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Rethinking technological change in smallholder agriculture

Dominic Glover[1], James Sumberg[1], Giel Ton[1], Jens Andersson[2] and Lone Badstue[3]

Abstract

The concept of technology *adoption* (along with its companions, *diffusion* and *scaling*) is commonly used to design development interventions, to frame impact evaluations and to inform decision-making about new investments in development-oriented agricultural research. However, adoption simplifies and mischaracterises what happens during processes of technological change. In all but the very simplest cases, it is likely to be inadequate to capture the complex reconfiguration of social and technical components of a technological practice or system. We review the insights of a large and expanding literature, from various disciplines, which has deepened understanding of technological change as an intricate and complex sociotechnical reconfiguration, situated in time and space. We explain the problems arising from the inappropriate use of adoption as a framing concept and propose an alternative conceptual framework for understanding and evaluating technological change. The new approach breaks down technology change programmes into four aspects: propositions, encounters, dispositions and responses. We begin to sketch out how this new framework could be operationalised.

Keywords

Technology adoption, agricultural research and development, agricultural extension, evaluation, affordances

Introduction

Developing and spreading new technology is widely considered to be essential for increasing the productivity, sustainability and resilience of small-scale farming systems in the global South (InterAcademy Council, 2004; InterAcademy Partnership, 2018; McIntyre et al., 2009). The generation, testing and dissemination of technology are at the core of development-oriented agricultural research (Thornton et al., 2017; von Kaufmann, 2007). In the context of small-scale farming systems, how should agricultural development professionals conceive of technological change and how can it be most meaningfully and effectively documented, measured and evaluated? Understanding the processes of technological change and assessing their outcomes are first-order challenges to the people and organisations involved in development-oriented agricultural research. We contend that the concepts and methodologies most commonly used for this are flawed conceptually and operationally, and increasingly unfit for purpose. Specifically, the dominant concept of technology *adoption* provides a poor basis for understanding processes and consequences of technological change. We review a diverse body of literature that has introduced more sophisticated frameworks for understanding technology and technological change. Using these as a resource, we propose an alternative conceptual framework, which can help to improve the design and targeting of technological change in development-oriented agricultural research.

Formal research is only one of multiple sources of new and improved technology (Biggs, 1990; Douthwaite et al., 2001). Scientific research institutes are only one type of component within interacting systems of innovation (Hall et al., 2001; Sumberg, 2005), in which different kinds of knowledge and practice are connected – including the locally rooted, informal, practical and experiential knowledge of farmers and farming communities as well as the abstract, formal, theoretical and experimental knowledge of formally trained scientists. However, our principal focus in this article is on processes of technological change that are deliberately stimulated and orchestrated, rather than innovations that emerge from farmers' own experimentation and learning.

[1] Institute of Development Studies (IDS), University of Sussex, Brighton, UK
[2] Sustainable Intensification Programme (SIP), International Maize and Wheat Improvement Center (CIMMYT), Wageningen, the Netherlands
[3] Socioeconomics Programme (SEP), International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico, USA

Corresponding author:
Dominic Glover, Institute of Development Studies (IDS), University of Sussex, Brighton BN1 9RE, UK.
Email: d.glover@ids.ac.uk

The conceptual framework that we introduce in this article has four aspects: *propositions*, *encounters*, *dispositions* and *responses*. These can be used to think about and examine a technological change process, while paying due attention to the agency of the actors involved in the process. Attending to the agency of farmers, alongside that of scientists, project managers and extensionists, will be important to our discussion of how a novel farming technology may be perceived (or not) as a relevant opportunity – something useful, accessible and realistic – by different farmers. Specifically, we will employ the concept of *affordance* to explain how and why a proposed change in technical inputs and practices may be appreciated and taken up in particular ways by different farmers and cultivators, including those who are deliberately targeted by the intervention, as well as those who become aware of it through other, informal and unintentional ways.

The article is organised as follows. The next section reviews the conceptual and operational critiques of adoption and highlights some of the ways that adoption research is being and could be extended. The section that follows presents an alternative conceptual vocabulary for technological change in smallholder agricultural systems. In the final section, we suggest how this framework could be developed so that it is useful to those designing, funding, implementing and evaluating development-oriented agricultural research.

The problem with adoption

The theory of technology adoption and diffusion as articulated by Rogers (2003) has been hugely influential and remains the bedrock for analysis of technical change within developing country agriculture. The limitations of adoption, and conventional ways of measuring it, have long been recognised (Doss, 2006; Feder et al., 1985: 287–288; Temple et al., 2016). Despite this, measuring (or purporting to measure) the adoption rate of newly introduced technologies remains central to the evaluation of agricultural research and decision-making about new investments. Glover et al. (2016) highlight two key issues. The first is a tendency to treat technology as a black box, especially when it is conceived as an embodiment of knowledge within material inputs and practical tools (as in the phrase 'embodied technologies' (Shih and Chang, 2009)). The black box idea underpins the common portrayal of technologies as discrete, generic and mobile packages that are capable, in theory and principle, of being transferred smoothly from one setting to be adopted and implemented in another (Glover et al., 2017). This taken-for-granted conception of technology accentuates its practical, material and technical features, while obscuring social, cognitive, epistemological, institutional and cultural processes that are actually essential to the way the package has been assembled, configured and stabilised (Bijker et al., 1987; Latour, 2005; MacKenzie and Wajcman, 1999). The second is a conception of technological change as a relatively simple, largely individual, dichotomous switching process, constituting a linear progression from old and inferior materials, tools and methods to new and superior ones.

Surprisingly often, evaluation studies completely omit a functional definition of what should be counted as an instance of adoption (Andersson and D'Souza, 2014; Herdt and Mines, 2017; Loevinsohn et al., 2013). In other studies, adoption is defined in simplistic, binary terms so that technology practitioners are classified crudely into two mutually exclusive groups of adopters and non-adopters (Sumberg, 2016). This binary classification is sometimes used even in cases where the authors acknowledge that the construct of adoption is crude and limiting (Kabwe et al., 2016). Adoption studies also typically take a snapshot of a practice without considering dynamic processes of learning and experimentation, even though these capacities are essential to technological change.

The conceptual critique

We argue that the concept of adoption is flawed conceptually, because it offers an oversimplified model of what happens during all but the very simplest processes of technological change. Contributions from development studies, innovation studies, science and technology studies, anthropology, political economy and other fields have enlarged and deepened the understanding of technological change as an intricate and complex reconfiguration of various social and technical components. In particular, we draw attention to approaches that emphasise the agency of technological practitioners.

Adoption as a model of technological change is particularly associated with the theory of innovation diffusion and the classic work of Everett Rogers (Rogers, 2003; see Mica, 2013). Within this perspective, technology is often depicted as a technology package and the input of a diffusion process. The spread of technology through a community or society is portrayed as an epidemiological process of propagation. The new technology flows and spreads through a sequential accumulation of decisions by many individual adopters. Adoption involves a rather simple, transactional substitution, whereby existing techniques, artefacts and practices are displaced by newer and better ones (Mica, 2013).

The concept of adoption also fits harmoniously with induced innovation theory, in which new technology is developed in response to a resource scarcity and adopted because it increases efficiency or intensifies the use of resources, resulting in an improved production function. According to this theory, technological change is induced by fluctuations in factor prices that create relative scarcity or a competitive opportunity. The focus is on the contextual drivers of technological change, while technology itself remains an abstraction (Boserup, 1965; Hicks, 1931; Ruttan and Hayami, 1984).

Within both of these bodies of work, technology adopters are seen to exercise a limited and reactive kind of agency, whereby rational calculation leads naturally to, or induces, the selection of new and improved technology.

Engagement with the technology is largely confined to a simple, binary choice.

Adoption also features in evolutionary perspectives on the study of technological change, in which technologies resemble organisms or species, whose fitness is tested within a selection environment (Dosi, 1982; Parayil, 2003; Perez, 2010). Researchers, inventors, entrepreneurs, investors and policymakers are identified as prime movers of technological change, because they create and nurture innovations that produce a diversity of alternative technical options and make them available to potential users. Again, the agency of technology adopters is confined to an exercise of choice among readymade technological packages, artefacts and systems.

Social science literature on innovation and technological change has progressed far beyond the simplified model of technology adoption. This includes the thinking of Everett Rogers himself, who, in later iterations of diffusion theory, acknowledged that technology packages do not circulate and spread as fixed entities, but are changed as they are implemented or re-invented locally (Mica, 2013). The bodies of literature discussed below are more attentive to the agency of so-called adopters or users as actors and practitioners in the construction of technology.

The agency of technology users is recognised to a certain degree within critical political economy analyses of innovation and technological change. These perspectives typically portray technologies as weapons in struggles for social and economic power and dominance. Big corporations, governments and capitalists are usually perceived to have the upper hand over ordinary citizens, poor and marginalised people and dispossessed minorities. Users of technology are sometimes portrayed not merely as passive adopters, but as victims. Technology is often depicted as a fixed entity, endowed with intrinsic characteristics and immanent potential that strongly determine outcomes, although it is sometimes also recognised that technologies could be redesigned and reconstructed using more democratic and accountable principles, to achieve alternative outcomes. An example of this type of debate is the contention that corporate-controlled biotechnologies (e.g. transgenic crops protected by patents and technology licences) and open-source biotechnologies could have very different implications for the stakeholders concerned (Kloppenburg, 1988; Kloppenburg, 2010; Ruivenkamp, 2005).

Critical political economy analysts can be guilty both of overestimating and underestimating the power of technology users to reconfigure technical systems. Nonetheless, these approaches helpfully draw attention to asymmetrical relations of power that are expressed and reproduced through technology. Importantly, this perspective undermines key assumptions, namely (1) that technologies are taken up through free and economically rational individual choices, and (2) that the technologies that spread are necessarily and objectively better than those they displace or those that fail to diffuse.

The agricultural innovation systems literature highlights the interactions, agency and capabilities of multiple actors involved in the development and spread of novel technologies (Clark, 2002; Sumberg, 2005). Methods of participatory technology development and assessment – including participatory crop improvement – are supposed to ensure that intended users are involved in the construction of innovations and that new technologies are sensitive to the concerns, priorities and demand of the target population (Almekinders and Elings, 2001; Ceccarelli and Grando, 2007; Hennen, 1999). Within these discourses, the notion that users are merely adopters breaks down substantially, and it is not sufficient to measure the success of innovation systems through the metric of adoption rates (Ronner et al., 2018; Weyori et al., 2018).

The theories and approaches discussed above are quite well established in professional practice. We now turn to a set of perspectives that have had substantially less influence on the thinking and practices of development professionals, researchers and evaluation specialists. These social constructionist approaches share an attentiveness to the agency of technology practitioners – both individuals and groups – and the ways in which technology is reconstructed and reconfigured as it moves from one situation and community of practice to another.

Participatory and social learning (Leeuwis and Pyburn, 2002; Röling and Wagemakers, 2000) and actor-oriented (Long, 1989) perspectives emphasise that technology involves the practices and collective actions of many social actors, such as farmers, researchers, entrepreneurs, companies and aid donors, who are portrayed as agents interacting to produce and disseminate technological innovations. We highlight here, in particular, Norman Long's actor-oriented sociology, where technological change is seen to involve encounters and exchanges between actors inhabiting different worlds of knowledge and practice (Long, 1989). These kinds of approaches recognise that knowledge changes as it travels between different social worlds and biophysical contexts to generate specific, local configurations of technological practice.

The theories of the social construction and social shaping of technology (Bijker and Law, 1992; Bijker et al., 1987) and actor–network theory (Latour, 2005) depict technological change as sociotechnical ensembles, heterogeneous networks or actor networks of interacting people, objects, artefacts, institutions and symbols. Technological change is represented as a process whereby scientific insights and sociotechnical configurations are 'translated' through the making and breaking of relations and connections to create new actor networks (Callon, 1986). This process of translation makes technical objects and systems meaningful and relevant to different actors and groups. From this perspective, it is not possible to represent technology as a discrete, independent and mobile black box that can be transferred smoothly from one place to be adopted in another.

Ethnographic or technographic approaches, inspired by the work of Emile Durkheim and Marcel Mauss, view technology through the notion of *habitus* (Jansen and Vellema, 2011; Richards, 2000; Schlanger, 2006). Here, technology is seen as an essential form of human and social practice, enabled and constrained by biophysical materiality and by local social relations and material interactions. Understanding technology is all about understanding the knowledge, skills, routines, institutions and practices of its practitioners, both individually and in coordination with others.

These insights affirm that technological change has much to do with:

- the reconfiguration of relations among people, objects and artefacts, materials and biophysical environments;
- the redistribution of agency through the reorganisation and reconfiguration of tasks;
- the reformation and reconfiguration of social networks and institutional arrangements; and
- the acquisition or development of new practices and their associated skills and knowledge, while abandoning or adjusting existing repertoires.

We suggest that much could be learned from these approaches, which are more actor-oriented but less methodologically individualistic; which recognise different kinds and loci of agency; and propose a more processual understanding of technology as 'something people do, make or remake', rather than 'something they receive or adopt' (Glover et al., 2016: 4). In other words, technology is better understood as a technical practice rather than something embodied within novel artefacts and systems. Meanwhile, technological change is better conceived as the outcome of a reconfiguration of sociotechnical relationships and interactions, rather than the input that triggers or even constitutes innovation.

The operational critique

The adoption concept creates operational problems for the designers, implementers and evaluators of programmes that are intended to stimulate technological change and bring about improvements in agricultural systems. This is because current approaches to understanding technological change reify a rather peculiar and special case as a general model – namely, the simple substitution of one readily identifiable artefact or package for another – which is neither relevant to, nor representative of, much that happens in real-world processes of technological change. For any technological change that involves greater sociotechnical complexity, the outcomes of a technological reconfiguration are likely to be indeterminate, the more so as complexity increases. The adoption model is inadequate to cope with the processes, impacts and ramifications of more complicated cases of technological transformation. In these situations, the number and diversity of material components involved in technological change increases, the range of required knowledge, skills and techniques expands, the network of relationships affected grows, the intricacy of institutional frameworks increases and the sociotechnical reconfiguration becomes more complicated (see Box 1).

Arguably, more complex technologies are increasingly important as scientists, policymakers, farmers and others recognise a need for an agricultural transformation that will entail more integrated, sustainable agricultural systems. The adoption concept breaks down whenever it is applied to complex technologies, which involve the integration and coordination of multiple social and technical components, such as integrated soil fertility management, integrated pest management, conservation agriculture (CA) or the System of Rice Intensification. In such cases, it is difficult and often contentious to specify what counts as adoption (Andersson and D'Souza, 2014; Berkhout and Glover, 2011). Moreover, the adoption of one component of such an integrated system, in the absence of complementary practices, might very well result in negative outcomes (Thierfelder et al., 2018). Scenario 2 in Box 1 suggests such a case, in which planting a higher yielding variety without an adequate nutrient supply could have a negative effect. In such circumstances, measuring adoption rates will likely fail to provide an adequate means to measure technological change or evaluate its impacts.

More fundamentally, we argue that detecting something that can be interpreted as an instance of adoption can be less revealing and important than understanding other changes that may have occurred as a consequence of, or under the influence of, a programme or intervention that seeks to promote new technology. When adoption is used as the principal indicator of success or failure, there is a real risk of overlooking wider ramifications (positive or negative) of technological change, including unintended benefits, costs and risks, distributional questions and especially the ways in which the target population, or other people, may be creatively appropriating and adapting the technology. This can lead to two types of error. In the first case, a programme might be judged a success, because farmers' behaviour has conformed to an expected pattern and something recognisable as adoption has been detected. Yet, in the process, considerable harm might have been done, for example, to existing social relations (e.g. inequality, social justice), to agro-ecological practices (e.g. sustainability) or to local resilience (e.g. the ability to detect and respond nimbly to environmental or economic turbulence).

In the second case, a new technology programme might be judged a failure, because farmers' behaviour has not conformed to the programme designers' expectations, which is therefore recorded as non-adoption. Nonetheless, positive and valuable impacts might have developed along the way, which however were unintended and unanticipated, and thus likely go undetected and unrecorded. For example, farmers might have been exposed to new sources of information and acquired new knowledge, skills or self-confidence; they might have formed new associations or networks that improve their performance, reduce vulnerability and strengthen resilience. The final impact of the intervention could have been a net positive, despite the negative evaluation of the extent of adoption.

An alternative conceptual framework

Various scholars have argued that the design and evaluation of technology change programmes should take account of the agency of technology users and try to map the diverse

Box 1. Three illustrative scenarios of technological change

Scenario 1: A simple substitution. Consider a situation in which most farmers already use a hybrid maize variety and purchase their seed from a commercial company. Some farmers switch to an alternative hybrid seed, also purchased on the market. The new hybrid is very similar genetically except for an improved yield potential. The recommended management practices do not change.

Analysis: This example represents the simplest possible technical substitution. No major changes to crop management or the crop or farm system are required or anticipated; the end product (grain) is indistinguishable; and no new commercial or social relationships are required or likely to result from the introduction. *Adoption is an adequate concept to represent the technological change, and conventional ways of measuring adoption and impact could be sufficient. However, such simple cases are very rare, peculiar and relatively inconsequential.*

Scenario 2: A more complicated substitution. Consider another situation, in which most maize farmers use open pollinated varieties (OPVs). To boost productivity, some farmers start planting hybrids, which have a higher yield potential than the local OPVs, but which require higher levels of management, irrigation and soil fertility in order to reach that yield potential. These changes may have knock-on effects on other aspects of the cropping and farm systems: New commercial channels and relationships must be developed to supply the seed and other inputs; training and advice may be needed to help farmers to take full advantage of the hybrids' potential and manage the increased risks of a higher investment.

Analysis: This example represents a more complex scenario of technological change, involving new seed, new and more demanding management practices and new commercial relations. These have to be configured in specific ways in order for the new technical inputs (improved cultivars) to deliver their intended benefits. There is some potential for negative or positive unintended consequences. *In this example, the limitations of a linear conception of technological change, and conventional ways to measure adoption and impact, are evident.*

Scenario 3: A complex transformation of a cropping system. Consider a third situation, in which farmers currently produce irrigated rice using a conventional system. Although there is much variation around each element of the existing system, in general, most farmers puddle their levelled fields and keep them flooded throughout most of the production cycle; transplant closely spaced, relatively mature seedlings; and use synthetic fertiliser and some pesticides. A development organisation introduces the System of Rice Intensification (SRI), which is based on four key principles that interact with each other: early, quick and healthy plant establishment; reduced plant density; improved soil conditions through enrichment with organic matter and reduced and controlled water application. The specifications for each of these principles, as well as their combination, are supposed to be adapted and adjusted locally to suit farmers' specific circumstances.

Analysis: This example represents a very complex scenario of technological change. Some of the SRI principles and practices imply extensive reorganisation of the crop and farm system and may require new investments, novel techniques, closer supervision, new patterns of labour allocation and changes in intra- and inter-household relations. Because there can be adaptation around every practice and their combination, the expected outcomes of the technological change process are, in principle, indeterminate at an individual household level and potentially multifarious on a community scale. It may be difficult to determine whether, or to what extent, a particular farmer is practising SRI. There is wide scope in principle for local experimentation and learning and a considerable potential for negative or positive unintended consequences. In this situation, *conventional approaches to modelling and evaluating adoption as a bivariate choice have very limited value – and could be misleading.*

pathways of technological change that may unfold after an intervention (Brown et al., 2017; Brown et al., 2018b; Douthwaite et al., 2003; Mausch et al., 2018). Glover et al. (2016) proposed a design specification for an alternative concept that could replace adoption, which should be (a) conceptually robust and theoretically informed, while also (b) providing a practical, reliable empirical framework for assessing and evaluating technological change and the impacts arising from it. In this section, we introduce and discuss an alternative conceptual vocabulary that responds to the first part of this specification. This framework is inspired by the actor- and practice-oriented perspectives discussed in the second section, which give due weight to the agency of people involved in processes of technological change.

The agency of technological practitioners can be appreciated through the theory of affordances, which was first articulated by the ecological psychologist James Gibson (1966) and has since been taken up by anthropologists and sociologists of technology. Gibson and others defined affordances as the resources available in a situation or an environment, which offer opportunities for functional interaction (Hutchby, 2001; Pfaffenberger, 1992; Sigaut, 1996). In other words, an affordance is an opportunity, perceived by an agent, to put an object or material to some use. The perception of an affordance is subjective, situational and relational. Affordances arise from the material properties of an object or environment and the characteristics of the people interacting with it, including their mental and biophysical capacities (e.g. their knowledge, intelligence, creativity, strength and dexterity) and their resource endowments (of money, energy, land, labour, etc.), conditioned by timeliness (in relation to seasonality, sequences or conjunctions of events, and stages of life) and shaped by the social and cultural norms and rules that govern appropriate behaviour (e.g. in many societies, different agricultural tasks and tools are seen as the proper domains of men or women, respectively) (Arora and Glover, 2017).

The key insight to draw from affordance theory is the recognition that the affordances of different agricultural technologies are specific to different people and groups in different situations. For example, a maize hybrid and its recommended cultivation practices may have quite different affordances for two farm households in the same village, or for similar households in different agro-ecological zones. We should expect the responses of these households to differ, and that their pathways of technological change will also be different.

These differences in households' responses to a technological package are likely to be only partially attributable to observable household characteristics, such as assets, the household head's years of formal schooling or the number of links in their social networks. The theory of affordances reveals that opportunities are present, not due to intrinsic and objectively measurable attributes of the technical package, nor to the fixed characteristics of the potential users, but within the specific and dynamic relations and interactions between them.

Our proposed framework seeks to respect the agency of technological practitioners and apply the insights of affordance theory. It comprises four key components: *propositions*, *encounters*, *dispositions* and *responses*. We elaborate on the four components below.

Propositions

We use the term proposition to evoke the sense that any new technology is encountered or perceived for the first time as an idea or as an image of what could or might be. The proposition conjures up the possibility of an alternative way of working or making to achieve new or different outcomes. A proposition could be an opportunity that is perceived through the creative agency of a farmer, who comes across a new idea or concept and discerns within it the possibility – a set of affordances – to change their agricultural practice. However, in this article, we are concerned principally with propositions that are deliberately framed and presented to farmers by agricultural research and extension programmes.

The proposition has three essential components: first, it includes a variety of biophysical resources, such as raw materials, tools, equipment, machines, energy and built infrastructure. In the case of agriculture, these would classically include living organisms such as seeds and livestock, mineral and organic fertilisers, crop protection products such as herbicides, pesticides and fungicides, machines such as seed drills, combine harvesters and backpack crop sprayers and infrastructure such as barns, polytunnels and irrigation canals.

Second, it includes methods, techniques and practices. This category includes a set of specific instructions, recommendations, guidelines and protocols associated with the use of particular artefacts, resources or inputs that are at the heart of the proposition. These recommendations are usually set out by scientific experts, such as plant breeders, microbiologists, entomologists and irrigation engineers, and are usually oriented toward optimal performance of a specific artefact or input. They likely draw on basic principles of good agronomy or crop protection, specific knowledge derived from experimental results or on-farm experiences and knowledge about, or drawn from, local farming systems, contexts and practices.

In development-oriented agricultural research, the first two components of the proposition are drawn from experimental science and the technical expertise of agricultural researchers and field technicians. They correspond approximately to the hardware and software dimensions of technology that are recognised in other theoretical approaches (e.g. Rogers, 2003). In our framework, these two technical components are incorporated into a proposition when they are combined with a third element, which is a proposed mode of engagement in agricultural production.

The proposed mode of engagement typically embodies implicit assumptions or explicit suggestions about the motivations and capabilities of a target group of farmers who are invited to take up the artefacts, methods and techniques being proposed. Choosing to take up the proposition will very likely mean engaging in new kinds of behaviour (e.g. purchasing crop insurance) and establishing or modifying relationships with a range of other actors and institutions (e.g. agricultural extension services, seed companies, NGOs, other farmers and labourers, value chain actors and regulators). Propositions are often very specific to a particular target group of farmers, but this specificity is not always clearly articulated or acknowledged. For example, the proposition might rest on the assumption that farming is or should be pursued as a commercial business; or that farmers are able and willing to engage in collective action (e.g. community-based natural resource management or a producers' cooperative).

The suggested mode of engagement is not incidental or ancillary; all three components of the proposition are essential. Together, they constitute a kind of script or programme, which some farmers are made aware of and invited to follow. This occurs through some kind of encounter.

Encounters

Members of a farming community become aware of a new proposition through an encounter. The encounter is the occasion or arena where this awareness occurs. It is a distinct step or element in the process of change, rather than an inherent aspect of the proposition. Here, we draw on Norman Long's characterisation of agricultural extension processes as encounters at an interface between different worlds of knowledge, practice and expertise (Long, 1989). Deliberately convened, choreographed and orchestrated encounters are a core element of agricultural development programmes and the raison d'être of most public and private agricultural extension activities. Farmer meetings, training events, demonstration trials, farm visits, field days, field schools and radio programmes all constitute encounters. Encounters can also occur spontaneously and without formal direction, such as when a farmer sees a new technology being practised by a neighbour or relative or hears about it through local gossip. This implies that a spectrum or continuum exists between more and less deliberately organised encounters.

Importantly, all encounters include dimensions of politics and power. They involve interactions between social actors and organisations that possess different kinds of authority, resources and interests. An encounter is a relational, co-produced event, in which the quality and intensity of interactions between the participants determine how the utility and value of the proposition are interpreted and assessed. Depending on how an encounter is organised and choreographed, it may enable and/or constrain agency, opening up some kinds of possibilities or opportunities (for some actors), while closing down others (for other actors). This implies that the quality as well as the quantity of encounters plays an important role in defining the scope and freedom experienced by intended beneficiaries, or other potential users, to appreciate a proposition and mobilise in relation to it.

Dispositions

An encounter is organised to raise awareness of a proposition, but above all to stimulate interest and encourage a response. The people on the receiving end of propositions are agents within encounters, who may be disposed to respond in a variety of ways, including ways that have not been anticipated, intended or desired by the people or organisation behind the encounter.

The theory of affordances suggests that the variety of dispositions is shaped simultaneously by the individual characteristics and circumstances of people and households, by the dynamics and quality of the encounter and by features of the proposition. Each of the three components of the proposition – the material, the practical and the relational – may create a specific set of affordances for different individuals and groups. Combinations of cultural, economic, biophysical, spatial, temporal and other factors shape perceptions of a proposition. They generate a spectrum of multiple, unique dispositions among the variety of people and households that encounter the proposition. They determine whether, and in what ways, a proposition is perceived as a relevant and interesting opportunity for each individual decision maker.

The multiple factors shaping dispositions can change so that, for example, a disinclination to respond to the proposition immediately after an encounter could turn to a decision to engage with it at some point in the future. Dispositions may evolve as people engage with a proposition and their experience of it develops, so that their perceptions evolve over time and gradually shape an emerging pathway of behavioural change.

Responses

People who are positively disposed to a proposition, and respond to it, embark on a process, and create a discrete pathway, through which the three components of the proposition – artefacts, methods and modes of engagement in farming – are unpacked, reassembled and configured. This process may involve calibration, adjustment, experimentation, adaptation and other moves that result in a functional (re)configuration of the technological design to suit its new situation (Glover et al., 2017). As this process unfolds, technical, practical and social aspects of the technology may be incorporated and absorbed into the wider farm system. New techniques, materials and practices might be rejected after a trial period. The interacting agency of multiple people is involved in this process – including farmers, household members, hired labourers and their communities – which defines and shapes emerging pathways of change that are specific to each situation. The key insight to grasp is that the array of responses available in principle to farmers is potentially wide and diverse. The potential for an intervention to generate effects that were unintended or unanticipated may be large, and the simplification of adoption is not adequate to capture most of these outcomes.

Towards operationalisation

As humanity attempts to address an array of development goals simultaneously, technological designs for the sustainable improvement of agricultural production are becoming more intricate and systemic. In this situation, the conceptual and operational critiques of the adoption model of technological change become increasingly salient. The alternative conceptual framework proposed in this article calls for an agent-, practice- and process-oriented approach, capable of analysing and exploring a variety of pathways of change that may unfold after a proposed technological change is introduced. The practical question is whether such a framework can be operationalised. What is needed is a suite of tools and methods that could capture the way propositions are constructed, the quality of encounters, the range of dispositions generated relationally through interactions between the proposition and people encountering it and the diversity of actions taken (or not) in response. To be considered successful, this tool kit should be practical, efficient and effective, while generating insights into technological change processes that are richer and more informative than given by the framework of adoption.

Precision and nuance have been added to the study of adoption through the development of methods and protocols to evaluate the intensity of adoption (Arslan et al., 2014), partial adoption, dis-adoption (Moser and Barrett, 2003; Neill and Lee, 2001) and other outcomes of technological change that confound the simplicity of the adoption concept. Technological changes that involve the complex integration and configuration of multiple components can be partly captured in econometric models that jointly analyse sets of dichotomous variables. Bunclark et al. (2018) proposed that the adoption of water harvesting technologies occurs along a spectrum, corresponding to degrees or intensity of adoption, rather than a binary state. Other scholars agree that the local modification and adaptation of complex, integrated technologies such as CA are more important to understand than the wholesale adoption or non-adoption of singular technology packages (Brown et al., 2018a; Brown et al., 2018b; Thierfelder et al., 2018). Ronner et al. (2018) examined adaptation rather than adoption, using a methodology that was sensitive to diversity in the use of cultivation methods and practices within a complex farming system.

These are serious, thoughtful and sophisticated efforts to apply the adoption concept in more subtle and insightful ways, yet they pose significant conceptual, methodological and data challenges that limit the usefulness of their conclusions to decision makers (Joly et al., 2016; Pardey et al., 2016; Walker et al., 2014). Nowadays, few studies assess adoption using only an econometric modelling approach; many studies combine methods, and it is often the more descriptive and qualitative analyses within these studies that are most insightful. Nonetheless, the underlying conceptual framework of adoption generally remains intact, as is evidenced in the policy documents used by development agencies (e.g. Tam et al., 2014). Meanwhile, an expanding vocabulary of adjectives, distinguishing partial-, dis-, temporary-, pseudo- and non-adoption may provide evidence of conceptual fatigue (Kiptot et al., 2007). Especially when it comes to understanding how to improve outcomes at scale, development professionals need approaches and tools that help them to appreciate the dynamism and indeterminacy of complex change processes which flow in the aftermath of a technological change intervention (Wigboldus et al., 2016).

Critics of our framework might argue that the conceptual framework outlined above is merely introducing a modified and extended vocabulary – of propositions, encounters, dispositions and responses – that is chiefly useful for labelling qualitative aspects of technological change that are already discussed in many conventional adoption studies. However, it is essential to note that these terms emerged from our reading of a diverse social science literature, which is not rooted in conventional theories and frameworks of technology adoption and diffusion. That literature highlights critical dimensions of technological change processes that are almost completely ignored by the conventional concepts of adoption–diffusion theory. By systematising an alternative set of concepts and terms, we hope to provide a basis for more informative and powerful descriptive and qualitative analyses. We hope that the new terminology may provide foundations for new methodologies of technological change analysis that combine qualitative and quantitative data and methods in innovative and insightful new ways.

Evidence from the literature suggests that there is a ready appetite for novel approaches that can help development professionals and their organisations to improve the targeting of diverse farmer needs (Almekinders et al., 2019; Verkaart et al., 2019); to redeploy agricultural research efforts towards matching different solutions to diverse situations rather than aspiring to develop generic, widely applicable solutions (Coe et al., 2014); and to appreciate the agency of users in adapting and reconfiguring technologies that are introduced to them (Mausch et al., 2017). Scholars already recognise that the uptake and spread of new technology depends strongly on an alignment of a technological design (i.e. a proposition with potential affordances) and the capacities and aspirations of potential users (agents with emergent dispositions towards the affordances of the proposed technology); however, they lack a conceptual vocabulary to adequately comprehend and describe the processes that constitute the so-called ‘adoption’. Instead, analyses of how to enhance adoption rates typically fall back on ‘getting the technology right’ (i.e. they attempt to optimise the affordances of artefacts, techniques and practices for one or more target groups of potential users), while fixing institutional and policy contexts to encourage uptake (i.e. they attempt to orchestrate encounters of sufficient quantity and quality, while influencing the dispositions of farmers through advertising, training and support with inputs and credit) (Orr, 2018). Farmers’ agency – to encounter new technology, perceive affordances within it and respond creatively to those propositions – is rarely placed at the centre of attention.

We believe that our framework can help analysts to think more methodically and discretely about different aspects of technological change, by considering the relationships and interactions among what is designed (the character of technological propositions), how it is brought to attention (the nature, number and quality of encounters), how its opportunities are perceived (the relational, interactive generation of affordances and dispositions for particular people or groups) and the range of multiple ways in which people may respond.

Further work is needed to operationalise the new framework proposed in this article. For instance, one response to the second and third scenarios outlined in Box 1 would be to draw from methodologies of project design and evaluation that are based on theories of change. Realist evaluation, process tracing and contribution analysis are examples of evaluation methodologies that proceed by building, verifying and adjusting theories about how change processes unfold (Mayne, 2012; Pawson and Tilley, 1997; Weiss, 1997). Data is collected on multiple indicators at a variety of points along pathways of change, for a range of different stakeholders across a variety of contexts, in order to detect, verify and/or test whether different impact pathways are unfolding as predicted by the overall theory of change or a specific impact pathway within it. Using these approaches, an observation that a particular artefact, practice or process has been taken up by an individual or group represents only one of many indicators necessary to detect and verify that technological change pathways are occurring and to understand the cognitive and behavioural mechanisms driving change.

The analysis of potential pathways of change is common in ex ante appraisal (Alene et al., 2007; Kostandini et al., 2016; Mills, 1997). For example, the ADOPT tool is a method for predicting technology adoption, which is based on investigating potential users' perceptions of a technology's value and ease of use, as well as their personal or household characteristics that are assumed to influence the propensity to adopt (Kuehne et al., 2017). Methods like these could be used much more in the design stages of technology change interventions. A variety of techniques could be applied, ranging from simple thought experiments to more structured modelling of alternative scenarios of technological change, which might integrate market analysis and foresight methods, such as visioning and scenario building.

For the organisations and programmes involved in designing, implementing and monitoring technology change projects, the alternative framework raises questions about how propositions are designed and compiled; how and why they are targeted towards particular farmers, communities or agro-ecologies and how much room or flexibility they allow for adjustment and adaptation to suit its intended beneficiaries or other potential users who might engage with it (i.e. its affordances). For other stakeholders, observers and analysts of development-oriented agricultural research, the framework suggests ways to examine the relationships of power and accountability which propositions and encounters embody.

A design principle arising from the framework is that, particularly when technology is complex, multidimensional and/or systemic, propositions should either be very carefully targeted to a particular population or be designed to have expansive affordances that allow potential users a generous scope to adapt, adjust and reconfigure the technology to suit their local and individual circumstances. Methods of technology and programme design and evaluation are needed that are sensitive to the agency of farmers and their communities to assess propositions, interact through encounters and make choices and decisions that will shape pathways of change.

Encounters are the domain of applied agronomy, strategic communication and extension. Here, not only the quantity but the quality of encounters is important to shaping what happens next. There is a lot to be learned about issues such as facilitation, inclusiveness, sympathetic and effective communication, the effects of social distance between extension agents and farmers, trust and confidence and the possibility of joint problem-solving, experimentation and learning rather than directive communication of instructions.

The theory of affordances may offer a useful guide for investigating conceptually and empirically how specific dispositions in relation to a proposition are generated, through encounters, for different stakeholders. This work may present the hardest challenge to operationalising the framework we have presented in this article. However, the payoff, in terms of understanding much better how individuals and groups appreciate propositions, engage in encounters and assess the landscape of opportunities that face them, could be very valuable for both the design and evaluation of investments in technological change.

With regard to the detection and analysis of pathways of technological change, a practical first step could be to compile from existing literature or newly construct a typology of generic indicators that could show when and how a process of learning, experimentation and behavioural change is unfolding.

Authors' note

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ORCID iD

Dominic Glover https://orcid.org/0000-0003-2055-1996

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