Faso found that in addition to water availability, the profitability of the technology enhanced the likelihood of adoption (Ayuk 1997). A recent study looking at the factors determining tree planting on farms in rural Rwanda found that significant predictor variables include the gender of the head of the household, the number of salaried members of the households, the amount of on-farm fuelwood, the number of meals per day, the geographical location of the households and the selling of tree products (Ndayambaje et al. 2012). This study concluded that the presence of different tree species on farms was driven mainly by economic factors, including availability of food, firewood and poles, and total income, and not by environmental objectives. Although most agroforestry technologies provide direct food benefits and concurrently produce ecosystem services and benefits that benefit the society, according to Ajayi *et al.* (2007) farmers receive no incentive for the environmental services that result from agroforestry adoption, and therefore, they have little motivation to change to more environmentally friendly land uses such as agroforestry.

Although economic considerations are often found to play an important role in the adoption process of agroforestry, a wide range of other variables affects the decision to plant trees. For example, a study looking at the factors determining the decision to adopt and adapt alley farming in Nigeria showed that both economic variables as well as farmer characteristics were significant in explaining farmers' adoption decisions (Adesina and Chianu 2002). Similarly, Krause *et al.* (2007) analysed smallholder farmers' decisions for the integration of woody plants in Ethiopia and found that resource-based factors as well as personal characteristics of the farmers are major decision-making determinants. Thangata *et al*. (2002) constructed a model to simulate household decision-making in relation to agroforestry adoption in Malawi, and found that the adoption pattern for improved fallows is mainly driven by the availability of land and labour. In a subsequent study, the differences between adopters and non-adopters of the fertilizer tree *Gliricidia sepium* in Malawi were examined (Thangata and Alavalapati 2003). The results suggest that age of the farmers, extension contact and the number of people contributing to farm work, are important factors in the adoption process.

A recent study on the adoption of traditional gum Arabic agroforestry systems in western Sudan used a binary probit model to investigate which factors influence the decision to adopt this technology (Gibreel 2013). Their results show that farmers with less commercialization, access to credit, less fragmented land, more education, high gum Arabic gate price, located away from the markets and with more years of experience in farming, are more likely to adopt the traditional gum Arabic agroforestry system. In contrast, the allocation of more working days for commercial sole crop production, more fragmented land and a higher commercialization index reduces the likelihood of adoption. Matata *et al.* (2010) identified the factors which drive the adoption of improved fallows among smallholder farmers in western Tanzania. The results suggest that significant explanatory variables include receiving information on improved farming, farmer participation in improved farming, membership of farm groups and contacts with extension, whereas marital status, formal education and regular off-farm income had no influence on the decision to plant improved fallows. Farmers listed a number of constraints to the adoption of improved fallows, and the main obstacles listed were lack of awareness or poor knowledge of improved fallows, unwillingness to plant trees and the inability to wait two years before getting benefits from the technology (Matata *et al.* 2010).

Ajayi *et al.* (2003) presented a synthesis of a number of studies that looked at the factors influencing farmers' decisions to adopt fertilizer tree-based agroforestry in Zambia. Their analysis identified a number of factors positively associated with the planting of fertilizer trees: farmer awareness of the technology, membership of farmers' group, wealth status, size of the land holding, the use of modern farm inputs, possession of oxen and cash crop production. Factors having a negative relationship with the decision to establish fertilizer trees included labour constraints and a short investment horizon of the farmer. Gender, education, marital status, age, size of the household, off-farm income and size of the maize field did not have a direct relationship with farmers' decision to initially test fertilizer trees in their fields during the early years of the dissemination of agroforestry in farming communities (Ajayi *et al.* 2003). Over time, policy and institutional factors such as incidents of fire and grazing, land tenure and other policy factors assumed greater importance in influencing farmers' adoption decisions. Similarly, Allen (1990) investigated homestead tree planting practices in Swaziland and linked these to socio-economic characteristics of the homesteads. He found that the poorest and newest homesteads were less likely to have planted trees and the wealthiest homesteads were most likely to have planted woodlots, suggesting that wealth status affects adoption. In contrast, Phiri *et al.* (2004) evaluated the relationship of gender and wealth status with the planting of improved tree fallows in Zambia to assess how these farmer characteristics affect the uptake of agroforestry technologies. They concluded that improved fallows are both gender-neutral and wealth-neutral, which suggests that there are other factors which determine the adoption potential of these agroforestry technologies.

Recently, Bullock *et al.* (2013) measured the influence of socio-economic characteristics, physical and financial assets, tenure security and plot-specific attributes on the adoption of soil replenishment practices in cardamom agroforestry systems in the East Usambaras in Tanzania. A logistic regression analysis showed that marital status, household size, remittances, credit access and tenure security significantly affected the adoption of fallows and the application of organic inputs. In a study focusing on the East African region, Wambugu *et al.* (2011) looked at the adoption process of fodder shrub innovations in Kenya, Tanzania, Uganda and Rwanda. The study identified several key elements for scaling up the adoption of fodder innovations, including: the inherent attributes of fodder shrub technologies and the landscape; collective action; a pluralistic extension approach; involvement of large non-governmental organization (NGO) promoters; dissemination facilitators; farmer-to-farmer dissemination; involvement of the private sector in inputs, supply and marketing systems; facilitating seed flows; civil society campaigns; gender and equity 'inclusivity' in extension approaches and strategies; 'piggy-backing' of fodder innovations on other technologies preferred by the farmers; and an enabling political environment. This study demonstrates that in addition to extrinsic characteristics such as attributes of the innovation and the external environment, dissemination and extension play a key role in the scaling up of this type of agroforestry technology in East Africa.

Studies focusing on intrinsic factors

Most of the original agroforestry adoption studies published have sought to explain adoption by looking at extrinsic factors, with a strong focus on socio-economic factors. Relatively few studies look at how agroforestry projects are perceived by farmers and how they view the benefits and challenges, and how these perceptions in turn affect the uptake of the technology. Over the last decade, several studies looking at attitudes and perceptions in relation to agroforestry and its adoption have been published (Table 2). There are only a few examples of studies from sub-Saharan Africa which explore attitudes and perceptions in relation to agroforestry adoption. These examples are described here and explore the perceptions farmers have about certain agroforestry practices, their impact and management (Douthwaite *et al.* 2002, Mekoya *et al.* 2008, Sileshi *et al.* 2008b). There are a few more examples of studies outside of sub-Saharan Africa which set out to measure attitudes towards agroforestry and the environment and link these to the decision to adopt (Sood and Mitchell 2004, Zubair and Garforth 2006, McGinty *et al.* 2008); however, these are not discussed here as they are beyond the scope of this paper.

In Ethiopia, Mekoya *et al.* (2008) found that farmers generally had positive perceptions about multipurpose fodder trees for their feed value and contribution to soil conservation, but that adoption was constrained by agronomic problems, low multipurpose value and land shortage. They recommended that farmers should be involved at all stages of project design and implementation to enhance adoption. Similarly, Sileshi *et al.* (2008b) assessed farmers' knowledge and perceptions of tree mortality, pests and pest management practices in agroforestry in Malawi, Mozambique and Zambia. The study showed that farmers perceived insects as the primary cause of tree mortality, followed by drought, bush fires and livestock browsing. Farmers' perceptions of tree mortality was then linked to several independent explanatory variables and found to be a function of operator-specific variables such as gender, education level and years of experience with tree species.

Frequently, farmers have different perceptions of agroforestry benefits than research and extension staff who are trying to promote the technology, which could result in lower adoption levels when ignored. After evaluating the experiences of stakeholders with alley farming and the use of *Mucuna* cover crops in West Africa, Douthwaite *et al.* (2002) found that researchers had quite different and more positive perceptions of these technologies compared to farmers. Researchers believed that *Mucuna*'s main attraction for farmers was its ability to improve soil fertility, whereas farmers valued its weed-controlling qualities higher than its soil fertility enhancing ones. However, one of the reasons that the adoption of *Mucuna* was more successful compared to alley farming was that researchers were more aware of these differences and took them into account when recommending its use. In addition, *Mucuna* was simpler to use and more suitable for farmers to adapt to their existing system compared to alley farming, which contributed to its higher adoption rate. Agroforestry adoption is often seen as a process in which the farmer merely adopts or rejects the technology, whereas the farmers themselves often adapt the technology and can play an important role in the development of the technology (Douthwaite *et al.* 2002).

Implications

The review of adoption studies (Tables 1 and 2) shows that there are a large number of factors which affect the decision-making process on the uptake of a new practice. The analysis confirms that both extrinsic variables, such as the characteristics of the adopter, the characteristics of the innovation and the external environment, as well as intrinsic variables, such as knowledge, perceptions and attitudes, influence the decision to take up a new agroforestry technology. However, there seems to be considerable variation between studies in which variables are considered and what their effects are. As some variables can have a positive impact in one study but a negative or insignificant effect in other cases, it is difficult to establish their role in the uptake of agricultural technologies. As the adoption process is very complex, it is almost impossible to understand the influence of all possible factors involved as well as their interdependencies. The analytical framework presented in this paper attempts to bring together all variables which play a role in the decision-making process; however, more information is needed on how the extrinsic variables are related to each other and how they shape the intrinsic variables.

The various empirical agroforestry adoption studies reinforce the need to consider both intrinsic and extrinsic factors simultaneously rather than separately in order to better understand the decision to adopt agricultural practices. As each individual adoption study tends to focus on a unique case, these studies only shed light on which variables are important for that specific situation. Rarely does any single study incorporate all factors outlined in the framework. Each individual study is context specific and can seem to focus on part of the story, and only when we put all the different studies together, we start to get the broader picture. In this way, the framework is useful as a way of organizing and bringing together the variables analysed in the various adoption studies. It shows that both extrinsic and intrinsic variables can explain adoption and ideally should be studied together to increase our understanding of this complex process. However, research focussing on the role of intrinsic variables on the adoption of agroforestry practices in sub-Saharan Africa is limited to date. In addition, few studies have incorporated both sets of variables, and there is little understanding of how the perceptions and attitudes are shaped by the various extrinsic factors in our framework. Future research on agroforestry adoption in sub-Saharan Africa should look beyond merely studying extrinsic variables and should aim to include both sets of variables to better understand the adoption process.

Although the importance of the role of knowledge, perceptions and attitudes in the adoption process of agroforestry has been recognized before (Fischer and Vasseur 2002, Sood and Mitchell 2004, Zubair and Garforth 2006, McGinty *et al.* 2008, Mekoya *et al*. 2008, Sileshi *et al.* 2008b), one possible reason for the fact that these factors have received relatively little attention to date is that there are several methodological challenges associated with measuring them. It is more straightforward to measure characteristics of the farmer or the external environment than measuring someone's knowledge, perceptions and attitudes. Several methodologies have been developed to measure complex constructs such as attitudes (Oppenheim 1992); however, there is still a lot of debate over the validity and consistency of such methods (Roberts *et al.* 1999).

In the foregoing discussion, agroforestry was used as an example to illustrate how the analytical framework can be used to categorize the different adoption studies and help to understand the broader picture of decision-making in adopting new agricultural innovations. The framework can be used to better understand the adoption process of other agricultural innovations. A mechanistic understanding of how intrinsic and extrinsic factors drive adoption can help in targeting technologies appropriately or redesigning them to be locally relevant and sustainable. It will be useful to have more synthesis studies which cut across different fields of agricultural research and bring together findings of adoption processes for a wider range of sustainable agricultural innovations.

Conclusions

We have provided an analytical framework for examining the adoption process of agricultural innovations that simultaneously takes account of both extrinsic and intrinsic factors and their interaction in the decision-making process for the adoption of agricultural innovations. While we suggest that knowledge, attitudes and perceptions in relation to the benefits and challenges of the technology play a key role in the decision to adopt, we do not claim that conventionally studied variables such as farmer characteristics and economic variables are not important in the decision-making process or that existing models focusing on extrinsic factors are flawed. Rather, we suggest that there is an intermediate step in the adoption process, where farmer characteristics and economic variables affect adoption indirectly by influencing the knowledge, attitudes and perceptions, which in turn influence farmers' decisions of whether or not to adopt an innovation. Our framework emphasizes that these extrinsic factors affect the knowledge and perceptions and, consequently, the attitudes in relation to the technology. When we comprehend what knowledge and attitudes people have in relation to agricultural innovations and how these are brought about, we can start designing projects to be of local relevance. We can also target existing innovations or redesign them to suit the preferences and/or particular conditions of farmers to guarantee adoption and sustainability.

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Note

1. In the literature, the terms 'belief' and 'perception' are often used interchangeably and to make matters more complicated, the term belief has different meanings to different authors as it is also being used to refer to religious views. To avoid any confusion, here we refrain from using the term 'belief', instead we use the term 'perception' to refer to the views a person has about a certain behaviour or object.

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