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11èmes Journées de Recherches en Sciences Sociales (JRSS)

Influence of social network on the diffusion of local rice innovations in Benin

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Abstract

In Benin, developed and disseminated innovations in local rice value chains hardly find a place in the rural smallholders' environment, although improved and technically more efficient. Studies carried out about adoption of rice innovations in Benin stayed focused on a purely economic analysis on the assessment of intrinsic factors either of the innovation and / or the consumer. Therefore; they omit small farmers social integration and relation with his environment. The objective of this paper is to analyze the influence of the social network, constituted by the innovation platform (IP), on the diffusion of rice innovations in Glazoué Rice Hub. Data were collected from 244 randomly selected rice producers and parboilers. We apply the social networks theory and logistic regression models of innovations knowledge to relational data. The results show that awareness of rice innovations is positively correlated with membership of an innovation platform, number of contacts, experience in professional organizations and central or intermediate position in the network. While, strong ties based on the network density, distance to the closest innovation platform, closeness centrality are the factors that negatively influence knowledge of these innovations. Ultimately, the further rice actors are from the IP, the less information access they have.

Keywords : Social network, diffusion, innovation, local rice.

CODE JEL: O32, Q1, Q16, Q55, Z13

Introduction

In developing countries such as Benin, rice has a central role in food security for the poorest groups of people (AfricaRice, 2012, Seck, et *al*., 2010). However, rice production increase is more due to the better extension capacity in producing areas than of the yield efficiency (UNDP, 2015). That is why new technologies and innovations have been developed since several years to improve productivity and increase the incomes of rice stakeholders (Hinnou, 2013).. Although they are improved and judged technically more efficient (Maboudou, 2003), these technologiesare not adopted by the stakeholders along the rice value chains (Adégbola et *al*., 2010). The reasons often used to justify the low use of innovations are attributed to the intrinsic characteristics of the technologies and / or to the users' perceptions (Adégbola, 2010; Hinnou, 2013). Similarly, there is a lack of attention to the context (agro-ecological and socio-economic) in which technologies must be applied and also to the less consideration of farmers' knowledge (Van Der Steen et *al*., 2010). The limitations of innovations development and diffusion approaches are also pointed out (Leeuwis, 2004; Van der Steen et *al*., 2010). In this register, Adégbola (2010) reinforces the thesis of Rogers (2003) that the efficiency of the innovation transfer and its result depend on the type of communication channel that is used.

Thus, to overcome the major difficulty in promoting new technologies due to the cost and intensivity of the labor market needed, social networks appear to be a main vehicle for information (Beaman and Dillon, 2014). Obviously, knowledge is not a mere externality, but it circulates through willing exchange and sharing networks (Suire and Vicente, 2008) because of the geographical and relational proximity (Amisse, 2011). In this context, in order to maximize diffusion of innovations, a synergy of actions should be created in close collaboration with farmers, researchers, extension service (AfricaRice, 2012) and to evaluate opportunities for co-learning and negotiation (Tollens et al., 2013). To achieve this, the Innovation Platform (IP) approach is adopted as a channel to improve access to agricultural technologies and markets (Devaux *et al*., 2009; Organo *et al*., 2010; Gildemacher and Mur, 2012; Wennink and Ochola, 2011). In addition, it is important to consider interactions between individuals when studying diffusion of innovation (Steyer and Zimmermann, 2004). This is even more observed in rural areas where social structuring is still very rigid, complex and hierarchical. Exposure to information is enough to become informed, and potentially convey information to someone else (Ba *et al*., 2012).

However, studies carried out about adoption of rice innovations in Benin stayed focused on a purely economic analysis on the assessment of intrinsic factors either of the innovation and / or the consumer. The aspects related to the social integration of the individual through his relations with the social environment is generally overshadowed. As a result, these different researches have not led to substantial improvements in the rates of adoption of introduced or internally generated technologies or innovations. The present research objectives is to close this gap and analyzes the influence of the social network around the innovation platform participants, on the diffusion of rice innovations in Glazoué Rice Hub.

Structural analysis and innovations diffusion model

The Social Network Analysis is made through the interactions between the stakeholders of rice IP and the roles they play in the diffusion of information about innovations.. The notion of diffusion is the basic of the coherence of the behaviors and representations, and therefore of the coordination of people actions (Steyer and Zimmermann, 2004). Diffusion is therefore the process by which an innovation is communicated through certain channels over time between a social system members (Rogers, 1983). It is in this light that this paper analyzes the diffusion of rice innovations based on the utilitarian view of Aral (2011), who defines influence as the extent to which a person's behavior can alter the utility function. This influence is reflected in the externality effects of social networks. In this sense, the analysis is based on the collective influence exerted by the social network on an individual in the process of information transmission about any rice innovation. To this end, we will mobilize the social networks theory which considers that the process of collective contagion results from the repetition of processes of successive individual influences (Vernette et *al*., 2012).

The diffusionist model consider the adoption of an innovation as a five decision-making step ranged as follows: the first consumer exposure (knowledge), the persuasion, the decision to adopt or reject the innovation, the implementation and the confirmation (Dauphin-Pierre, 2011, Rogers, 2003). In this decision-making process, the consumer's reasoning is based on his perceptions of innovation and on the information he has. In other words, consumer information resources and origin determine his choice (Joseph, 2010). According to Rogers (1995), the innovation must be more attractive than other alternatives and conform to values, ancient pratices of usage and obtained results. As for Joseph (2010), he evokes functional, psychological or informational order of barriers.

Moreover, interactivity is a notion that would be more important in the diffusion of an innovation (Dimmick et al., 2007; Rogers, 2003). The path of influence result of a transmission to an individual from a whole of his or her relational environment. Thus, where the influence of one individual on another is insufficient to bring about change, the cumulative influence of its social environment may allow it (Steyer and Zimmermann, 2004). In this dynamic of social interactivity, the sharing (diffusion) of information is fast (Berger and Heath, 2007; Van den Bulte and Stremersch, 2004).

As such, the sociometric approach formalizes the usual process of interpersonal research. But this approach assumes that the consumer is aware of or realy remembers the people who influence him / her in the decision-making process related to innovation (Vernette et al., 2012). To correct this sociometric limit, social capital appears as an alternative in the analysis of the determinants of the diffusion of innovations. Thus, the degree of connection between stakeholders, source of social capital, provides channels for the diffusion of information and produces norms on the behavior “to be adopted” (Coleman, 1988). Meanwhile, social capital itself is constructed within diverse and open relational networks rich in structural holes (Burt, 1992). In this register, weak ties, unlike strong ties, facilitate the exchange of information with new entrants with different ideas, favorable to the development of innovations (Del Vecchio, 2010). In fact, dense networks often transmit redundant and trivial information. On the other hand, the weak ties and non-redundant bring more new information (Callois, 2005; Granovetter, 1973; Burt, 2000). In practice, two indices are used to measure social capital in a social network: the closure (density) of the network and the structural holes (Burt, 2000).

Specification of the diffusion model and definition of variables

Since the adoption decision depends on been aware of the innovation, a latent variable $Y_i^{C^*}$is defined indicating whether the stakeholder has the information about such innovation or not. We assume a linear specification of the latent variable $Y_i^{C^*}$ which implies that $Y_i^C = 1$ if the stakeholder is aware of the innovation and $Y_i^c = 0$ if not. Thus, we have:

$$Y_i^c = \begin{cases} 1 = if\ Y_i^{c^*} = \propto_i X_i + \varepsilon \geq 0 \ \Leftrightarrow \propto_i X_i \geq -\varepsilon \\ 0 = if\ Y_i^{c^*} = \propto_i X_i + \varepsilon < 0 \ \Leftrightarrow \propto_i X_i < -\varepsilon \end{cases} \quad (1)$$

With $\propto_i$ the vector of parameters to be estimated, X_i is the vector of explanatory variables of the information awareness and ε is the error term.

The dependent variable of the estimated models is the awareness of rice innovations (Awainov)). In a relational approach based on social network externality effects, the variables that are supposed to influence the rice stakeholder likelihood of being informed about one or all innovations and their diffusion are as follows:

Membership to a multi-stakeholder organization (*Mbrpi*). Institutions play a regulatory role, facilitate the flow of information and create laws, ethical and moral norms that shape the individuals behavior within the system (Biggs and Matsaert, 2004). In this paper, institutions are assimilated to the innovation platforms implemented to serve as an interface between stakeholders with common interest but in a certain divergence and different power exrcises. *Mbrpi* is a dichotomous variable and takes the value 1 if the rice stakeholder belongs to an innovation platform and 0 otherwise. The affiliation of a rice stakeholder to an organization of the kind would have a positive influence on his/her access to information in connection with innovations. Moreover, this positive influence would be more significant when the stakeholder is closer to the innovation platforms (*Distpi*).

Number of membership networks (Nbrop). Membership to an agricultural stakeholder organization reflects the intensity of contact with other farmers, enabling them to learn from each other about new technologies (Adegbola and Gardebroek , 2007). Similarly, individuals with a large number of ties in a network tend to adopt earlier in a diffusion process (Vernette et al., 2012). Thus, the more an individual belongs to networks, the more he increases the probability to be interconnected and therefore more exposed to information related to innovation. This variable will have a positive influence on the diffusion of innovations since it exposes the individual and reduces the information gap. Similarly, the number of years of membership in a professional organization (*Expop*) reflects the stakeholder experience in rice field and a high probability of being in contact with the introduced innovations. A positive sign of this variable is expected in the models of knowledge and diffusion of innovations.

Degree centrality « in degree (Nbcont)» or « out degree (Cdegree) ». The degree centrality is an indicator of the communication activity or popularity of an stakeholder (Abbasi, 2011; Haythornthwaite, 1996). Thus, the rice stakeholder, who has a large number of direct connections with others, occupies a more central position in the social network and would be more exposed to innovation (Borgatti, 2005, Lemieux and Ouimet, 2004).. Vernette et *al*. (2012) have argued that the central position of a rice stakeholder is an engine to accelerate the contagion effect for the diffusion of a new technology. This variable, which is a proxy of influence, is introduced in the models in disaggregated form in terms of the number of contacts cited (*Nbcont*) by the rice stakeholder and the number of times he/she is cited (*Cdegree*) by other stakeholders in its social network. A positive sign of these variables is expected.

Closeness centrality (Cclosenes). The closeness centrality appreciates the distance separating the rice stakeholder from other stakeholders of the social network (Haythornthwaite, 1996). It is therefore an indicator of integration or isolation of network members (Müller-Prothmann, 2007). A strong closeness centrality indicates a greater autonomy of the individual (Freeman, 1979; Hanneman and Riddle, 2005; Haythornthwaite, 1996; Lemieux and Ouimet, 2004). Consequently, the closeness position of a stakeholder in the network could have a negative influence on the process of information transmission in the social network.

Betweness centrality (Cbetwenes). The betweness centrality is an index that indicates the role of bridge or brokerage ensured by a stakeholder and which most often allows him to control the flow of information in the social network (Freeman, 1979, Hanneman and Riddle, 2005, Haythornthwaite, 1996, Müller-Prothmann, 2007). Indeed, the betweness centrality indirectly measures the potential for social contagion.: (Vernette *et al*., 2012). In communication networks where access to information is restricted, bridging stakeholders can derive a comparative advantage (Degenne, 2013, Hoppe and Reinelt, 2010, Olivier de Sardan, 1995). This index will have a positive sign on access to information and diffusion of rice innovations.

Social Capital (Lienfort). The stakeholder who develops (weak) external ties will generally be more successful than another who builds strong ties because strong ties tends to become saturated (Callois, 2005). Structural holes, refer to weak ties that are more likely to link "different worlds", complementary resources and new information (Burt, 2000; Granovetter, 1973). For correlation reasons, only the *Lienfort* variable was introduced in the models. We postulate that this variable will have a negative influence on the acess of the information.

Type of social network (collaboration, exchange of knowledge, influence). In a social network, the dissemination of information depends on its members and the links that unite them (Maunier, 2008). This concern Collaboration ties (*Apuitech*), Exchange of knowledge / information (*Einform*) and Influence (*Nbrinflu*). Indeed, knowledge plays an important role and the amount of knowledge exchange is positively correlated with the amount of collaboration between an organization within the innovation network (Hermans *et al.*, 2017). The influential stakeholder of a social network exert an attraction force on their surroundings and thus act on the perception and the decisions of others within the network (Bertrandias, 2003, Vernette, 2006). This type of network (*Nbrinflu*) will therefore have a negative influence on the diffusion of rice innovations due to an asymmetry of information. It is hoped that these networks (*Apuitech* and *Einform*) will positively influence the diffusion of innovations within the rice networks.

Sampling, data and analysis model

Research site and sampling

This research was conducted in Glazoué Rice Hub located in the Department of Collines in Benin. Stratified sampling combined with simple random sampling were used to chose survey units both rice stakeholders (rice producers and parboilers) and villages. The advantage of this method is to create a certain homogeneity within heterogeneous groups and to give all individuals the same probability of being sampled independently of each other. Thus, the villages were stratified in two levels on the basis of their membership and their proximity to an IP. In the first group, we have villages from Glazoué and Bantè in which IPs were initiated and villages from Dassa-Zoumé and Savalou located on the borders of the two first communes. The second stratum consists of the villages from Ouèssè and Covè, which participate in the activities of rice IPs, but located more than 100 km from the landmarks of these platforms. As the current size of the IPs is unknown, it is difficult to set a probability sampling. Thus, for each stratum, random sampling was used to select the stakeholder . This choice is made to better appreciate the influence of IPs on the level of knowledge. A total of 244 rice producers and 116 rice parboilers were interviewed in about 20 villages in six (06) communes.. Thus, in each village, the list of active stakeholders in rice production and / or processing was established. On average, about ten producers and parboilers were selected randomly per village (Arouna and Diagne, 2015).

Data and collection methods

The data used in this research concerned innovations introduced or disseminated from 2012 onwards through IPs. The list of these innovations was obtained from databases of the Rice Subprogram of the National Institute of Agricultural Research of Benin (INRAB) and from AfricaRice. The data were collected using a sociometric approach with questionnaires specific to each category of stakeholder. Moreover, observations made and qualitative data collected during our facilitation activities with the various IPs were useful for analysis.

In addition, relational data were collected using the name-generating instrument . This was combined with the nominalist approach to assess the influence of stakeholders in the social network (Butts, 2008; Hermans et al., 2017 , Löblich and Pfaff-Rüdiger, 2011;) in relation to the diffusion of rice innovations. The "name generator" approach was used to ask rice producers and parboilers to indicate the contacts (as exhaustive as possible) to whom they resorted in case difficulties. Each respondent identified the stakeholders they considered to be the most important on the network in terms of influence or knowledge exchange concerning rice (Hermans et al., 2017). The list-based approach was adopted to appreciate the relationships of rice producers and parboilers with riceorganizations and institutions.

The data were collected through structured interviews between February and April 2017. First, the qualitative data collection phase made it possible to identify and categorize the relational variables likely to influence innovations knowledge or diffusion. Thus, this approach has provided a better understanding of the empirical realities (Creswell and Plano Clark, 2006). This first phase consisted of focus group discussions with 10 to 15 in twenty villages of all municipalities that participate in IPs activities.The second phase took place with questionnaires specific to each category of actors. We were supported by a team of experienced professionals (10 enumerators and 2 controllers). The questionnaires were validated through pre-tests with about ten rice producers and parboilers by trained enumerators. This led us to refine the questionnaires and adapt them to the context.

Methods of Data Analysis

Three types of analysis were used to assess the influence of the rice social network on the diffusion of innovations. First, the structural analysis, using the UCINET 6 software, made it possible to estimate the indices relating to the position of the stakeholder (rice producers and parboilers) in their social network. For this purpose, sociometric data were used to construct the adjacent relational matrix. The elements of the matrix a_{ij} are numerical values (1 if there exists a relation between two stakeholders and 0 if not) attached to the relation between the pairs of stakeholders or nodes (Hoppe and Reinelt, 2010, Sutanto et al., 2011). This matrix, constructed for both rice producers and parboilers, has thus made it possible to estimate the degree centrality (number of close contacts cited "*in degree*" and number of people who cited the respondent as close contact "*out degree* "), the betweness centrality and the closeness centrality. Similarly, variables related to social capital (strong ties and weak ties), networks of influence (number of influential contacts), knowledge (number of contacts with who the stakeholder has technical support relationships) and information (number of contacts based on the exchange of information) were estimated from the collected data. Secondly, content analysis of the relationships was adopted in order to better understand the circulation of resources in the rice stakeholders networks (Del Vecchio, 2010). This analysis identifies knowledge or other resources (confidence, influence, ...) that determine the diffusion of innovations and specify the dynamics of learning and skills acquisition. This content analysis is reinforced by descriptive statistics and statistical tests comparing the different levels of the sample. Finally, the econometric approach allowed to model the behavior of the rice stakeholders in relation to the new technologies introduced. Although the dependent variable is binary (1 = yes for been aware of the innovation and 0 = no), the Hausman test was used to make the choice between Probit and Logit by comparing coefficients in terms of variances (Green, 2007). This test showed consistency for the Logit model with larger coefficients. Then, residue analysis eliminated aberrant or influential observations and re-estimated the models in order to choose the best ones on the basis of information criteria such as the logarithm of the likelihood, the Akaike (AIC) and Schwartz (BIC) information criterion and then the R^2 of McFadden (Green, 2007). Thus, hypotheses linked with knowledge and diffusion of innovations are tested with the following general empirical equation:

$$AWAINOV_i = \alpha_i + \beta_1 MBRPI_i + \beta_2 DISTPI_i + \beta_3 NBROP_i + \beta_4 EXPOP_i + \beta_5 NBRINFLU_i + \beta_6 APUITECH_i + \beta_7 EINFORM_i + \beta_8 LIENFORT_i + \beta_9 NBCONT_i + \beta_{10} CDEGREE_i + \beta_{11} CCLOSENES_i + \beta_{12} CBETWENES_i + \varepsilon_i$$

where AWAINOV represents the dependent variable that corresponds to the knowledge or diffusion of innovation (NERICA lowland group of improved varieties, weeder, wheels, tresher-winnower cleaner, winnower and all innovations for production, parboiling equipment, Drying area and set of innovations for transformation), indicates the constant, are the regression coefficients and is the error term. In addition, the collinearity test indicates low variance inflation (VIF) for the explanatory variables introduced in the models, which implies that our data are not subject to the multicollinearity problem (Chattefuee and Hadi, 2006; O'brien, 2007). All these statistical analyses were done with softwares SPSS 20.0 and STATA 14.0.

Findings

The correlation matrices, means and standard deviations of the explanatory variables introduced in the models are presented in Tables 1 and 2.

Table 1. Rice production innovations correlation matrix, mean and standard deviation of the variables of knowledge models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1. Distance from the IP (Distpi)	1											
2. Membership to a rice IP (Mbrpi)	-,454***	1										
3. Number of social organization belonging to (Nbrop)	-,174***	0,114	1									
4. Experience in an PO (Expop)	,160**	0,026	,156**	1								
5. Number of cited contacts (Nbcont)	0,09	-0,041	0,117	,246***	1							
6. Number of influents (Nbrinflu)	0,039	,175***	,141**	,201***	,280***	1						
7. Number of strong ties contacts (Lienfort)	-,135**	-0,009	-0,026	0,03	,267***	,277***	1					
8. Number of technical support contact (Apuitech)	-,145**	0,096	0,028	-0,086	,131**	,171***	0,096	1				
9. Number of exchange of information contact (Einform)	,168***	-0,017	0,099	0,073	,294***	0,105	,193***	-,173***	1			
10. Degree Centrality (Cdegree)	,201***	0,119	,201***	,283***	,314***	,276***	-0,018	0,014	,281***	1		
11. Closeness Centrality (Cclosenes)	-,702***	,160**	0,065	-,292***	-,245***	-,166***	0,034	0,04	-,138**	-,377***	1	
12. Betweness Centrality (Cbetwenes)	-,152**	,184***	,136**	0,001	,200***	0,041	-0,042	-0,075	,143**	,314***	-0,044	1
Obs.	244	244	244	244	244	244	244	244	244	244	244	244
Mean	84,48	0,25	2,07	8,32	7,10	4,30	2,77	0,93	2,28	4,32	1537,01	266,58
Standard deviation	63,62	0,44	1,149	5,53	3,69	1,27	2,89	1,54	3,02	3,52	1008,88	797,75

**** p<0,01 and ** p<0,05*

Table 2. Rice parboiling innovations correlation matrix, mean and standard deviation of the variables of knowledge models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1. Distance from the IP (Distpi)	1											
2. Membership to a rice IP (Mbrpi)	-,452***	1										
3. Number of social organization belonging to (Nbrop)	-,219**	0,099	1									
4. Experience in an PO (Expop)	-,205**	,345***	0,136	1								
5. Number of cited contacts (Nbcont)	-0,115	,297***	0,103	0,178	1							
6. Number of influents (Nbrinflu)	0,158	0,151	0,008	0,026	,476***	1						
7. Number of strong ties contacts (Lienfort)	-0,002	-0,033	0,153	0,018	,295***	,203**	1					
8. Number of technical support contact (Apuitech)	-,195**	0,043	0,083	-0,003	,210**	,275***	0,027	1				
9. Number of exchange of information contact (Einform)	,309***	-0,121	0,075	0,041	,331***	0,089	0,134	-,192**	1			
10. Degree Centrality (Cdegree)	-0,057	,271***	-0,002	0,179	,395***	,281***	-0,042	0,095	0,144	1		
11. Closeness Centrality (Cclosenes)	,255***	-,487***	-0,029	-,266***	-,306***	-0,13	0,169	0,026	-0,026	-,488***	1	
12. Betweness Centrality (Cbetwenes)	-,210**	,273***	-0,169	,236**	,208**	0,011	-0,125	0,073	0,045	,412***	-,368***	1
Obs.	116	116	116	116	116	116	116	116	116	116	116	116
Mean	53,42	0,45	2,16	7,67	8,53	3,87	2,52	0,87	2,25	3,45	1058,83	185,76
Standard deviation	41,83	0,50	1,14	5,71	3,85	1,47	2,55	1,51	3,17	2,29	292,34	448,88

*** $p<0,01$ and ** $p<0,05$

Knowledge of local rice production and processing innovations

Tables 3 shows the knowledge level of rice production and precessing innovations in the study area. It reveals that introduced rice production innovations are less known by stakeholders we interviewed. On average, 44% of rice producers are aware of at least one NERICA-L group of improved varieties. This rate is lesser concerning weeder and tresher-cleaner known respectively by 14% and 13% of interviewees. As for wheels to seed rice, it is known in average by 28% of rice producers. 49% of the interviewees are aware of the paddy winnower. Besides, the level of post harvest innovations awareness is better. Therfore, an average of 45% of parboilers states they have informations about paddy winnower while 52% for parboiling equipment. These rate are higher regarding milling machine and drying area which are known respectively by 78% and 81% of interviewed parboilers.

Table 3. Knowledge of local rice production and parboiling innovations

Innovations		**Knowledge**	
		Count	**Percentage (%)**
Rice producers (n=244)			
Improved varieties	Yes	107	43,90
	No	137	56,10
Weeder	Yes	35	14,30
	No	209	85,70
Wheels	Yes	67	27,50
	No	177	72,50
Tresher-cleaner	Yes	32	13,10
	No	212	86,90
Winnower	Yes	119	48,80
	No	125	51,23
Rice parboilers (n=116)			
Winnower	Yes	52	44,83
	No	64	55,17
Parboiling equipment	Yes	60	51,70
	No	56	48,30
Milling machine	Yes	90	77,60
	No	26	22,40
Drying area	Yes	94	81,00
	No	22	23,28

Determinants of knowledge of rice innovations

The results of the estimation of the factors that determine the knowledge of production and processing innovations show that the models are globally significant at the 1% level (*prob> chi2 = 0.000*) indicating that all the coefficients of the explanatory variables are not simultaneously zero (Table 4 and Table 5). Otherwise, there is at least one coefficient that can discriminate producers or parboilers who know the innovations of those who do not. Similarly, the results indicate a satisfactory predictive power of the estimated models. The overall predictive capacity of the models varies between 80 and 96% for the production innovations and 82 to 94% for the processing innovations. These statistics therefore reveal that the models correctly predicted access or not to information related to rice innovations by producers and rice parboilers. Moreover, the quality of discrimination of the models is globally appreciable. In all estimated models, the range of ROC curves (area between the curve and the coordinate axes) ranges from 0.88 to 0.99 for production innovations and from 0.91 to 0.99 for processing innovations, thus reflecting exceptional discrimination. The statistical tests thus presented show that the logit model is valid and that the results can be used to determine the factors that influence the knowledge or the diffusion of rice innovations in the study area.

Determinant factors of production innovations knowledge

Six models of knowledge were estimated concerning production innovations such as improved varieties, the rice weeder, the wheels to facilitate seedling, the tresher-cleaner, the winnower, and all the production innovations. The estimated Chi-square likelihood coefficients have a probability at the 1% level indicating that all models are statistically significant (Table 4). In addition, knowledge of all production innovations is explained at 48% by the explanatory variables (*Pseudo* $R^2 = 0.48$). The most important variables are the number of contacts in the producer's rice social network (ß = 0.38, $p < 0.01$), the distance from the respondent's home to the closest IP (ß = -0.04, $p < 0.05$) and the density of strong ties in the network (ß = -0.49, $p < 0.1$). The more relations the rice producer has, the easier he has access to information and therefore a high likelihood of knowing all the rice innovations diffused. This chance increases if he/she is located near an IP. However, the negative sign of the coefficient of the variable *Lienfort* shows that the stakeholder's relations is based more on friendly and family ties implying a form of redundancy of the information he receives.

The transversal analysis of the production innovations models indicates that knowledge of improved varieties by rice producers is positively affected by the number of contacts cited and the *out degree* centrality ($p < 0.01$) and then membership to an IP ($p < 0.05$). This knowledge is negatively correlated with the proximity of the producer to an IP ($p < 0.01$), the network of influence (number of influents cited), the high density of the network (number of contacts with strong ties) and the closeness centrality ($p < 0.1$). These variables account for 37% of knowledge of improved varieties. As for the weeder, his knowledge is positively influenced by the membership of the IP, the experience in professional organizations and the number of contacts mentioned ($p < 0.01$) and then the producer *out degree* centrality ($p < 0.05$). The distance of the producer from the IP ($p<0.01$), the knowledge network, the number of influential contacts with which the producer has strong ties ($p<0.05$) negatively determine the knowledge of the weeder by the respondent. As for the wheels, its knowledge depends positively at 1% level on membership to an IP, the relational force of the producer and his/her central position in the rice network. While the network of influence ($p<0.01$), proximity to IP, and the producer knowledge network ($p<0.05$) have a negative effect on access to information on wheels. Indeed, influential people in the social network of the producer could constitute its potential sources in technical support (exchanges of knowledge). However, these people induce a form of asymmetry thus reducing the access to information. Concerning the tresher-cleaner, its knowledge by rice producers is positively influenced by membership in the IP, the number of contacts cited (*p <0.01*), the number of years spent in organizations (*p<0.05*) and the number of social organizations that he/she belongs to (*p<0.1*). On the other hand, the network of influence and the producer's central position (*p<0.01*), the betwenness centrality and the distance of the producer from the IP (*p <0.05*) the density of his/her social network (*p <0.1*) negatively determine his/her knowledge of innovation. It should be noted that the tresher-cleaner is recently introduced into the study area by local artisans who are the manufacturers. The source of information and the mode of introduction of this innovation are not favorable to the knowledge of the "bridges" stakeholders who maintain very little relationship with these manufacturers. Finally, the factors that positively influence producers' knowledge of the paddy rice winnower are IP membership and experience in professional organizations (*p<0.01*), number of contacts based on exchange of information (*p<0.05*) and the relational force of the producer (*p<0.1*). While the producer's central position in the rice network (*p<0.01*), the producer proximity to an IP, his/her network of influence (*p<0.05*), and the respondent's betweness position (*p<0.1*) have a negative influence on the knowledge of the paddy rice winnower. These variables account for more than 80% concerning the knowledge of innovation by rice producers in the study area.

Tableau 4. Estimation models for production innovations knowledge

Variables	Improved varieties	Weeder	Wheels	Tresher-cleaner	Winnower	All the innovations
Mbrpi	0.93**	3.35***	1.53***	4.81***	7.82***	
Distpi	-0.02***	-0.03***	-0.02**	-0.05**	-0.03**	-0.04**
Nbrop				0.74*	0.94**	
Expop		0.17***		0.16**	0.21***	
Nbinflu	-0.30*	-0.67*	-0.93***	-1.50***		
Apuitech		0.34*	-0.37**		-0.55**	
Einform					0.34**	
Lienfort	-0.14*	-0.13*		-0.23*		-0.49*
Nbcont	0.17***	0.35***	0.28***	0.44***	0.07*	0.38***
Cdegree	0.31***	0.23**	0.26***			
Cclosenes	-0.00*			-0.01***	-0.01***	
Cbetwenes				-0.00**	-0.00*	
Constance	-3.64***	-2.24	1.11	8.24**	16.63***	-2.27
Pseudo R^2	0.37	0.48	0.36	0.49	0.82	0.48
Wald chi2	118.72***	72.43***	68.51***	62.42***	257.15***	33.53***
Observations	232	232	212	229	233	244

*** significant at 1% (*p<0.01*) ** significant at 5% (*p<0.05*) * significant at 10% (*p<0.1*)

Determinant factors of processing innovations knowledge

Table 5 presents the the models estimates concerning the knowledge of the winnower, the improved parboiling equipment, milling machine, drying area , same as all the processing innovations used in rice parboiling. The results show that the Wald Chi2 is statistically significant at the 1% level, indicating that the coefficients of the models are jointly significant and that the explanatory power of the variables included in the model is satisfactory. The knowledge of all post-harvest innovations is explained by 80% of the variables introduced in the model. The factors that positively determine this knowledge are related to the relational force (*p<0.01*), membership of the rice IP (*p<0.05*) and the number of social organization that the rice parboiler belong to (*p<0.1*). Otherwise, the more the woman rice parboiler militates in social networks, the more she strengthens her contacts and the greater the likelihood of knowledge of innovations. On the other hand, the position of isolation or autonomy of the woman rice parboiler, translated by the closeness centrality (*p <0.05*) added to the high density of her networks fostered by strong ties (p <0.1), exert a negative influence on the knowledge of all innovations.

Tableau 5. Estimation models for parboiling innovations knowledge

Variables	Winnower	Parboiling equipment	Milling machine	Drying area	All the innovations
Mbrpi	4.56***	3.22***		1.89*	9.36**
Distpi	-0.05***	-0.04**	-0.04***		
Nbrop		0.82**			1.64*
Expop	0.17**	0.16*		0.32***	
Nbinflu	-0.76**				
Apuitech	1.42***	0.62*			
Einform	0.25*	0.34*	1.16***		
Lienfort			-0.60*	-0.27*	-0.71*
Nbcont	0.39**			0.28**	0.92***
Cdegree		0.51**			
Cclosenes	-0.01**	-0.00*		-0.00*	-0.05**
Cbetwenes	0.00*	0.02**			
Constance	-0.80	-1.27	0.91	0.91	23.67*
Pseudo R^2	0.60	0.61	0.561	0.432	0.80
Wald chi2 (12)	86.88***	94.07***	56.59***	50.52***	104.22***
Observations	107	111	109	113	112

*** significant at 1% (*p<0.01*) ** significant at 5% (*p<0.05*) * significant at 10% (*p<0.1*)

Specifically, knowledge of the winnower by the women rice parboilers is positively influenced by the membership of an IP and the number of contacts they have with technical support (*p <0.01*), experience within professional organizations and the number of contacts mentioned (*p <0.05*), the information network and the betweness centrality (*p<0.1*). This shows that the woman rice parboiler who occupies a betweness position within her networks rich in exchange of information and knowledge has a strong chance of knowing the winnower. Whereas, the distance to the nearest IP (*p<0.01*), the network of influence and the closeness centrality (*p <0.05*) have a negative impact on the knowledge of the winnower by the parboilers. Concerning the improved parboiling equipment, its knowledge is positively influenced by whether the stakeholder belongs to an IP (*p<0.01*), the number of social organizations to which the rice parboiler belongs, the central or betwenness position in the social network (*p <0.05*) and then within the professional organizations, the stakeholders knowledge and information network (*p<0.1*). Factors such as distance from the IP (*p<0.05*) and closeness centrality (p <0.1) have a negative effect on the knowledge of this rice innovation. Moreover, knowledge of the milling machine is negatively influenced by the distance of the rice parboiler compared to the nearest IP ($p<0.01$) and the high density of her social network characterized by strong ties ($p <0.1$). Only the satkeholders' information network had a positive effect ($p <0.01$) on her knowledge of the milling machine. Finally, the knowledge of the drying area is positively correlated with the experience of the rice parboiler within the professional organizations ($p<0.01$), its relational strength ($p <0.05$) and its membership in the IP ($p<0.1$). Conversely, the central position in the rice social network and the number of strong ties (p <0.1) negatively influence the knowledge of the drying area by the women rice parboiled surveyed.

Discussion

This research applied social network theory to analyze and understand the diffusion of innovations. Based on social dynamics and interactions, we assess in this paper, how relational force or the relational potential combined with social capital can determine access to information related to innovations in local rice value chains. The empirical results show that the relational resources integrating social capital constitute corridors of transmission of information and knowledge useful for the decision-making for rice stakeholders. Also, the position of the rice producer in the social network influences his/her access to information concerning innovations. These findings reinforce earlier works which argue that social networks appear to be a main vehicle for information on agricultural technologies (Beaman and Dillon, 2014; Amisse, 2011, Suire and Vicente , 2008). The IP membership effect on the knowledge of the improved technologies introduced was perceptible. Indeed, there is a wide gap between the knowledge of innovations by rice producers and processors members of IPs and those who are not IP members. The membership of an IP is positively and strongly correlated with the knowledge of 7 out of 9 technologies whose models are estimated. It appears that membership provides an opportunity for rice producers or rice parboilers to participate regularly in research and development activities or the promotion of improved technologies. This exposes stakeholders to information and knowledge about innovations as close as possible they are to the sites where the IP activities are carried out. On the other hand, belonging to the same network favors communication externalities (Torre, 2009) that emerge from the direct interaction between individuals who have opportunities to exchange information (Vicente, 2005). Similarly, Lançon (2010) argues that IPs appear to be a nursery favorable to innovation, and the diffusion of these innovations generated either from outside or inside networks. In addition, social learning occurs most effectively through joint problem solving and reflection, sharing experiences and ideas within learning networks. This collaboration implies vertical ties between the different levels of the organization and the horizontal ties between stakeholders (Berkes, 2009). This information exchange can result from the collective interactions that farmers have with organizations leaders.

Obviously, the information network of farmers as in the number of contacts based on the exchange of information has an expected sign coefficient for some estimated models. The knowledge is not merely external, but it circulates through networks of exchange (Suire and Vicente, 2008). And we saw that the innovations knowledge rates recorded in villages that are near IPs are generally much better than in remote villages. This trend is in accordance with the negative sign observde in all the estimates models. In other words, the more a rice farmer moves away from IP, the less he/she is exposed to information on innovations. While it is recognized that IPs are not abstracted at borders, it is clear that participation in IP meetings has a cost that none of the stakeholders (IP members) is willing to pay . This limits the integration and inclusion of farmers in the management of relevant informations and knowledges concerning their activities. Amisse (2011) and Ba et *al*. (2012) came to the same conclusion that geographic and relational proximity has a positive influence on the dissemination of informations.

This research also shows that the number of years in rice professional organizations is a determining factor of access to information on innovations (positively correlated with been aware of the innovations in more than 50% of the estimated models). Indeed, the seniority of rice producers or rice parboilers in professional organizations gives them a certain opportunity to participate in activities organized for local rice value chains stakeholders. In this situation, they interact with a large number of stakeholders and are therefore more exposed to information. The underlying idea is that individual behaviors and the results from the interactions are correlated with stakeholders' experiences (Amisse, 2011, Steyer and Zimmermann, 2004). Similarly, individuals generate their own state on the basis of signals they received from the social environment and in turn pass on to the environment a reflection of they their state (Steyer and Zimmermann, 2004). Their innovative or conservative character, their favorable or unfavorable judgment on innovation determines the results of the diffusion (Ba et *al*., 2012). In addition, this experience reinforces the stakeholder status in terms of resources from personal knowledge. Firstly, these resources can serve as a support for negotiation or creation of links favorable to access to information. Secondly, based on acquired resources, the farmer has a technical production potential that could be decisive for the innovation or knowledge of new technologies. Due to his/her notoriety, the stakeholder having a proven experience in the professional organizations is a source of information or reception of information for their network members. Similarly, Vernette et *al*. (2012) argued that some individuals interact more than others and / or have a different status that allows them to exert a potential influence on their environment.

In this register, the negative sign displayed by the variable "number of strong ties contacts" in most models reinforces the assumption that information flow is facilitated by the presence of weak ties. Indeed, strong link networks convey redundant information that is not conducive to the diffusion of innovations (Burt, 2000; Del Vecchio, 2010; Callois, 2005; Granovetter, 1973). The more isolated producers, parboilers and their partners, the better the situation: the information and control advantages get accumulated and reinforced (Burt, 1992). On the contrary, resources (trust, visibility, solidarity) coming from the dense networks would improve the informal flow of information and the exchange of knowledge between stakeholders and would undoubtedly have a positive impact on the diffusion process (Del Vecchio, 2010; Saglietto et *al*., 2013). Sometimes these resources may be hindered by conflict of interest situations within social networks. In any case, the apparent density of rice networks is not favorable to the diffusion of innovations.

Moreover, the number of contacts mentioned (*in degree* centrality) by rice parboilers and especially rice producers has a positive and significant influence on the knowledge of introduced innovations. The more respondants are in contact with other stakeholders in their network, the greater the likelihood of being informed by one or the other. Also by diversifying their network (number of contacts), the stakeholders are likely to know at least one of the technologies. Indeed, where the influence of an individual is insufficient to bring about change, the cumulative influence of his/her social environment may allow it (Steyer and Zimmermann, 2004). For these authors, the effect of cumulative influence has important consequences on the social structure and therefore on the potential of diffusion. Moreover, Forsé (2008) indicated that the interactions between stakeholders of a social network influence the diffusion of innovations in general. However, relational wealth alone does not constitute social capital, and the structural characteristics of relationships matter (Saglietto *et al*., 2013). In other words, the position of the stakeholder in the social network is also decisive in access to information. Thus, the *out degree* centrality which expresses the number of times that the actor is mentioned by his peers, shows a positive sign with sometimes a remarkable significance. It means that the ones centrality position within their social network have a decisive effect in the diffusion of rice innovations. This findings agrees with Steyer and Zimmermann (2004) who argue that the success of the diffusion process in a non-homogeneous social structure context is determined by the position of initial adopters. This is reflected in the degree of the rice producers' popularity in the social network. His contact with a large number of other actors induces its exposure to information concerning innovations. Vernette *et al.* (2012) came to the same result when they asserted that the central position of a stakeholder constitutes a motor for accelerating the contagion effect for the diffusion of a new technology. Similarly, Coleman (1966) showed in the medical field that the more or less centrality of doctors within their networks is the explanatory factor in the innovation diffusion process. This centrality is more decisive when the rice producer or parboiler finds himself in an intermediary situation. At this position, he/she is more exposed and controls a mass of information that strongly influences his knowledge of innovations. Otherwise, by placing itself between two unconnected stakeholders, the rice actor derives multiple competitive advantages: faster access to information, access to better information (because of its non-redundancy) and control over the diffusion (Burt, 1992; Fregean, 1979; Granoveter, 1973; Hoppe and Reinelt, 2010; Olivier de Sardan, 1995; Saglietto et *al*., 2013; Steyer and Zimmermann, 2004). The betwenness centrality is also an indicator of social contagion in the innovations diffusion process (Vernette et *al*., 2012). The possibility of information selection by the rice producers and parboilers who occupy this position is an opportunity to diversify their knowledge about innovations. In the context of the rice social network in the study area, which is characterized by very low density, closeness centrality is not a favorable indicator for the diffusion of innovations. Indeed, the actors who occupy this position in the network regard themselves rightly or wrongly as autonomous actors by privileging isolation to social integration (Freeman, 1979; Hanneman and Riddle, 2005; Müller-Prothmann, 2007) . This situation leads to a form of retention of information specific to innovations. The autonomy of thesestakeholders is a source of disinformation that is harmful to the diffusion of innovations because everything depends on how they communicate (Long et *al*., 2015) with their peers in the social network.

Limitations and further research

The construction of the relational matrices was done on the whole study area considered here as a homogeneous space where the exchanges between the actors are done 'normally'. This approach is justified by the fact that an IP has no geographical boundaries, at least in terms of its functioning. However, the effect of the distance between actors constitutes an obstacle to the development of links that would facilitate exchanges. This spatial heterogeneity of the rice social network thus constituted may explain the weak connection between stakeholders of the different local rice value chains. The other limit is related to the "name generator" approach used to constitute the social network of each rice farmer (Hermans et al., 2017, Löblich and Pfaff-Rüdiger, 2011, Butts, 2008). This approach calls to the stakeholder memory use to mention people with whom they have relations concerning rice production or processing. This assumes that the farmer is aware of or really remembers people who influence him/her in the decision-making process concerning innovation (Vernette et al., 2012). It is therefore not obvious that the interviewee make an exhaustive list of the contacts of his/her social network. It means that important and decisive contacts in the transmission of information or knowledge might be omitted. Therefore, it would be interesting to limit the collection of relational data on a smaller scale in order to consider all the relations of the sample and the intensity of these relations which could be also decisive in access to information.

The other limit concerns to the maturity of the innovation platforms, which were not implemented until 2014. As a result, the animation of these IPs dependent on the financing and the support of the project. Such situation induces some questionings. Do the functionning mode and governance of the various initiated IPs that are exclusively supported by a project ensure their viability? Is the post-project situation favorable to the interconnections between stakeholders for the diffusion of knowledges or informations on innovations? It is necessary to investigate these issues by testing our assumptions on IPs in an independence situation regarding their functioning. Future research may also focus on a comparative analysis of the influence of IPs that imanate from the "direct" stakeholders of local value chains and those "pushed" by development projects.

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