The European Journal of Development Research
https://doi.org/10.1057/s41287-022-00548-8

ORIGINAL ARTICLE

A Multidisciplinary Approach to Assess Smallholder Farmers' Adoption of New Technologies in Development Interventions

Diane Kapgen[1] · **Laurence Roudart**[2]

Accepted: 30 March 2022

Abstract
In spite of decades of research, the complexity of new technology uptake by smallholder farmers in the context of development interventions is still little understood. In order to unravel the motives for, and barriers to, technology adoption, we propose a multidisciplinary qualitative framework that expands the Sustainable Livelihoods Framework with the agronomic Agrarian system approach and the Development anthropology-based ECRIS (Rapid Collective Inquiry for the Identification of Conflicts and Strategic Groups) approach. Such a framework allows to analyze smallholder farmers' livelihoods, agricultural activities from an ecological cum technical cum economic point of view, and social learning processes involving power relationships. Its use is exemplified by studying the adoption of stone bunds in an agroecological development program in Burkina Faso. Many farmers cannot adopt this technology fully because of agricultural production system or livelihood shaped barriers, and because of power relationships bearing on the technology uptake process.

Keywords Analytical framework · Innovation adoption · Agroecology · Burkina Faso · Farmer groups · Farming system · Power asymmetry · Social learning

Résumé
Malgré des décennies de recherche, la complexité de l'adoption de nouvelles technologies par les petits exploitants agricoles dans le cadre d'interventions de développement est encore mal comprise. Afin d'appréhender les motivations et les obstacles liés à l'adoption de technologie, nous proposons un cadre d'analyse qualitatif pluridisci-

✉ Diane Kapgen
diane.kapgen@uni.lu

Laurence Roudart
laurence.roudart@ulb.ac.be

[1] Faculty of Humanities, Education and Social Sciences, University of Luxembourg, Belval Campus, 11, Porte des Sciences, 4366 Esch-sur-Alzette, Luxembourg

[2] Faculty of Philosophy and Social Sciences, Université Libre De Bruxelles, Brussels, Belgium

Published online: 30 June 2022

plinaire qui élargit le cadre des moyens d'existence durables en intégrant l'approche agronomique en termes de système agraire, ainsi que l'approche ECRIS (Enquête collective rapide pour l'identification des conflits et des groupes stratégiques) qui s'appuie sur l'anthropologie du développement. Un tel cadre permet d'analyser les moyens d'existence des petits exploitants, les activités agricoles d'un point de vue écologique et technique et économique, ainsi que les processus d'apprentissage sociaux impliquant des relations de pouvoir. Son utilisation est illustrée par l'étude de l'adoption de cordons pierreux anti-érosifs dans un programme de développement agroécologique au Burkina Faso. De nombreux agriculteurs ne peuvent pas adopter pleinement cette technologie en raison d'obstacles liés au système de production agricole ou aux moyens d'existence, mais aussi parce que des relations de pouvoir influencent le processus d'adoption de la technologie.

JEL Classification Q16 · O33

Introduction

The need to support smallholder farmers in developing countries, especially in sub-Saharan Africa, to increase their agricultural production and productivity in a sustainable way has been largely recognized in the face of huge challenges such as feeding the growing population and lifting as many farmers as possible out of poverty, while protecting or restoring the environment (World Bank 2007; Pretty et al. 2011). However, researchers and development practitioners have known for decades that the adoption by smallholder farmers of new technologies in the context of development interventions is a tricky matter.

Research on the adoption of innovations has a long history (Rogers 2003). In the 1950s and 1960s, the focus was on the diffusion of innovations, these being considered as given by experts like technicians or engineers, and a priori benefitting society by increasing productivity, in particular labor productivity. From the 1980s, the focus switched to understanding the social processes underlying the development and adoption of innovations. Thus, the sociotechnical analysis of innovations as proposed by Akrich et al. (1988) considers the process of reciprocal adaptation between the technical object and different categories of potential users, resulting in sociotechnical trade-offs.

The studies about the adoption of innovations by smallholder farmers in developing countries are numerous. In the 1960s, many studies investigated the transfer of agricultural technologies conceived in external laboratories and the way to spread them as much as possible, notably by relying on "pilot farmers." Over the decades, studies have gradually moved on to take into account the diversity of ecological, technological, and economic conditions in which farmers operate (Norman and Collinson 1985) and then have considered that farmers themselves are innovators (Chambers et al. 1989). In essence, this literature has shown that adoption is not an instantaneous binary event (there is adoption or not), but a process that supposes that farmers meet certain conditions: they have access to information, they have incentives to adopt, and they have the capabilities to do it (Jones 2002). These conditions in turn depend on a multiplicity of economic, social, environmental, and psychological factors, which vary across farmers and across regions (Chavas and Nauges 2020). An abundant strand of literature consists in micro-level studies aiming to identify and prioritize the factors explaining adoption, with results varying according to contexts (Doss 2006; Okello et al. 2019; Zakaria et al. 2021).

In his inventory of the main factors bearing on the adoption of sustainable agricultural technologies and natural resource management practices in developing countries, Lee (2005) pointed to the importance of information and social networks. Social learning from peers may happen via formal or informal discussions gathering more or less people, or via demonstration trials on farm or on a dedicated plot, with or without learning by doing elements (Lambrecht et al. 2014). More recently, several research works have shown that peer-to-peer communication, through verbal discourses or experimentation, is all the more effective as the disseminating farmer is close to the target farmer from locational, agronomic, or social characteristics (Díaz-José et al. 2016; Benyishay and Mobarak 2018; Shikuku 2019).

However, many studies about social learning ignore power relationships within the populations concerned by the innovations. This may be related to the fact that many research works fit within an Economics perspective and are quantitative. In addition, each study generally adopts a particular lens—social learning, or other factors of an ecological, or technological, or economic, or social nature—and overshadows the other aspects of smallholders' livelihoods. Furthermore, farmers' heterogeneity is rarely related to differences in adoption patterns. Rare also are studies that simultaneously pay attention to structural factors at higher levels than the farm or the village, or to the dynamics over years of the adoption process.

According to Glover et al. (2016), the scientific literature about technology adoption by smallholder farmers is fraught with serious limitations, due to a widespread misconception of the very idea of adoption. In this article, the authors call for a more relevant and heuristic analytical framework, informed by social sciences and their use in Science and Technology Studies (STS), that allows to grasp technological changes as processes which may be partial and/or adaptive, and that enables to study the effects of more or less complex technologies, at different scales.

Yet, it should be noted that the analysis of technology as being in an indivisible way natural, material, and social is present in the technology adoption literature. This has been especially the case of publications about irrigation infrastructures and other water management innovations, which have built on long-standing and rich bodies of literature that consider hydraulic technologies as being fundamentally social in nature (Pfaffenberger 1988; Ruf and Sabatier 1992; Vincent 1997; Shah and Boelens 2021). More recent works have added political science concepts aiming to grasp how the design and the use of hydraulic innovations are shaped by, and shape in return, power relations (Mollinga 2014; Valadaud and Aubriot 2019; Cleaver et al. 2021).

In this paper, we propose an analytical framework, adaptable to local situations, that allows for understanding processes of agricultural innovation adoption by taking into account the diversity of smallholder farmers, based on their various resources and activities, as well as the social learning processes involving power relationships.

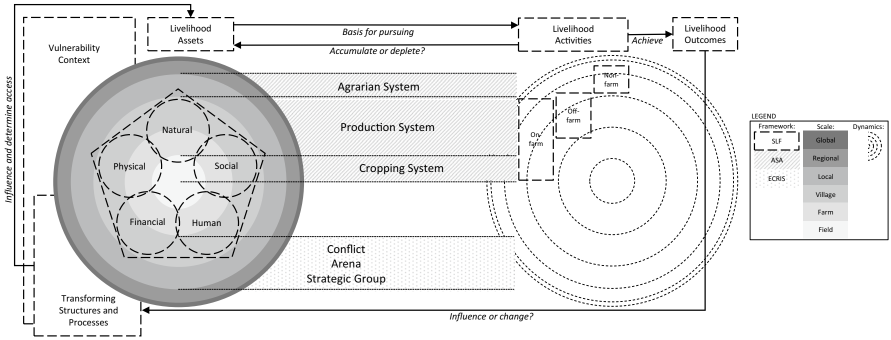

Fig. 1 The Combined SLF + ASA + ECRIS Framework. In this figure, the elements in dashed-lined boxes and dashed-lined circles show the dimensions of the SLF and the arrows show the main interrelations between these. The main concepts of ASA, referring to the analysis of agriculture at field, farm and regional scales, are depicted by the light upward line pattern. The concepts of ECRIS, referring to structural factors of social nature within the local scale, as well as between local scales, are depicted by the dotted pattern. To underline the importance of scale and the interactions between scales, we picture them as various tints of grey circles that are embedded in each other–from the most local scale in the core circle to the global scale in the most outer circle. The lines connect the different concepts to their operating scales. To visualize dynamics, we reproduce the different circles of scale using black, dashed half-circles depicting an imagined timeline

Our framework combines the Sustainable Livelihood Framework (SLF) with the francophone Agrarian system analysis[1] approach and the Development anthropology-related ECRIS[2] perspective. After presenting the combined framework, we use it in a case study to analyze the adoption of a farming technology (stone bunds) promoted in the context of an agroecological development program in Eastern Burkina Faso. We then discuss our results and conclude.

Presentation of the Combined Framework

The SLF is a well-known analytical framework (Chambers and Conway 1991; Ellis 2000; Van Dijk 2011; Scoones 2015). It is at the core of our combined framework as it is holistic, dynamic, multi-scale, without disciplinary, or sectoral boundaries, adaptable to various situations and it enables to analyze livelihoods from the viewpoint of farmers themselves. The SLF has different variants but several fundamental elements buttress nearly all the studies it has inspired (See Fig. 1). Each individual or household uses assets—made of more or less limited natural, physical, human, social, or financial capital[3]—for one or more activities, in order to achieve certain

[1] *Analyse de système agraire* in French.

[2] ECRIS stands for *Enquête Collective Rapide d'Identification des conflits et des groups. Stratégiques* and is translated here into *Rapid Collective Inquiry for the Identification of Conflicts and Strategic Groups.*

[3] In this paper, we use "assets" as a generic term, broadly defined; this notion is itself subdivided into more precise forms of "capital.".

outcomes. This choice of activities according to constraints and objectives constitutes a livelihood strategy. Access to assets and the actual capacity to use them depend on structural factors which are specific to each context and which must be identified and analyzed. Some structural factors may be influenced by farmers to a certain extent, like social institutions, for example, whereas others, like climate change or world market prices, are largely beyond their control. Structural factors are either tendential, seasonal, or sudden, hence the phrase "Transforming structures and processes" (Fig. 1).

The diversity of livelihoods has been emphasized, leading to distinguish on-farm, off-farm,[4] and non-farm activities (Ellis 2000). Yet, there are many regions, especially in sub-Saharan Africa, where agriculture is the main livelihood for the immense majority of people, and non-farm activity opportunities are rare (Losch et al. 2012). In this case, it is more useful to concentrate on analyzing the diversity of *agricultural* activities rather than *livelihood* activities. This is even more the case when analyzing agroecology-based development interventions, which rather hold the view that on-farm activities should allow smallholders to gain decent livelihoods, without needing to search for non-farm compensatory activities. The SLF, however, does not provide a profound conceptualization of *agricultural* activities. Nor does it provide concepts to grasp their evolution over time, or their spatial organization at different scales.

Adding an Agricultural Dimension to the SLF

The analysis of agriculture in terms of systems is a vast research and development domain (Spedding 1976; Colin and Crawford 2000; Darnhofer et al. 2012). We focus hereunder on the francophone Agrarian system analysis (ASA) approach, which has roots in geography, agronomy, agricultural economics, and system analysis. ASA is, in its essence, the study of agricultural development seen as a continuous, long-term agricultural transformation made of combined biophysical and social processes (Mazoyer and Roudart 2006). ASA is also a critical action-orientated approach, which aims to design and analyze agricultural development interventions based on a profound understanding of the realities faced by different categories of farmers, especially the poorest (Mazoyer 1993; Barbier and Benoît-Cattin 1997; Burnod and Medernach 2015). These features point to convergences between ASA and sustainable livelihood approaches. ASA relies on a set of nested concepts—agrarian system, production system, cropping/livestock system—that enable to analyze agriculture at different scales and with a systemic cum dynamic approach (Trébuil et al. 1997; Barral et al. 2012).

[4] In the SLF, "off-farm" refers to agricultural activities that are not part of the own farm, in many cases as wage worker.

Agrarian System

Mazoyer and Roudart (2006, p. 51) define an agrarian system as the "theoretical expression of an historically constituted and geographically localized type of agriculture, composed of a characteristic cultivated ecosystem and a specific social production system." The scale concerned is that of a region, from small to large. A cultivated ecosystem has both a structure and a functioning. Its structure is defined by its composition of several complementary and proportionate landscape units, each unit being characterized by its ecological features and its mode of use by farmers (for instance, ploughed land with a particular crop rotation, hay meadows, pastures…). Its functioning refers to the variety of farmers' practices in producing and renewing the biomass, which is useful for humankind. The social productive system is the conceptual construct corresponding to the set of farms using and renewing, in a concurrent and complementary manner, the useful biomass. These farms are defined by the type of production system they practice (see below) and by the social category to which they belong. We shall not elaborate this question of social category further in this paper as it is the dimensions included in the production system concept, which are the most complementary to the SLF.

The functioning of an agrarian system involves flows of matter, energy, and value inherent in the system or in relation with the rest of the world (Ferraton and Touzard 2009; Roudart and Mazoyer 2012). Thus, the main focus of the agrarian system concept is agricultural production as a result of interactions between a human society and the rest of the ecosystem.

Production System

The production system[5] is a subsystem of the agrarian system. It is defined at the farm level, or for a group of farms. At the farm level, this concept is similar to that of "farming system." It has been defined in various ways. We retain hereafter a definition which allows to understand how and why farmers adopt, adapt, or reject new farming technologies: the production system of a farm is the combination (the nature and proportions) of its productive activities (vegetal and animal) and of its production factors (land, labor, equipment, farm buildings) (Chombart de Lauwe and Poitevin 1957; Gafsi et al. 2007). This concept may also be used to designate categories of farms, according to the just above-mentioned criteria, leading to farm typologies (Mazoyer 1963).

Cropping and/or Livestock System

The cropping system[6] is a subsystem of the production system. It has received several definitions also. In order to gain a profound understanding of farmers' practices, we retain here the definition adopted by many French agronomists following

[5] *Système de production* in French.

[6] *Système de culture* in French.

Sebillotte (1977): "[the cropping system comprises] (…) all the technical modalities implemented on plots treated in the same way. Each cropping system is defined by the following: the nature of the crops and their order of succession; the sequence of techniques applied to each of these different crops, which includes the choice of varieties for the selected crops".[7] Thus, this definition concerns the scale of the plot.

The livestock system[8] is a subsystem of the production system also, defined at the scale of the farm's herd(s). It comprises the herd composition and its management, including feeding practices, breeding, herd movement, and care. It may imply a large geographical scale, especially when transhumance is prevalent and vast uncultivated areas are grazed by animal herds. Often, there are interrelations between the cropping and the livestock systems (Landais 1994).

Considering Contested Development Arenas

Many SLF inspired studies are focused on assets and on households or individuals, while obscuring or downplaying social relations within and between communities (Van Dijk 2011).

In our view, it is especially social and power relations within seemingly homogeneous categories of (poor) people that fail to be adequately addressed. This might not least be due to the fact that livelihood approaches do not provide conceptual tools to analyze social and power relations at the micro-level (De Haan and Zoomers 2005). One way forward might be to use the concept of social capital, which is already integrated in the framework but, even if it includes the dimensions of power relations, distribution, and inequalities, it does so in a "surrogate" (Bebbington 1999, p. 2036), unspecific, non-operationalized manner (Lehtonen 2004). In addition, development interventions entail particular social and power relations that have to be accounted for (De Haan and Zoomers 2005).

In this section, we argue that the SLF may be enriched with concepts derived from the Development anthropology's ECRIS method, which draws from a power-centered social sciences perspective and claims that "a village is an *arena*, permeated by *conflicts* in which various '*strategic groups*' confront each other" (Bierschenk and Olivier de Sardan 1997, p. 239), in particular when a development offer exists.

Conflict

The ECRIS thinkers, referring to the works by Gluckman (1956, 1958) in particular, explain that conflicts are an expression of differences in positions people occupy within the social *structure* and are regulated by various forms of custom like conventions, moral rules, and cultural codes (Bierschenk and Olivier de Sardan 1997; Olivier de Sardan 2005). There is a second dimension to explaining conflicts,

[7] Our translation from French.

[8] *Système d'élevage* in French.

namely *individual* actors pursuing their personal strategies. Everyday life is of course defined not only by conflict but also by consensus. However, focusing on conflicts enables to identify and analyze social and power structures, single actors' strategies, as well as consensus and further forms of sociability. It allows grasping the functioning of small groups, revealing their internal heterogeneity, structures, and norms. Furthermore, by distinguishing between structural and individual factors, it echoes the SLF "transforming structures and processes" category on the one hand, and people's individual asset base and agency on the other hand.

Arena

In social sciences, the concept of arena is closely related to that of "field" which, as a general rule, designates a system of relationships which hold at the macro-level and which impose themselves on the population that experience them (Bourdieu 1992). The ECRIS thinkers provide an interactionist and empirical conception of "arena," defined on a small scale and giving strong attention to conflicts among actors. In a nutshell, they refer to arena as "a place of concrete confrontation between social actors interacting on common issues" (Bierschenk and Olivier de Sardan 1997, p. 240). By talking about "local development arena," they understand development interventions as "a system of resources and opportunities which everyone tries to appropriate in his or her own way" (Olivier De Sardan 2005, p. 185).

Strategic Groups

Strategic groups are not built from a priori criteria for permanent social groups, but on criteria deduced from forms of interaction between actors. The ECRIS thinkers use this notion at the local level: in a given community, individuals do not all share the same interests and representations; rather, their interests, representations, and behaviors form different clusters according to their social position in relation to a specific given issue. In a development intervention context, the concept of strategic groups is used to understand how actors' positions actually differ regarding the development offer and why (Bierschenk and Olivier de Sardan 1997; Olivier de Sardan 2005).

Application of the Combined Framework: Analysis of an Agroecological Program in Eastern Burkina Faso

Our case study concerns the development interventions carried out by the NGO *Association pour la Recherche et la Formation en Agroécologie* (ARFA, Association for Research and Training in Agroecology) in the municipality of Bilanga, located in the Gnagna province in the Eastern Region of Burkina Faso. Given its own conception of agroecology, ARFA promotes the diffusion of a set of farming technologies through the delivery of training, equipment, inputs, and farm infrastructures to farmer groups. Given space constraints for this article, we use the above-presented analytical framework to examine the adoption, or adaptation, or non-adoption by farmers of one of the technologies promoted by ARFA, namely stone bunds.

Data Collection and Analysis

The fieldwork lasted 6 months, in three successive phases. During the first exploratory phase, we distinguished several zones in the biophysical environment according to pedological, geomorphological, and vegetal characteristics; we retraced agrarian history, identified the different production systems co-existing today, and assessed the socio-cultural, demographic, and ecological trends, using transect walks, semi-guided interviews with key informants and participant observation. During the second phase, we led in-depth semi-guided interviews with farmers so as to understand the diverse production systems. An interview contained two parts. The first "agricultural" part was about the cropping- and livestock systems, the production system, the farming techniques, the changes in farming techniques and inputs, the farming calendar, and difficulties on the farm, and it was complemented with participation in and observation of field work, as well as field walks. The second "social" part of the interview, conducted on a different day than the first part, was about the barriers to adopting new farming technologies, the functioning of farmer groups, the details of the membership, the conflicts within the groups, between the groups, the power relations within the village, as well as further elements about the social fabric. Each interview also contained questions about personal opinions, household characteristics, education, and age and left room for open discussions on subjects not pre-defined. In the third field phase, we repeated the second phase procedure, based on interview guides that were slightly adapted according to the insights gained during the preceding phases, so as to enlarge our sample and achieve saturation (Olivier de Sardan 2008) for each production system category. In all, we conducted interviews with 90 male farmers, 10 female spouses, and 10 other key informants—elders and peasant leaders from 7 villages in Bilanga. Of the 90 male farmers, 75 were interviewed twice, whereas 15 were interviewed about the "agricultural" part only. As patriarchal order is prevailing in the Eastern Region of Burkina Faso, male farmers make the decision about adopting farming technologies. Therefore, they constitute the large majority of our sample. However, to acknowledge that households are not (necessarily) homogeneous units without conflicts or differing interests, we also conducted interviews with spouses and with young farmers still living in their father's compound. Villages were chosen based on similar farming systems, soil types, as well as an approximate 50% membership of farmers in ARFA groups to avoid biases if comparing villages with very different rates of participation. In our sample, half of the farmers are group members and half are not.

We entirely transcribed the vast material collected during the interviews and examined it through qualitative content analysis (Mayring and Gläser-Zikuda 2005). We used a mixed coding approach combining categories, dimensions, and indicators based on the literature review on the one hand, and on the field research data on the other hand, resulting in a tree structure with approximately 300 codes and subcodes, used upon each interview transcript.

The Vulnerability Context, Transforming Structures and Processes, and the Agrarian System

The study area is populated mainly by the Gourmantche ethnic group (around 80%), other groups being foremost the Mossi and the Peulh.[9] It lies within the territory of the ancient Gulmu kingdom and has been historically relatively isolated from other areas of Haute-Volta (during the French colonization) and of Burkina Faso (since its Independence in 1960). This isolation has resulted in limited infrastructural development of all kinds until today: nonexistent electricity supply in many villages, low density of roads, no paved road, which implies that large areas remain inaccessible during the peak of the rainy season, as well as poor radio transmission, mobile phone, and internet network coverage. Moreover, farmers complain about the lack of access to basic education for adults, a finding that echoes the school enrollment rate (12%) and alphabetization rate (7%) put forward in previous studies (Ouédraogo 2006). Illiteracy and non-proficiency in French—the official language of Burkina Faso—hinder access to information from different sources for the vast majority of farmers.

According to the elders interviewed, the growing population in Gnagna province (from ca. 229.000 inhabitants in 1985 to 408.500 in 2006 and to 530.467 in 2015, according to the official statistics, INSD 2016) is a major driver of the evolution of the area, as it has resulted in a growing pressure on cultivable land. Some fifty years ago, there were still open forests in the area and farmers, after having cropped a piece of land for a few years, were leaving it idle for more than ten years, so that the natural vegetation could regenerate the soil fertility. With the increasing population density, virtually all the forests have been felled, idle land durations have been reduced to a few years only (Mazoyer and Roudart 2006, own field data). Farmers link this to climate changes in the area: increased wind, diminution of humidity, higher temperatures.

The study area, located in the Sudano-Sahelian zone, is semi-arid, with one single rainy season per year, from May to September, bringing about 630 mm of rainfall on average (MEE[10] in Ouédraogo 2006). Another major problem is the high variability in the number of rainy days, ranging from 30 to 65. Even more problematic are the rainy season's delay, interruption, or prolongation, all three increasingly observed in recent years and badly affecting harvests. As farmers' livelihoods rely almost exclusively on their on-farm activities—off-farm and non-farm activities are very scarce in this area—these erratic climate patterns contribute to farmer households'

[9] The Peulh people have an economy, use of land and sociocultural organisation very different from that of both Gourmantche and Mossi (Hagberg 2008). We did not integrate them in our sample, also because they are not represented in farmer groups.

[10] MEE: *Ministère de l'Environnement et de l'Eau* (Burkinabé Ministry for Environment and Water).

vulnerability. During the hot and dry season, the Harmattan, a dry, dust-bearing wind from the Sahara, contributes to drying out the soil and vegetation. In Gnagna province, data from 1961 to 1997 show a decline in average rainfall (Ouédraogo 2006), a fact that was unanimously cited by the farmers we interviewed as a major problem they encounter.

Most of the soils are poor: they have a low inherent chemical fertility, their textures make them difficult to till, their depths make them prone to drying out, and their combined textures and depths often make them vulnerable to nutrient run-off and erosion during heavy rainfall (Ouédraogo 2006), all these facts being confirmed also by our interviews with farmers. Soils also suffer from sealing and crusting: farmers report the increase of *Zippélé*, which is a completely denuded soil with a very hard surface crust, where not even the most undemanding vegetal species can grow.

The agriculture practiced is of the type rainfed cereal and pulse cropping associated with pastoral livestock husbandry. There are three main field types. *Compound fields* immediately border farmers' compounds and are intensively cultivated with sorghum, maize, as well as groundnut, sesame, and cowpea, without fallow periods but with high doses of organic fertilizer including household refuse. *Village fields* are located within the central perimeter of the villages and nowadays are cropped mainly with maize, groundnut, and cowpea but, as they have been cultivated without fallow periods long enough to maintain the soil fertility, many of them are difficult to crop today or even are abandoned. *Bush fields* lie at some distance from the village centers: they bear the major part of cereals (sorghum and to a lesser extent pearl millet, intercropped sometimes with cowpea or groundnut), which alternate with fallows of a few years only. Finally, grazing areas in the bush are used by Peulh-pastoralists and herd-keeping farmers alike for their cattle.

All units of production are family farms, most families being nuclear (a man, his wife or wives, and children). The hire of agricultural workers being extremely rare in the region (one case only in our sample), the family composition strongly determines the workforce available in each farm.

When asked about their main problems, farmers almost unanimously cite the change in rainfall patterns and the decline in soil fertility. Further difficulties cited by the majority of farmers are inherently poor and difficult-to-work soils, increasing erosion and washing out of nutrients during heavy rain, increasing erosion of soil during the hot, windy period. In order to provide answers to these problems, and in the name of agroecology, ARFA has been implementing for two decades a package of various farming technologies, which ultimately aim at augmenting yields and make farms more climate-resilient. The now most widespread of these technologies is stone bunds,[11] which are lines of stone built slightly off perpendicular to the slope, thus preventing water as well as organic matter run-off and reducing erosion.

[11] The other technologies promoted by ARFA are as follows: compost production, use of early-maturing varieties of crops, plough-tilling with subsequent row seeding, plough-weeding, Zaï planting pits, agroforestry, livestock housing, biological control of plant pathogens and biological soil stimulation, crop rotation, intercropping, soil cover with crop residues, and natural wind protection.

Table 1 Typology of production systems, with the numbers of observations in the sample

Tillage type Liver ownership	Manual daba	Donkey-draught plough	Zebu-draught plough
No animal	6	2	1
Animal without cattle	11	6	2
All anima	13	22	27

According to Niada Jean, peasant in the village of Silguin, "if you use stone bunds, your yield is almost double."

Activities, Assets, and Production Systems

On-Farm Activities

In order of importance, farmers cultivate white sorghum, pearl millet, red sorghum, maize, groundnut, sesame, cowpea, and rice. The vegetable okra completes the crop portfolio. Depending on soil type (gravelly or sandy or clayey) and household composition, as well as personal preferences, farmers cultivate all or some of these rainfed crops. Although the difference between farmers' crop portfolio is small, we did not use this criterion to differentiate production systems. While cereals are food crops, legumes (groundnut, sesame, cowpea) are both cash and food crops.

Animal husbandry includes cattle, sheep, goats, poultry, donkeys,[12] and has three main functions: living saving,[13] source of cash revenue, and source of manure (Ouédraogo 2006) plus—as regards donkeys and, more rarely, cattle—a function of power provider for transport and plough-pulling. The latter function strongly influences the adoption, or not, of stone bunds (see below). This is why we divided farmer households into three categories of livestock possession: those that own animals of every category, those that own goats, sheep, poultry, and donkeys (and hence no cattle), and those that own no animals at all.

Equipment or Physical Capital

All households own the following small agricultural tools: hoes (*dabas*) for tilling and weeding, small pickaxes, and calabashes for sowing, as well as machetes, knives, and baskets for harvesting. In addition, better-off farmers own shovels, large pickaxes, forks, rakes, axes, wheelbarrows, and furrowers. Some of these additional tools facilitate the efficient adoption of stone bunds (see below). Yet, it is especially the possession of a cart or a plough which facilitates this adoption through its impact on labor efficiency: the cart renders much easier and faster the transport of heavy or numerous loads—stones for constructing stone bunds, and also crop harvests, water for domestic

[12] Free-ranging pigs can be observed in some of the larger villages, but remain an exception.
[13] *Épargne sur pied* in French.

use, wood for construction and cooking, etc. —while the plough considerably increases the speed and the efficacy of tilling and weeding. Moreover, the type of draught animal—donkey or zebu—also plays a role: donkeys are weaker than zebus, which leads to slower and shallower tillage. But, many farmers cannot afford a plough and a draught animal. Based on these two limiting factors, there are three main tillage methods—manual with a hoe, mechanized with a donkey-draught plough, and mechanized with a zebu-draught plough—which may be used to categorize farms.

Typology of Production Systems and Barriers to the Adoption of Stone Bunds

Based on the above analysis, Table 1 proposes a typology of farms, relying on two criteria: the tillage method and the type of livestock ownership.

Table 1 makes clear some relationships between these criteria: farmer households tilling manually often do not own cattle nor any livestock at all; those cultivating with a zebu-drawn plough most often own all types of animals. Donkey-tilling farmers commonly own cattle but the herds are generally smaller than those of zebu-tilling farmers.

Several elements of the production system, and thus of farmers' livelihood asset base, are essential to the efficient adoption of stone bunds: access to a cart and a donkey to transport stones and access to large pickaxes to crush stones and to shovels to move them. Access to an abundant workforce is necessary also as the installation of stone bunds is very physically demanding and time consuming. The availability of workforce in turn depends on the tillage method as it determines the time and manpower necessary for two main farming operations: tilling and weeding. Aboré Louis, a manually tilling farmer in the village of Yamliguidi, puts it: "No, I don't use stone bunds. (…) As I already have to work with my hands, I don't have enough strength left."

This means that in our sample, out of the 75 farmers interviewed twice, 15 only, mainly those tilling with a zebu-draught plough, have adopted this technology in the most efficient manner. 56 farmers, most of them tilling with a donkey-draught plough or manually, have *adapted* the technology—without using appropriate tools to measure ground contours and position the bunds at optimal depth, height, and intervals; by applying it on a small portion only of the fields; by building the stones less dense and less deep in the soil; or without planting shrubs along the stone bunds to reinforce them—which leads to very few results. Four farmers have completely given up.

Farmer Groups as Innovation Diffusion Structures

As mentioned earlier, ARFA promotes farming technologies through the diffusion of knowledge and the supply of farming equipment, inputs, and infrastructures via farmer groups. Yet, the functioning of these groups does impact the adoption, or not, of the technologies promoted.

Bureau Members and Ordinary Members as Strategic Groups

Each group operates within a single village, and it generally counts 30 to 40 members and is composed of bureau and ordinary members. Bureau members occupy the functions of president, deputy-president, secretary, treasurer, and messenger. As a rule, ARFA led the group creation process and chose the initial bureau. In the early days, bureaus were often composed of elderly men and complying with reigning power structures. More recently, personal attributes became prominent, with key factors being literacy, sense of responsibility and leadership, open-mindedness to innovation, actual capacity to implement new technologies (this depending fundamentally on equipment and labor availability as explained above), and trust. Thereby, the traditional power structures based on elderly men's dominance are confronted. Even more, a de jure democratic election procedure for renewing the bureau opposes traditional succession. In practice, however, in many villages, the leadership has been in the hands of the same family or families since the group's creation: if elections actually take place during the general assemblies, there are no alternative candidates. As a result, while power structures are indeed challenged by farmer groups, this takes place at the elder–younger frontier within traditionally leading families, rather than being a replacement between more and less powerful, or richer and poorer, families.

The procedure for joining a group as ordinary member seems simple: the applicant has to ask the group's president. In general, groups set no limitation to the number of farmers they admit. Consent to internal regulation, acceptance by other members and payment of the membership fee (which is low) are the only admission requirements. However, several barriers make access almost impossible for the lay farmer. The overarching one is the non- or little visibility of the groups: in most cases, the groups' leaders invite befriended farmers to become members, but they virtually do not inform others about the existence and activities of the groups. These are known mainly by hearsay or by chance of observation, which is not that likely, especially for those farmers who are isolated and too poor to buy even a bicycle. For some farmers, their not being invited to join is equivalent to their not having the permission to join.

Furthermore, acceptance by other members is not always easy: farmers sometimes encounter bureau members' opposition or discrimination, based on personal conflict, or rivalry between families, or religion, or microsocial power structures. As for internal regulation, patience and willingness to give in are attributes that group leaders especially expect from group members. This means that there is virtually no open discussion of problems related to the development offer between bureau members and ordinary members.

Arenas and Conflicts Regarding the Distribution of Farm Equipment

A prime motive for farmers to join groups is the distribution of farm equipment provided by ARFA's head office. Indeed, ARFA conducted a pre-project assessment, which revealed that many farmers lack the equipment necessary to implement the new technologies promoted, including stone bunds. Hence, it decided to distribute equipment as an integral part of the project. Yet, the common echo among group members about this is "It's not enough for everyone!". As regards stone bunds, group members received the equipment which is necessary to adopt the technology efficiently as follows: a cart for 1 in 10 farmers, as well as a shovel, a large pickaxe, and a wheelbarrow for 1 in 4 farmers. In addition, at the group level, a leveling device is used in order to measure the heights in the field so as to build the bunds at precise depth, height, and intervals, and a truck may be borrowed to transport stones on a long distance.

Moreover, ARFA does not provide guidance about, nor does it control the distribution once the equipment has arrived at group levels. Bureau members de facto manage this distribution. At one extreme, there are leaders who do not inform ordinary group members of the support they received and keep all the equipment for themselves, even when they already own such an equipment, thus increasing their already better physical capital. At the other extreme, there are leaders who organize an assembly to discuss the distribution among members. But, even in this case, ordinary members generally lack the power to make their voices heard, meaning that they may wait for years to receive equipment. However, such a situation may turn against bureau members, especially when too many other members leave the group after having waited for years, to no avail. This may become a reason for their not keeping all the equipment for themselves. In the end, rare is the situation where the equipment provided via the groups allows worse-off farmers to "catch-up" with better-off farmers.

Arenas Regarding the Diffusion of Knowledge

For many farmers, acquiring knowledge and know-how about new farming technologies is another core motive for joining farmer groups. The knowledge transfer process is thus crucial to the efficacy of ARFA's programs. As a general rule, this process follows two stages: 1) the groups' leaders, which means bureau members, are trained by ARFA's extension agents; 2) ordinary group members are trained by these leaders afterward. For the first stage, the main type of training consists in regional-level seasonal farmer field schools (FFS), where the techniques are concretely demonstrated while embedded in the different farming operations. The organization of FFS lies in the hand of a single local extension agent who struggles with the quantity and quality of the work to be done, leaving participants' knowledge about new techniques unconsolidated. For the second stage, the group leaders organize the training at the village level, either in a field of a leader farmer or at his compound, or under a tree (or similar social gathering place). The latter training forms consist in a generally oral sharing of the learned elements and are characterized by incomplete, faulty, or unambitious transmission. In particular, oral repetition without the possibility to "see and touch" makes it difficult for farmers to learn in depth, as exemplarily reflected in these farmer statements: *But when they return* [leader farmers from their training with the ARFA extension worker], *they will teach them the theory but not the practice. So he can say that, really, only into the mouth* [a purely oral account] *isn't training. You must show the person in practice! As they are farmers they need the practice. (…) Often, he doesn't understand sufficiently what they teach him. They don't show the practice, so that he would be able to see very well with his own eyes how in detail it should be done.*

In sum, by organizing a two-stage process of knowledge diffusion, by failing to establish a monitoring system of the equipment distribution as well as of the training quality within the groups, ARFA ignores the unequal power bases of farmers in even the smallest village, which translates into development interventions being conflicting arenas (Gray et al. 1997). This leads to an increase in inequalities of asset bases, concerning especially physical and human capitals, and of incomes as it is mainly already better-off farmers who manage to adopt the technology efficiently.

Discussion

In the above case study, we used our framework to analyze *ex-post* the adoption of an agricultural innovation. This framework could also be used for *ex-ante* studies aiming to assess the feasibility and impacts of an innovation. Our framework shares similarities with others built to take into account the complexity of African smallholder farms, as well as their heterogeneity between and within areas and villages, so as to design and target appropriate technological innovations. Within this perspective, Tittonell et al. (2010) and Giller et al. (2011) combined farming system analysis with livelihood analysis to elaborate farm typologies. In the same vein, the socio-ecological niche (Ojiem et al. 2006) is a conceptual framework that aims to identify the ecological, socio-cultural, and economic constraints faced by different kinds of farmers: these constraints delineate multidimensional spaces within which some innovations may be adapted, but others are not, given the farmers' objectives. This framework is dynamic: it acknowledges that variables, processes, and interactions bearing on the niche may change over time, thus modifying the contours of the niche and the compatible innovations. It also clearly considers different spatial scales—at the farm level and at the area level—as regards biophysical factors.

Isgren (2016) stresses that research on innovation adoption and impact should also investigate politico-economic and cultural structures at larger levels, and points particularly to the agricultural knowledge system, the agricultural policies and politics, as well as the ideological dimensions of agricultural change. Building in particular on N. Long's conception of technological change, Glover et al. (2019) propose a processual framework: propositions, encounters, dispositions, and responses. This framework assumes that smallholder farmers are not passive receivers of new technologies, they do adapt them to their social and biophysical contexts, and their responses vary according to how they perceive affordances, which are opportunities "to put an object or material to some use. The perception of an affordance is subjective, situational and relational" (p. 174). In order to analyze the practice of new agricultural technologies and their effects, whether anticipated or not, Taylor et al. (2021) use a framework combining insights from political agronomy, critical agrarian studies, and political ecology. Thus, they scrutinize the political and economic drivers of agrarian change, the effects of local power relationships on how new technologies are introduced and practiced and the reverse effects, as well as the influence of agricultural innovations on agroecosystems. Building on Mollinga's work (2014), Valadaud and Aubriot (2019) combine insights from sociotechnical analysis and critical realism in order to understand how the political use of irrigation artifacts can contribute to the change, or the reproduction, of power relations. Hence, these four latter types of analysis include political considerations.

As compared with these frameworks, the main originality of ours is to fully deploy and articulate three subframeworks, which enable to analyze livelihoods, agricultural technologies, and techniques as well as local politics. It provides guidance for empirical research in these three domains and is thus operational. In other words, the various concepts coming from the subframeworks are defined so as to guide data collection in a structured way during fieldwork. The risk deriving therefrom is that researchers stick very strictly to the framework, to the point of remaining blind to other features of the real world that may be important in a specific context. This risk is inherent to any structured conceptual approach, even though most scientists are aware that remaining open to unexpected information during fieldwork is part and parcel of a scientific posture (Becker 2007). The risk is mitigated in the case of our framework as it contains many dimensions and the concept definitions leave room for adaptation to local specificities.

As shown in our case study, our framework enables to grasp the influence of the social power relationships within a seemingly homogenous farmer community upon the distribution of new technical items and upon the social learning process. Social learning has been recognized for long as a complex process that can hardly be modelized: information flows multidirectionally through intertwining networks in which geographical proximity plays only a partial role, and the information transmitted is incomplete (Conley and Udry 2001). Instead of assuming naively that each farmer in a village can observe other farmers' experiments and receive information from them, our framework leads to identify strategic groups vis-à-vis the development offer that bear upon the dissemination of knowledge.

The framework's multidimensionality in turn requires an interdisciplinary approach, relying on social sciences and agronomy in a broad sense. Thus, a multidisciplinary team may be better able to use the full potential of the framework than an individual researcher.

As other analytical frameworks, it is meant to conduct case studies, each one being specific and regionally restrained. However, the key findings from different micro-level studies can suggest valuable pathways for conceiving further agricultural development interventions and public policies, provided that these studies are spread over the various agrarian systems in the country, and are numerous enough for each system to form a judgment.

The presented case study has wider relevance because farmer groups are still a preferred medium for communicating with farmer communities in development interventions in all types of regions (Jacob and Lavigne Delville 1994). This has been true since the colonial era, although their conception has evolved from purely utilitarian tools meant to transfer external technologies to more dialogical and participatory approaches, with a view to reach better appropriateness and wider adoption of the innovations emerging therefrom (Landini et al. 2014).

As mentioned above, the case study is located in an isolated area, which is a quite frequent situation in Africa. Yet, even if none of the farmer households in our sample had internet access and only group leaders possessed a second-hand mobile phone with prepaid card (but experienced financial difficulties to guarantee credit on the card), one may wonder whether the use of mobile phone and internet, which have served for agricultural information and extension in other areas (Ogbeide and Ele 2014; Quandt et al. 2020), could help overcome the knowledge transmission problems we identified. For the time being, this seems doubtful, as access to basic education is a prerequisite for making use of digital tools. Yet, this access is still a major issue in many areas of Africa, especially for marginalized groups based on gender, ethnicity, religion, or wealth. Furthermore, the need for farmers to apply practically new knowledge probably cannot be entirely substituted by digital learning. Moreover, several studies have shown that the potential of the new technologies of information and communication for accessing, learning, and adopting agricultural technologies has also been confronted with replicating power asymmetries (Carmody 2012; Butt 2014; Summers et al. 2020,).

Thus, the conclusions we derive from our case study may be valid in other poor agricultural areas which are isolated and where farmer groups are used in development interventions. The engagement of communities in social learning processes that collectively produce knowledge through debate, dialogue, and group interaction between equals can help address these power asymmetries (Scoones and Thompson 2009; FAO 2018; Kapgen and Roudart 2020).

Conclusion and Implications

In this article, we have used a holistic framework to understand, in a situated context, farmers' decisions regarding an innovation in relation with wider structural forces, with socio-differentiation, with both physical and social resources, as well as with farmers' agency (Jones 2002). Our results show that, for the case in point, the majority of farmers cannot adopt this innovation fully because of production system or livelihood shaped barriers, and because of power relationships bearing on the technology diffusion process.

This result is all the more puzzling as the project examined is conducted in the name of agroecology. Our case study thus illustrates the risk that such projects, which have gained a central place in many agricultural development programs today (Altieri 1989, Pimbert and Moeller 2010), mimic the top-down, transfer-of-technology projects which were common in the 1950s and 1960s and which have been very much criticized ever since (Chambers et al. 1989; Warner 2008; Scoones and Thompson 2009). Such a risk is related to a narrow conception of agroecology, limited to ecological principles (Méndez et al. 2013). Yet, a larger vision of agroecology relies on socioeconomic, political, and methodological principles also (Kapgen and Roudart 2020), among which bottom-up approaches, participation, empowerment, and social equity are prominent. The use of the framework presented in this article may help foster such a large conception of agroecology. Moreover, the framework is consistent with the need to reconcile "'bottom up' local aspirations for future lives [and] 'top down' aspirations as visions for change" (Mausch et al. 2021, p. 796) in designing and implementing development projects.

Funding This work was supported by the Luxembourg National Research Fund [AFR PhD Scheme, Reference 7923741].

References

Altieri, M.A. 1989. Agroecology: A New Research and Development Paradigm for World Agriculture. *Agriculture, Ecosystems & Environment* 27 (1–4): 37–46.

Akrich, M., M. Callon, and B. Latour. 1988. A Quoi Tient Le Succès Des Innovations? 1: L'art de l'intéressement; 2: Le Choix Des Porte-Parole Gérer Et Comprendre. *Annales Des Mines* 1988: 4–17.

Barbier, B., and M. Benoit-Cattin. 1997. Viabilité à moyen et long termes d'un système agraire villageois d'Afrique soudano-sahélienne. Le cas de Bala au Burkina Faso. *Économie Rurale* 239: 30–39.

Barral, S., Touzard, I., Ferraton, N., Rasse-Mercat, E., Pillot, D. (2012) Assessing smallholder farming. Diagnostic analysis of family-based agricultural systems in a small region.

Bebbington, A. 1999. Capitals and Capabilities: A Framework for Analyzing Peasant Viability Rural Livelihoods and Poverty. *World Development* 27 (12): 2021–2044.

Becker, H.S. 2007. *Writing for Social Scientists: How to Start and Finish Your Thesis, Book, or Article*, 208. Chicago: University of Chicago Press.

Benyishay, A., and A.M. Mobarak. 2018. Social Learning and Incentives for Experimentation and Communication. *Review of Economic Studies* 86 (3): 976–1009.

Bierschenk, T., and J.-P. Olivier De Sardan. 1997. ECRIS: Rapid Collective Inquiry for the Identification of Conflicts and Strategic Groups. *Human Organizations* 56 (2): 238–244.

Bourdieu, P., (with Wacquant, L.). 1992. *Réponses*. Paris: Seuil.

Burnod, P., and K. Medernach. 2015. Interrelations Between Agribusiness Companies and Family Farming Analyzed Through the Lens of the Agrarian System. *Cahiers Agricultures* 24: 224–231.

Butt, B. 2014. Herding by Mobile Phone: Technology, Social Networks and the "Transformation" of Pastoral Herding in East Africa. *Human Ecology* 43: 1–14.

Carmody, P. 2012. The Informationalization of Poverty in Africa? Mobile Phones and Economic Structure. *Information Technologies & International Development* 8 (3): 1–17.

Chambers, R., A. Pacey, and L.A. Thrupp, eds. 1989. *Farmer First. Farmer innovation and agricultural research*, 219. London: Farmer innovation and agricultural research. Intermediate Technology Publications. Southampton Row.

Chambers, R., Conway, GR. (1991) Sustainable rural Livelihoods: Practical Concepts for the 21st Century. IDS Discussion Paper 296, Institute for Development Studies, Brighton, pp. 29

Chavas, J.P., and C. Nauges. 2020. Uncertainty, Learning, and Technology Adoption in Agriculture. *Applied Economic Perspectives and Policy* 42 (1): 42–53.

Chombart de Lauwe, J., and J. Poitevin. 1957. *La Gestion Des Exploitations Agricoles*. Paris: Dunod.

Cleaver, F., L. Whaley, and E. Mwathunga. 2021. Worldviews and the Everyday Politics of Community Water Management. *Water Alternatives* 14 (3): 645–663.

Colin, J.-P., and E.W. Crawford, eds. 2000. *Research on Agricultural Systems: Accomplishments, Perspectives and Issues*. New York: Nova Science Publishers Inc.

Conley, T., and C. Udry. 2001. Social Learning through Networks: The Adoption of New Agricultural Technologies in Ghana. *American Journal of Agricultural Economics* 83 (3): 668–673.

Darnhofer, I., Gibbon, D. P., Dedieu, B. 2012. Farming Systems Research into the 21st Century: The New Dynamic.

De Haan, L., and A. Zoomers. 2005. Exploring the Frontier of Livelihoods Research. *Development and Change* 36 (1): 27–47.

Díaz-José, J., R. Rendón, B. Govaerts, A. Jorge, and M. Rodríguez. 2016. Innovation Diffusion in Conservation Agriculture: A Network Approach. *European Journal of Development Research* 28 (2): 314–329.

Doss, C. 2006. Analyzing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement. *Agricultural Economics* 34: 207–219.

Ellis, F. 2000. *Rural livelihoods and diversity in developing countries*, 296. New York: Oxford University Press Inc.

FAO. 2018. The 10 elements of agroecology. Guiding the transition to sustainable food and agricultural systems

Ferraton, N., and I. Touzard. 2009. *Comprendre l'agriculture familiale. Diagnostic des systèmes de production. Éditions Quae, CTA, Presses agronomiques de Gembloux*, 123. Gembloux: Wageningen, Versailles Cedex.

Gafsi, M., Dugué, P., Jamin, J.-Y., Brossier, J. (eds.). 2007. Exploitations agricoles familiales en Afrique de l'Ouest et du Centre : enjeux, caractéristiques et éléments de gestion. Versailles: Quae.

Giller, K.E., P. Tittonell, M.C. Rufino, M.T. van Wijk, S. Zingore, P. Mapfumo, S. Adjei-Nsiah, M. Herrero, R. Chikowo, M. Corbeels, E.C. Rowe, F. Baijukya, A. Mwijage, J. Smith, E. Yeboah, W.J. van der Burg, O.M. Sanogo, M. Misiko, N. de Ridder, S. Karanja, C. Kaizzi, J.K.M. KunguMwale, D. Nwaga, C. Pacini, and C. Vanlauwe. 2011. Communicating Complexity: Integrated Assessment of Trade-Offs Concerning Soil Fertility Management Within African Farming Systems to Support Innovation and Development. *Agricultural Systems* 104 (2): 191–203.

Glover, D., J. Sumberg, and J.A. Andersson. 2016. The Adoption Problem; or Why We Still Understand so Little about Technological Change in African Agriculture. *Outlook on Agriculture* 45 (1): 3–6.

Glover, D., J. Sumberg, G. Ton, J. Andersson, and L. Badstue. 2019. Rethinking Technological Change in Smallholder Agriculture. *Outlook on Agriculture* 48 (3): 169–180.

Gluckman, M. 1956. *Custom and Conflict in Africa*. London: Blackwell.

Gluckman M. 1958 [1940]. Analysis of a Social Situation in Modern Zululand, Manchester: Manchester University Press

Gray, I., T. Dunn, and E. Phillips. 1997. Power, Interests and the Extension of Sustainable Agriculture. *Sociologia Ruralis* 37 (1): 97–113.

Hagberg, S. 2008. Poverty in Burkina Faso. Representations and Realities. Uppsala-Leuven Research in Cultural Anthropology (ULRiCA)

Institut national de la statistique et de la démographie (INSD). 2016. La région de l'Est en chiffres, Burkina Faso, pp.12

Isgren, E. 2016. No Quick Fixes: Four Interacting Constraints to Advancing Agroecology in Uganda. *International Journal of Agricultural Sustainability* 14 (4): 1–20.

Jacob, J.P., and P. Lavigne Delville. 1994. *Les Associations Paysannes en Afrique*, 121–134. Paris: Organisation et dynamiques. Éditions KARTHALA.

Jones, S. 2002. A Framework for Understanding On-farm Environmental Degradation and Constraints to the Adoption of Soil Conservation Measures: Case Studies from Highland Tanzania and Thailand. *World Development* 30 (9): 1607–1620.

Kapgen, D., and L. Roudart. 2020. Proposal of a Principle Cum Scale Analytical Framework for Analyzing Agroecological Development Projects. *Agroecology and Sustainable Food Systems* 44 (7): 876–901.

Lambrecht, I., B. Vanlauwe, R. Merckx, and M. Maertens. 2014. Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo. *World Development* 59: 132–146.

Landais, E. 1994. Système d'élevage: D'une intuition holiste à une méthode de recherche, le cheminement d'un concept. In *A la croisée des parcours-pasteurs, éleveurs, cultivateurs*, ed. C. Blanc-Pamard and J. Boutrais. Paris: ORSTOM éditions.

Landini, F.P., C. Leeuwis, N.E. Long, and S. Murtagh. 2014. Towards a Psychology of Rural Development Processes and Interventions. *Journal of Community & Applied Social Psychology* 2014 (24): 534–546.

Lee, D.R. 2005. Agricultural Sustainability and Technology Adoption: Issues and Policies for Developing Countries. *American Journal of Agricultural Economics* 87 (5): 1325–1334.

Lehtonen, M. 2004. The Environmental-Social Interface of Sustainable Development: Capabilities, Social Capital, Institutions. *Ecological Economics* 49 (2): 199–214.

Losch, B., Fréguin-Gresh, S., White, E. T. 2012. Structural Transformation and Rural Change Revisited: Challenges for Late Developing Countries in a Globalizing World. World Bank Publications

Mausch, K., D. Harris, and J. Revilla Diez. 2021. Rural Aspirations: Reflections for Development Planning, Design and Localized Effects. *European Journal of Development Research* 33: 795–808.

Mayring, P., and M. Gläser-Zikuda. 2005. *Die Praxis der Qualitativen Inhaltsanalyse*, 299. Stuttgart: UTB GmbH.

Mazoyer, M. 1963. Les modalités d'application de la recherche opérationnelle en agriculture. *Revue Française De Recherche Opérationnelle* 27: 107–129.

Mazoyer, M. 1993. Pour des projets agricoles légitimes et efficaces. Théorie et méthode d'analyse des systèmes agraires. Réforme agraire, FAO, pp 5–17

Mazoyer, M., and L. Roudart. 2006. *A History of World Agriculture: From the Neolithic Age to the Current Crisis*, 512. London: Earthscan & Columbia University Press.

Méndez, V.E., C.M. Bacon, and R. Cohen. 2013. Agroecology as a Transdisciplinary, Participatory and Action-Oriented Approach. *Agroecology and Sustainable Food Systems* 37 (1): 3–18.

Mollinga, P.P. 2014. Canal Irrigation and the Hydrosocial Cycle. *Geoforum* 57: 192–204.

Norman, D., Collinson, M. 1985 Approaches to Farming Systems Research Farming Systems Research in theory and practice. In: Remenyi, J.V. (ed.) Agricultural Systems Research for Developing Countries: Proceedings of an International Workshop Held at Hawkesbury Agricultural College, Richmond, N.S.W., Australia, 12–15 May 1985. ACIAR Proceedings No.ll, pp. 189: 16–30

Ogbeide, O.A., and I. Ele. 2015. Smallholder Farmers and Mobile Phone Technology in Sub-Sahara Agriculture. *Mayfair Journal of Information and Technology Management in Agriculture* 1 (1): 1–19.

Ojiem, J., N. De Ridder, B. Vanlauwe, and K.E. Giller. 2006. Socio-ecological Niche: A Conceptual Framework for Integration of Legumes In Smallholder Farming Systems. *International Journal of Agricultural Sustainability* 4 (1): 79–93.

Okello, J., Y. Zhou, I. Barker, and E. Schulte-Geldermann. 2019. Motivations and Mental Models Associated with Smallholder Farmers' Adoption of Improved Agricultural Technology: Evidence from Use of Quality Seed Potato in Kenya. *European Journal of Development Research* 31 (2): 271–292.

Olivier de Sardan, J.-P. 2005. *Anthropology and Development: Understanding Contemporary Social Change*, 243. London: Zed Books.

Olivier de Sardan, J.-P. 2008. La rigueur du qualitatif. Les contraintes empiriques de l'interprétation socio-anthropologique, Louvain-la-Neuve, Bruylant Academia, pp. 365

Ouédraogo, FDC. 2006. La Vulnérabilité Alimentaire au Burkina Faso. Études Africaines, l'Harmattan, Paris, pp. 230

Pimbert, M.P., and N.I. Moeller. 2010. Absent Agroecology Aid: On UK Agricultural Development Assistance Since 2010. *Sustainability* 10 (2): 505.

Pfaffenberger, B. 1988. Fetishised Objects and Humanised Nature: Towards an Anthropology of Technology. *Man (london)* 23 (2): 236–252.

Pretty, J., C. Toulmin, and S. Williams. 2011. Sustainable Intensification in African Agriculture. *International Journal of Agricultural Sustainability* 9 (1): 5–24.

Quandt, A., J.D. Salerno, J.C. Neff, T.D. Baird, J.E. Herrick, J.T. McCabe, E. Xu, and J. Hartter. 2020. Mobile Phone Use is Associated with Higher Smallholder Agricultural Productivity in Tanzania East Africa. *PLoS ONE* 15 (8): e0237337.

Rogers, E.M. 2003. *Diffusion of Innovations*, 5th ed., 576. New York: Free Press.

Roudart, L., and M. Mazoyer. 2012. Origins, Development and Differentiation of World Agricultures. In *Encyclopaedia of Life Support Systems – World Environmental History*, ed. M. Agnoletti, et al. Paris: UNESCO - EOLSS Publishers.

Ruf, T., and J.L. Sabatier. 1992. La gestion sociale de l'eau. *Chroniques Du Sud* 008: 75–79.

Scoones, I., and J. Thompson, eds. 2009. *Farmer First Revisited: Innovation for Agricultural Research and Development*, 357. Warwickshire: Practical Action Publishing.

Scoones, I. 2015. Sustainable Rural Livelihoods and Rural Development. UK: Practical Action Publishing and Winnipeg, CA: Fernwood Publishing

Sebillotte, M. 1977. Jachère, système de culture, système de production, méthodologie d'étude. *Journal D'agriculture Traditionnelle Et De Botanique Appliquée* 24 (2): 241–264.

Shah, E., and R. Boelens. 2021. The Moralization of Hydraulics: Reflections on the Normative-Political Dimensions of Water Control Technology. *Geoforum* 121: 93–104.

Shikuku, K.M. 2019. Information Exchange Links, knowledge exposure, and Adoption of Agricultural Technologies in Northern Uganda. *World Development* 115: 94–106.

Spedding, C.R.W. 1976. Editorial. Agricultural Systems (1): 1–3. Applied Science Publishers Ltd, England

Summers, K.H., T.D. Baird, E. Woodhouse, M.E. Christie, J.T. McCabe, F. Terta, and N. Peter. 2020. Mobile Phones and Women's Empowerment in Maasai Communities: How Men Shape Women's Social Relations and Access to Phones. *Journal of Rural Studies* 77: 126–137.

Taylor, M., R. Bargout, and S. Bhasme. 2021. Situating Political Agronomy : The Knowledge Politics of Hybrid Rice in India and Uganda. *Development and Change* 52 (1): 168–191.

Tittonell, P., A. Muriuki, K.D. Shepherd, D. Mugendi, K.C. Kaizzi, J. Okeyo, L. Verchot, R. Coe, and B. Vanlauwe. 2010. The Diversity of Rural Livelihoods and their Influence on Soil Fertility Inagricultural Systems of East Africa: A Typology of Smallholder Farms. *Agricultural Systems* 103: 83–97.

Trébuil, G., S.R. Kam, F. Turkelboom, and B. Shinawatra. 1997. Systems Diagnoses at Field, Farm and Watershed Levels in Diversifying Upland Agroecosystems: Towards Comprehensive Solutions to Farmers' Problems. *Applications of Systems Approaches at the Farm and Regional Levels* 1: 99–114.

Valadaud, R., and O. Aubriot. 2019. Dialectiques hydrosociales à l'épreuve : Décrypter la dimension politique d'objets techniques utilisés pour l'irrigation au Népal. *Développement Durable & Territoires* 10 (3): 24.

Van Dijk, T. 2011. Livelihoods, Capitals and Livelihood Trajectories: A More Sociological Conceptualization. *In Progress in Development Studies* 11 (2): 101–117.

Vincent, L. F. 1997. *Irrigation as a technology, irrigation as a resource : A sociotechnical approach to irrigation*. Landbouwuniversiteit Wageningen. https://www.narcis.nl/publication/RecordID/oai:library.wur.nl:wurpubs%2F39297

Warner, K.D. 2008. Agroecology as a Participatory Science: Emerging Alternatives Technology Transfer Extension Practice. *Science, Technology & Human Values* 33 (6): 754–777.

World Bank. 2007. *World Development Report 2008: Agriculture for Development*. Washington, DC: World Bank.

Zakaria, A., S. Alhassan, J. Kuwornu, and S. Azumah. 2021. Beyond Participation: The Effect of Fertilizer Subsidy on the Adoption of Certified Seeds Among Rice Farmers in Northern Ghana. *European Journal of Development Research* 33 (1): 684–709.