DYNAMICS OF AN INNOVATION SYSTEM THROUGH THE PRISM OF SPATIAL DITRIBUTION. THE CASE OF CASHEW IN SOUTHWESTERN BURKINA FASO

The Adoption and Diffusion of Cashew-nut Production

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Spatial dynamics of an innovation system in Southern Burkina Faso.
The adoption and diffusion of cashew-nut production

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ABSTRACT.— **The innovation system is a concept designed for analyzing sociotechnical change. In this paper we study the propagation of cashew-nut farming from three dispersal centers in southern Burkina Faso. The rate at which the cashew orchards have spread and the way in which they do so are analyzed with the tools and methods typically used for characterizing innovation system structure and function. By measuring the spatial diffusion process through time, we reveal the diversity of social networks involved, examine the strength of social interactions, and identify the barriers to the cashew-farming adoption process..**

BURKINA FASO, CASHEW NUT,
FUNCTIONAL ANALYSIS,
INNOVATION SYSTEM,
SPATIAL DISTRIBUTION

RÉSUMÉ.— **Les dynamiques d'un système d'innovation à travers le prisme des diffusions spatiales. Le cas de l'anacarde au Sud-Ouest du Burkina Faso.— Le système d'innovation est un concept clé pour l'analyse des changements socio-techniques qui renvoie à une structure et à des fonctions qui contribuent à développer et à diffuser l'innovation. Cet article propose une approche originale d'analyse d'un système d'innovation au travers des processus de diffusion spatiale d'un produit agricole : l'anacarde (noix de cajou). Les formes et les vitesses de propagation des vergers d'anacardiers sont analysées et mises au regard de la structure et des fonctions du système d'innovation. Les résultats montrent que la mesure du processus de diffusion spatiale permet de révéler les types de réseaux, la force des liens entre les acteurs et d'identifier les dysfonctionnements du système.**

ANACARDE,
ANALYSE FONCTIONNELLE,
BURKINA FASO,
DIFFUSION SPATIALE,
SYSTÈME D'INNOVATION

Introduction

For the last ten years, the literature on innovation and sociotechnical change has been dominated by the concept of the innovation system. The construction of an effective innovation system must combine the many different components of an organization—the stakeholders, the institutions, the networks—that operate with one another in order to bring about the invention of the commodity of interest, its adoption, and its diffusion (Edquist, 2005; Geels, 2004; Bergek et al., 2008; Markard, Truffer, 2008). Technical changes in agriculture are no exception, with the result that the innovation system has become a key concept for analyzing the introduction of new crops or practices in rural areas (IFPRI, 2006; World Bank, 2006; Rajalahti et al., 2008; Klerkx et al., 2010).

First and foremost, the innovation-system concept is a methodological framework that allows the systemic analysis of the successes and failures of an innovation. Two major types of framework currently co-exist in the literature (Bergek et al., 2008): structural frameworks, which are aimed at highlighting weaknesses in the structure of a system; and functional frameworks, which are aimed at identifying system malfunctions. The former focus primarily on composition and organization, i.e., on stakeholders, institutions and networks; whereas the latter focus more on fundamental activities and functions (Bergek et al., 2008). The two frameworks appear to be complementary, and structural analysis should precede functional analysis (Markard, Truffer, 2008).

When innovation concerns a new commodity, system efficiency can be measured by observing the product's distrubution and market share (Bergek et al., 2008; Carlsson et al., 2002). According to the sociologist Everett M. Rogers (1983), an innovation is defined by the rate and pattern of commodity diffusion through space and time. This approach has been adopted by geographers in much the same way (Pumain, Saint-Julien, 2001). The diffusion channels operate not just because of geographic proximity but also as a function of existing human networks (whether material or immaterial)—which, depending on a range of factors, may hasten or delay the propagation of new knowledge (Langlois, Daudé, 2007; Wilhelmsson, 2009).

In this article we analyze the links between the spatial distribution of cashew-nut farming, which is a new agricultural product in southern Burkina Faso, and the structure and dynamics of the resulting innovation system. The aim is to understand what the patterns and varying rates of diffusion can tell us about the strengths and weaknesses of this innovation system. As far as we know, this reflective approach has not previously been adopted (Berger, 2001; Savastano, Feder, 2006). Cashew-nut farming currently covers an area of more than 100,000 ha (Ministère de l'Agriculture et de l'Hydraulique, 2008). We have chosen to focus on this geographical area because cashew-nut farming is a relatively recent phenomenon in West Africa. Examining its evolution allows us to explore and explain the many different variables at play.

We will first characterize the structure and general dynamics of the cashew-nut innovation system in Burkina Faso. We subsequently analyze the process of spatial diffusion of cashew orchards in three rural areas of southern Burkina Faso. For this, we study the profiles of the cashew farmers based on two spatial indicators of diffusion: average contact distance between orchards, and plantation area. Finally, we interpret the patterns and rates of diffusion by analyzing the strengths and weaknesses of the system's structure and of its fundamental functions. We conclude by emphasizing the value of spatial analysis in the study of innovation systems.

Cashew trees as innovation systems in Burkina Faso: structure, history, and geography

Cashew cultivation

The cashew tree produces a nut (effectively a seed), containing a kernel which can only be consumed after a complex transformation process, which involves roasting, followed by shelling, drying and peeling.

On family farms in Burkina Faso, cashew trees occur as orchards ranging in size from 0.5 to 50 ha. They generally produce annual crops in the first few years. Harvesting

is manual, takes place during the four to five months of the dry season, and is therefore separate from the intensive agricultural activity of the wet season. If tree spacing of ten meters, (as advised by technicians), is respected, then the average productivity reported by producers is 300 kg of raw cashew nuts per hectare.

Total production volume in 2013 was 30,000 metric tons, far behind that in the Republic of Côte d'Ivoire (385,000 tons; Ricau, 2013). In 2010, cashew-nut farming involved more than 45,000 households (Kankoudry Bila et al., 2010). Between 85 and 90% of the raw cashew-nut production of Burkina Faso is exported to India, which is the world's largest producer and importer (Kankoudry Bila et al., 2010). Burkina Faso has five processing units which employ more than 1000 people. Cashew-nut production is highly dependent on the global market. There is no regulation of export prices and the nuts are generally not consumed locally.

nstitutions and cashew marketing channels

The cashew tree was initially established as a forest species, but it quickly shifted to the fruit production sector. The Department for the Environment introduced the species in the 1970s by creating a 700 ha plantation close to the town of Bobo-Dioulasso. Little interest was shown before the 1980s in the production of nuts, but project "Anacarde" [Cashew, in French], which was co-funded by the Central Economic Cooperation Fund and the State of Burkina Faso, ws set up in order to develop cashew-nut production by establishing two large orchards of 500 ha each. Small-scale processing of raw nuts was subsequently developed through transfer of technology (Lyannaz, 1986). This project continued until the 1990s, after which time the State orchards were privatized and sold to two new proprietors who currently do not farm the land directly. During the initial phase of the project, several individual producers created their own orchards. In the 1990s, there was a cashew boom with the arrival of Indian buyers (Augusseau et al., 2006), a phenomenon that also occurred in northern Côte d'Ivoire (Bassett, 2009). In the 2000s, interest in the sector grew and support agencies including the African Cashew Initiative (ACI) funded by the German Cooperation and by INADES-Formation (funded by Rongead, a French NGO), began to step in. In 2012, Burkina Faso's Agriculture Ministry classified cashew production as an "economically important sector". The producers were initially organized into departmental, provincial and regional unions, but succeeded in scaling things up to a national union in 2013. This wide representation was intended to create a stronger professional body capable of increasing cashew-nut processing in Burkina Faso before export. The country's main processing company founded ANTA (National Association of Cashew processors). The whole cashew sector is currently being restructured in the light of high cashew-nut prices on the global market.

Structure and spatial pattern of the innovation system

The cashew innovation system can be divided into three different stakeholder groups and activities: production, support services for production, and marketing (IFPRI, 2006)(Fig. 1). The production area is situated in the southwest of Burkina Faso and has groups of active producers around the cities of Banfora and Orodara. Support services for production are concentrated in Bobo-Dioulasso. These include State services (provincial and regional chambers of agriculture) and offices for support and counseling structures (INADES-formation). They cover the activity of producer

organizations between Oradora and Banfora. For marketing raw nuts, the wholesalers depend on a dense and ramified network of mobile buyers known as trackers. Nuts are gathered in Orodara and Banfora by small wholesalers, or in Bobo-Dioulasso by major wholesalers. The trackers travel across the rural areas. A proportion of them are excluded from this system and cross the Ghana or Côte d'Ivoire borders directly, depending on the networks available to them. The raw nuts are then exported to the ports of Abidjan, in Côte d'Ivoire, or Tema, in Ghana. Industrial cashew-nut processing units are based in Bobo-Dioulasso, and the main semi-industrial and small-scale units are based in Orodara and Banfora. The small quantities of nuts processed in Burkina Faso (10 to 15%) are mainly sent by air to Europe, where they are sold in niche markets (organic and/or fair trade). Bobo-Dioulasso has effectively become the hub of cashew-nut production, dealing with all the stages of the commodity chain. It is currently the preferred location for business meetings among all the producers.

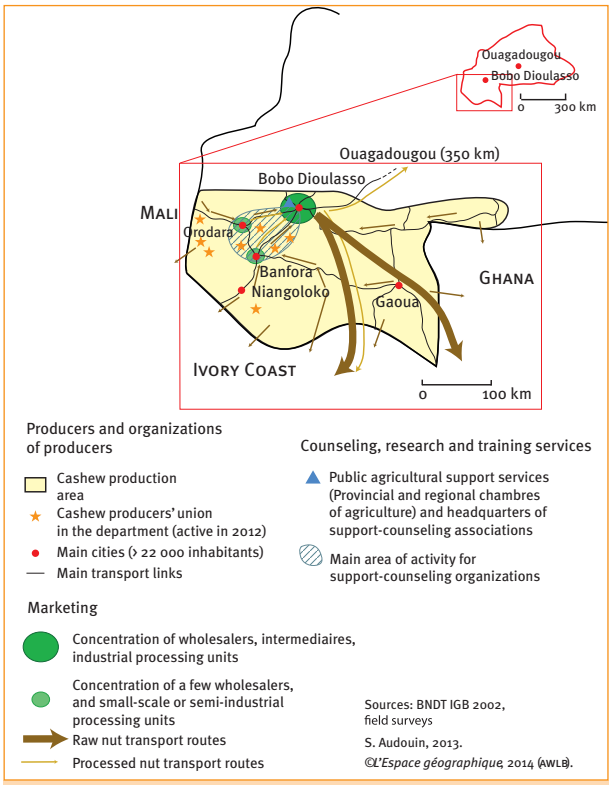

Fig. 1/ The cashew innovation system and its location

Observed and measured diffusion

The analysis of diffusion processes requires knowledge of system structure and dynamics (Langlois, Daudé, 2007). We focus here on describing and measuring how, and how fast, cashew orchards have been expanding across the landscape. These figures are based on observations carried out in three districts of the cashew-producing area of Burkina Faso: Toussiana, Kourinion and Sidéradougou.

Survey areas and data collected

These districts were selected for their socioeconomic diversity, their distance from national transport networks, and the history of cashew production in the region.

- at Kourinion, cashew nut farming started with the creation of a 500 ha orchard through project "Anacarde", which was launched by the State between 1980 and 1990;
- at Toussiana, the cashew was introduced during the 1970s by the Agriculture Department and the Local Support and Counseling Agency (Centre d'encadrement rapproché: CER), and involved the settlement of pilot project farmers;
- at Sidéradougou, the cashew appeared through the initiative of pioneering individual producers, without any support from projects or agriculture departments (Fig. 2).

Semi-structured interviews were carried out in 2012 among 180 cashew producers in the three study areas. Around sixty producers in each district were questioned. These surveys examined employee household characteristics and the agricultural production system. The main cashew producers were included in order to examine the

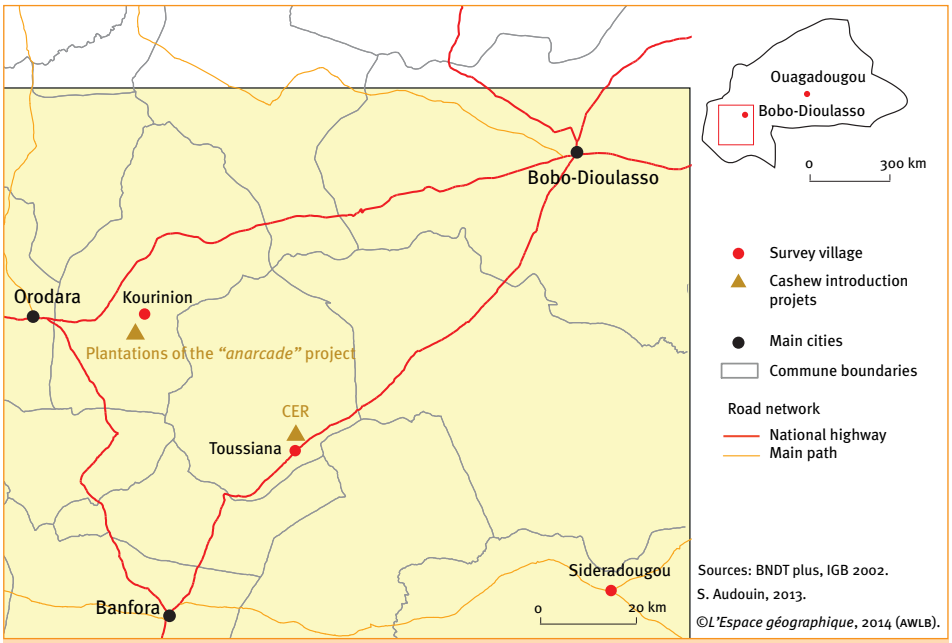

Fig. 2 / Toussiana, Kourinion and Sidéradougou: Three cashew-producing centers

context of cashew-tree implantation. In each district, thirty interviews were carried out in the main town, followed by ten others in hamlets close by. Each of the 328 cashew-tree orchards of the survey were then mapped, dated and demarcated by GPS. In order to define the historical phases of the innovation system, the subjects were interviewed in 2011, 2012 and 2013.

Pioneers, innovators, and followers

Through interviews with the producers, we identified how they initially came into contact with the innovation system stakeholders. We sketched a profile of cashew "adopters" based on the classification proposed by Mendras and Forsé (1983) and later taken up by Chauveau (1993). Among a given group of individuals who are willing to adopt a new commodity, these authors distinguish (in chronological order) the pioneers, the innovators, the early majority, the late majority, and the latecomers. In this study, the last three categories have been combined and are referred to as "followers"—i.e., people who imitate the behavior of others. These surveys helped to retrace the history of cashew introduction and to compare the stakeholder profiles as a function of land resource entitlements and various other social attributes.

In Kourinion, the majority of the pioneers worked as agricultural laborers in the State-owned plantation of project "Anacarde". Having noted the interest shown by the State for this product, they collected seeds and started their own orchards on their own lands. Socioeconomic surveys show that Kourinion's pioneers own more areas with cashew trees than the innovators and the followers. The same applies for their land capital (Table 1). The entrepreneurial character of these pioneers is highlighted by the fact that 91% of them had already attempted to introduce cultivation of new crops before moving on to cashews, as against 28% among the innovators and the followers.

Table 1/ Socioeconomic profiles of the pionnier (P), innovators (I) and followers (S)

	Average area of cashew orchards (ha)			Average area of uncultivated land (ha)			Positive response to trials of new crops before starting cashew (%)			Positive response to participation in earlier projects (%)		
	P	I	S	P	I	S	P	I	S	P	I	S
Kourinion	11.8	9.7	8.4	26.1	4.4	4.2	91	28	28	64	69	39
Toussiana	6.7	8	4.7	9.7	2.7	2.9	82	30	32	91	41	40
Sidéradougou	11.2	13.2	6.8	13.9	14.2	5.9	75	50	50	37	25	30

Participation in earlier projects does not, however, seem to be a differentiating factor among pioneers.

In Toussiana, the pioneers are the pilot-project farmers who were originally coached by the CER in the 1970s. Cashew orchards were established quite early, even before the project "Anacarde" started in Kourinion. Subsequently, some producers from Toussiana were hired in the Kourinion plantation, whereas others waited for the market to grow during the 1990s. These pioneers were, therefore, in touch with the Kourinion project, but the adopter profile here is nonetheless slightly different, i.e. despite having started first, the pioneers do not own larger orchards than the innovators; they nonetheless own more than producers among the follower community (Table 1). As in Kourinion, their overall land capital is high, as demonstrated by land that they can still afford to leave fallow. Land resources were therefore not a restricting factor for the pioneers, who were easily able to allocate land for perennial plantations. Contrary to the innovators and followers, these pioneers again showed willingness to experiment and had been enthusiastic participants in earlier projects.

In Sidéradougou, the cashew trees were planted later. Pioneers are mostly repatriates from Côte d'Ivoire. In the 1990s, there was sizeable cross-border migration and several Burkinabè left for Côte d'Ivoire to work in cocoa and coffee plantations, where they gained knowledge of plantation techniques that included cashew. During consecutive economic slumps in Côte d'Ivoire (1998, 2001), these Burkinabè were driven out and settled back in Burkina Faso, mainly in the south. Sidéradougou became a refuge for the return migrants because it was sparsely populated. The Prefecture imposed the settlement of the repatriates by asking landowners to accommodate them. This has resulted in a highly heterogeneous mix of sociolinguistic groups throughout the municipality. Our surveys show that these repatriated pioneers were major drivers behind the establishment and development of cashew orchards, taking the lead over all other initiatives—whether native or non-native (Table 2). Adopter profiles in

Table 2/ Average profile of the cashew adopters in the three zones

	Average age of cashew adopters (years)	Natives/ Non natives among the adopters (%)	Average orchard area (ha)	Average plantation date of the first orchards
Kourinion	51	80	9.7	1992
Toussiana	54	98	6.1	1995
Sidéradougou	53	15	8.3	1999

Sidéradougou are different from those of Kourinion and Toussiana. As in Toussiana, the pioneers do not own more orchards than the other producer categories. However, unlike the other two areas they do not manage more uncultivated land than the innovators, and thus do not possess substantial surpluses of land capital. The experimenting nature is less pronounced than in the other areas and the participation from pioneers in earlier projects was not very significant. These results confirm the specific profile of Sidéradougou's pioneers, who are largely non-natives and have a different social status to the more long-term local residents. Their status as newcomers to the area affects their opportunities of access to land. Previous waves of immigration had nonetheless promoted strong exchanges of knowledge, which implies that the adopters had already tested several innovations in the past. However, fewer projects seem to have targeted Sidéradougou compared to the other two rural towns (the participation rate among adopters, on the whole, is less than 30%).

Diffusion patterns

Each diffusion pattern was characterized by tracking through time an index of spatial dispersion for the new orchards. At regular five-year intervals, we calculated the average contact distance between new orchards and the nearest older orchards. This index allowed us to single out the main diffusion channels, which are either a function of geographic proximity or of social network patterns, and to compare the spatial concentration of orchards at different moments in time. Contact distances reveal the hierarchical organization of space and detects the faster information routes (Pumain, Saint-Julien, 2001). In a space where the population is uniformly distributed, constant contact distances reveal a process of diffusion through direct contact within the neighborhood (Fig. 3). Directional leaps indicate instead diffusion channels that are driven by social preference. These typically follow social hierarchies or fast-tracking routes other than physical space (Foltête, 2003).

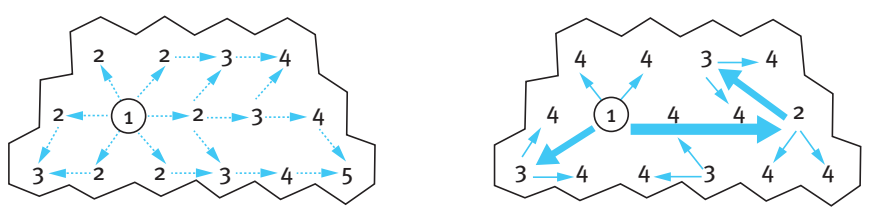

Fig. 3/ Links between contact distance and diffusion channels in an isotropic space.
Numbers 1 to 5 represent successive time steps in the diffusion of innovation at each considered point in space.

In this case study, the plantations of project "Anacarde" in Kourinion and the CER in Toussiana were the starting points for calculating distances to subsequent orchards. We call these propagation centers. For Sidéradougou, the original centers of production were taken to be the the first orchards to be established. The average contact distance curves (Fig. 4) for Kourinion and Toussiana show a similar form, with a large increase in distances until 1975–1980, followed by an irregular decrease in distances until 1995, and ending in a plateau after 1995.

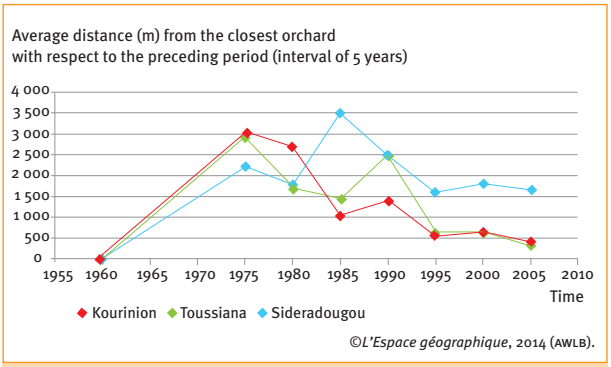

Fig. 4/ Diffusion pattern as a function of relative distance between older and newer orchards

The curve for Sidéradougou displays a perceptibly different form compared to the other two: the three stages are less distinct, and the slopes are different. The increase in distances was larger and more delayed until 1985, and the decrease much lower between 1985 and 1995.

For Kourinion and Toussiana, the first phase reflects the establishment of the first orchards at large distances from the initial centers (3 km on average). This distance demonstrates that during the first stage, geographic proximity was not the main factor of diffusion. Establishment of these first orchards, which then function in turn as secondary propagation centers, corresponds to the adoption of cashew among individuals with strong kinship ties, or among groups with strong social links. From the 1980s, the second stage reveals a change in the diffusion pattern, where we observed a decrease in contact distances. Diffusion continued to follow kinship connections but also operated through immediate neighborhood ties with pioneering adopters. The average contact distance also decreased slowly during that time. The third stage corresponds to a period when diffusion took place mainly in the immediate neighborhood of existing plantations, and the contact distance stabilized at around 600 m. In Toussiana, the increase in contact distance peaked during the 1990s and corresponded to the establishment of a new farming hamlet at a distance of 18 km from the main village.

In Sidéradougou, after the first stage of increase in contact distances from 1960 to 1985, the distances appear to have subsequently stabilized at around 2 km. This curve shape, where the three stages described earlier are less distinct, suggests that the diffusion channels were different. Given the patchwork of sociolinguistic groups at Sidéradougou, it is likely that diffusion channels were based more on neighborhood links than on kinship links, which were inevitably less intense in this setting.

The comparative analysis of contact distances also demonstrates the existence of various degrees of orchard concentration. In Kourinion and Toussiana, the progressive establishment of orchards has tended towards a higher spatial concentration of cashew trees than in Sidéradougou. This is due to the nature of the "fast-track" diffusion channels as well as to the intensity of land use—which is a function of population density. In Sidéradougou, population density is effectively less (19.5 km–2) than in the other two municipalities (34.5 and 24.3 km–2 for Kourinion and Toussiana, respectively) (Institut national de la statistique et de la démographie, 2008).

Adoption levels and diffusion rates

Propagation through time is usually analysed by monitoring the adoption rate—i.e., the number of adopters in proportion to the total population at each stage of the process. Unfortunately, in the present case, this population is unknown and it remains difficult to ascertain exactly how many farmers adopted cashew production before 2013. Consequently, we created for each village an "adoption level" index by relying only on our representative sample of producers surveyed in 2013. The dates of all orchards created between 1960 and 2013 could then be identified for each producer, with the corresponding surface areas. The proxy chosen for adoption level was the aggregate total surface area of the orchards created during time interval, t, in each village sub-sample. In order to normalize the index and make it comparable among villages, this area was adjusted to sample size. Figure 5 shows the evolution of the adoption level index as a function of time.

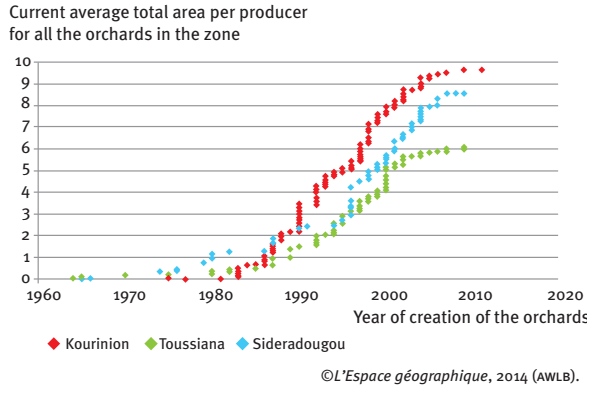

Fig. 5/ Curves displaying evolution of the degree of cashew adoption in the three surveyed village (total combined area of orchards, in ha)

Figure 5 displays three logistic curves with fairly distinct profiles: the Kourinion curve indicates the fastest diffusion rate; the Sidéradougou curve indicates an intermediate rate, with a fairly marked point of inflection between 1990 and 1995; the Toussiana curve shows the lowest diffusion rate, with a slower take-off phase and a lower plateau in the last phase.

In Kourinion, adoption seemed to occur rapidly; the average slope of the curve is 0.27 ha/surveyed producer/year.

The Toussiana curve, in contrast, shows that the first planters remained few until the 1980s. From 1980 onwards, the rate of orchard creation increased before leveling out in the 2000s—more distinctly so than for the two other curves. In addition, the total combined area attained on this plateau is much lower. Finally, the average adoption rate is twice as low as that of Kourinion, with an average slope of 0.13 ha/ surveyed producer/year.

In Sidéradougou, the curve shape indicates that the rate of new orchard creation remained quite low until 1995. However, the subsequent number and size of orchards increased sharply, soon overtaking the adoption rates recorded in Toussiana, and approaching the rates recorded at Kourinion. The average cashew adoption rate here has been 0.19 ha/ surveyed producer/year. Table 3 summarizes observations for the diffusion phenomena in the three zones.

Links between spatial diffusion and the structure and function of cashew innovation system

Here we attempt to explain the adoption rates and patterns of cashew cultivation with respect to the structure and function of the innovation system. Structure is characterized by the types of players present and by the strength of relationships between one another. Relationship strength is based here on a comparison with the survey

Table 3/ Synthesis of the patterns and rates of cashew diffusion

	Diffusion pathways	No. of propagation centers	Diffusion rate
Kourinion	Leaps through the social network, followed by diffusion through the immediate neighborhood	One	High
Toussiana	Leaps through the social network, followed by diffusion through the immediate neighborhood	One	Low
Sidéradougou	Diffusion through the immediate neighborhood	One	Average

results. System function is classified following Bergek et al. (2008). The activation level of each of these functions was also evaluated against the survey results and interpreted in the light of the cashew orchard history across the region.

What diffusion pattern and rate tell us about innovation system structure

The innovation system connects the various players who contribute to the development of the innovation. This connection reflects a relatively strong interaction within the network of players.

In Kourinion, diffusion is characterized by two types of channel: kinship connections during the first stage, followed by neighborhood proximity—in each case activated from a single propagation center. Diffusion occurs rapidly. These characteristics are due to the central role played by the "Anacarde" project and the strong kniship links between pioneers. The high initial diffusion rates are largely a result of the presence of State-employed technicians (the pioneers themselves were enrolled by the State), or are driven by strong kinship links. A steady diffusion rate is usually explained by continuity in counseling services, and by good neighborhood relations between producers. Today, the producers in this area are highly organized and have formed a very active group at the regional level. They also receive weekly news updates from Rongead on the evolution of farmgate prices. These interactions between producers, State employees, wholesale companies, and support and counselling agencies have generated a dense network of exchanges and discussion forums, thus supplying the system with a regular flow of information. They help to stimulate interest in cashew nuts, attract new converts, and promote the creation of new orchards.

In Toussiana, diffusion originated from a single propagation center, the CER, initially through kinship channels followed by neighborhood channels. The diffusion rate was slower than in Kourinion. As in Kourinion, the diffusion pattern was primarily due to the support provided by technicians from the CER, who trained the pioneers of Toussiana. The strong kinship links were activated to spread these techniques in accordance with the social hierarchy of the place. The network of producers and other players of the innovation system was as dense and organized as in Kourinion (existence of organized producer groups, access to information on prices). However, because the activities of the CER were essentially focused on the production of grafted mangos, it was probably less efficient at propagating the information or techniques for cashew-tree plantation.

In Sidéradougou, diffusion originated from several propagation centers, operated mainly through neighborhood channels, and followed exponential rates. The most dispersed form of spatial diffusion indicates a distinctive feature in the structure of the innovation system, which is primarily due to the initial presence of a swarm of centers. The pioneers, once repatriated from Côte d'Ivoire, negotiated their settlement in various villages or remote bush areas. They then propagated cashew planting from these isolated places out into their respective neighborhoods. The network of players in the innovation system was thus initially more scattered. Diffusion at first was slow, corresponding to a learning phase among the newly settled players—who in this case did not benefit from any support from technicians or counseling agencies. Immigration to these sparsely populated surroundings led to a fragmented land-use pattern and to a highly heterogeneous social mix that probably impeded the growth of strong links among producers. These weak links can be observed even today, with the quasi-absence of active groups of producers, of technical support, of wholesale buying structures, or of price information services. Diffusion accelerated in 1995 due to the arrival of a large number of new migrants and to the creation of orchards thereafter (77% of new orchards, as opposed to 52% in Kourinion and 63% in Toussiana). This period witnessed an evolution in the composition of the network, with ramifications now reaching Côte d'Ivoire. Through these family ties, the producers are now connected to the well developed wholesale buyers' networks in Côte d'Ivoire, thus reinforcing the economic strength of cashew-nut production. The native farmers subsequently followed their immigrant peers and started their own orchards. Sidéradougou thus shows that a dispersed form of diffusion may, nonetheless, include an intense adoption level when the system is able to use its networks differently—in this case through the generation of foreign connections.

What diffusion pattern and rate tell us about innovation system functions

A functional analysis of the innovation system shows a number malfunctions, which can be interpreted as symptoms of resistance to the innovation process:

- in Kourinion, no serious impediments were identified, and all the functions of the innovation system were apparently activated as soon as the first orchards had become established;
- in Toussiana, a true market for cashew barely existed before 1980, and difficulties of access to land resources restricted the innovation system;
- in Sidéradougou, the market really only took off after 1990, and the system still suffers from an absence of technical support and exchange of information.

In Kourinion, as we have already explained, cashew farming propagated rapidly and remained spatially concentrated around the initial propagation center. It was well received because of government support. Land resources were easily mobilized and the producers were able to find support and counseling from the government agents. Innovative plantation techniques spread easily in this environment via strong social proximities. A market was rapidly created and the produce was sold easily. Other factors also came into play here—for example the fact that the producer cooperatives also deal with other products (mangos, hibiscus flowers), in partnership with European buyers who promote fairtrade and organic niche markets. Income from cashew nuts has allowed several families to improve their living conditions (constructing houses,

buying motorcycles) and to invest more widely in agriculture (cattle raising, purchase of fertilizer for corn production, etc.). This synergy between different forms of production has perhaps accelerated the proliferation of cashew-nut farming.

In Toussiana, the diffusion curve is characterized by clear plateaus in the initial and final stages. These reveal the existence of stumbling blocks in the innovation system. The first obstacle (1965–1980) came from the buyers, who in Toussiana still preferred the Kourinion plantation. Subsequently, in the 1980s, independent wholesale buyers developed the local market. The second obstacle arose from the the difficulty in co-opting new land to cashew production. The number of new orchards is continually decreasing. Available space is closer to saturation than in Kourinion, and the population density in the municipality is 1.4 times higher. The other expected functions were fulfilled by the innovation system: supervision of the pilot-project farmers by the CER, for example, ensured some diffusion of knowledge, which spread through kinship links throughout the area. Once these obstacles had been lifted, the cashew-nut market developed rapidly. The innovation system generated a number of wider benefits, but to a lesser extent than in Kourinion. However, saturation of available tree-growing space resulted in the leveling-off of the innovation curve, ending in a low adoption rate in this area.

In Sidéradougou, the diffusion process accelerated after 1995 because of a modification in the innovation system structure, and because of new links with Côte d'Ivoire. A new market opened up to the producers: the influx of a large number of migrants increased the exchange of information about cashew and strengthened the sense that cashew is a crop worth investing in. An evolution in the rules of land use for migrants certainly contributed significantly to this acceleration. The cashew tree in Sub-Saharan Africa has actually come to play a key role in land administration. In addition to being a marker of land appropriation, planting a tree can give the planter a set of rights over the resource, such as exclusive harvest of its fruits and a rights over land management (Bertrand, 1991; Le Roy et al., 1996). Non-natives are thus generally not allowed to become involved in tree plantation because it would later be difficult to claim back land that was allocated to them (Lavigne Delville et al., 2002). In Sidéradougou, however, from 1995 onwards, arrangements between natives and non-natives allowed the non-natives to buy land (a practice which is still quite rare and taboo throughout the country), or to create orchards under certain conditions of patronage1. By buying land, the traditional prohibition on tree planting could thus be evaded. This is in line with an ongoing process of changes to land access under the influence of the repatriates from Côte d'Ivoire. These migrants are familiar with the cocoa plantation systems of Côte d'Ivoire but are also influenced by the internal migratory flows that are making an impact on the local social fabric (Chauveau et al., 2006). Positive benefits are still currently hard to identify, however, because of the relatively recent development of cashew-nut production. Despite the initial absence of a market for cashew nuts, and despite the adoption of cashew crops through State encouragement and technical training, it is above all this deregulation of land purchase and land use that has facilitated rapid and intense development in Sidéradougou.

Conclusion

Studying the phenomenon of diffusion tells us about the innovation process and the system that produced it. Analyzing successive states of propagation of cashew orchards in space reveals what are the diffusion channels, the strengths of information exchange networks, and existing system malfunctions—if any.

By monitoring two spatial indicators over time—namely average contact distance between new and old orchards, and average total combined orchard surface area—we were able to characterize the dynamics of the innovation system, its historical stages, and its blockage points. The evolution curves of the spatial indicators revealed some important turning points, which reflect changes in the structure and functionalities of the innovation system. Comparing the absolute or relative values of the spatial indicators (distance, surface area, diffusion rate) serves as a proxy for quantifying the strength of exchanges and social links among the players. This approach thus compensates for one of the recognized weaknesses of a purely structuralist analysis (Edquist, 2005; Bergek et al., 2008).

Thus, in Kourinion, the large number of orchards and the high diffusion rate reflect the strong links between players. The existence of well organized networks, which rely on geographic proximity as well as social lineage hierarchies, demonstrate an effective and dynamic innovation system.

In Toussiana, the contact-distance curve shows an adoption of diffusion channels and exchange networks similar to those in Kourinion. But the evolution of orchard surface area reveals some blockage points in the innovation system. These are mainly the absence of access to the market until the 1990s, and difficulties in land access.

In Sidéradougou, there was a slow start due to the absence of a market and a very loose network of pioneers. This initial phase was followed by a turning point in 1995, which corresponds to the arrival of new players, to the activation of networks in Côte d'Ivoire, and to a change in the land-use rules. In Sidéradougou, despite an innovation system structure that remains quite different to Kourinion, we can see that both the adoption speed and areas of land converted to orchards have been similar since 1995.

The efficiency of an innovation system depends on the balance between its structure, its functions, and how these affect diffusion. Our case study demonstrates that when all these elements are functioning well, diffusion is rapid. Spatial analysis can reveal, though not necessarily explain, the blockages that may occur. Some functions appear to interfere with each other and they do not all have the same impact on diffusion dynamics. In agricultural innovation, local access to the market and to land resources are vital. The failure of proactive land policies in West Africa shows that whereas centralized public action has a weak impact, local, consensus-based initiatives can be more successful (Cotula et al., 2004; Le Roy, 1995). In the context of a neoliberal global economy, access to the market depends on State intervention (through the construction of essential material infrastructure such as roads) as well as on the capacity of local players (producers, traders, intermediaries) to organize. The coordination of all these different system functions is a complex game between local, regional and national levels, in which the spatial structure, social organization and social dynamics at local district level all play key roles. As shown in this study, our understanding of the structural and functional attributes of innovation systems can gain many valuable insights from adopting a spatial approach.

1. According to Chauveau et al. (2006), the patronage system is a land-related and clientelist relationship that allows a native community to accommodate newcomers by ensuring that they gain access to cultivation rights on land owned by one of the families. However, the newcomer must respect social rules and return services to his patron and to the community.

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