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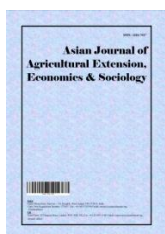
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How Communication's Channels Influence Diffusion of Eco-friendly Technologies? A Case Study of Sustainable Land Management Technologies' Diffusion in Benin, West Africa

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This article analyses the influence of communication channels in Sustainable Land Management (SLM) measures diffusion in Kandi and Savalou in Benin, West Africa. Data were collected among a sample of 18 farmers organizations' leaders and 301 producers applying implementing these technologies since two years at least. Descriptive statistics, Pearson Chi-2 and t student statistics were used via R.3.5.2 software to analyze data. Results show that formal and informal communication channels are used to disseminate SLM measures. The type of channel does not significantly influence the number of producers reached and those implementing SLM measures. Farmers organizations leaders play an important role in the process of SLM dissemination according to their status within organizations. Take into account both informal and formal communication channels and role played by opinion leaders can better contribute to increase awareness of land management technologies innovations introduced in rural areas and their diffusion at large scale.

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1. INTRODUCTION

In Benin, agriculture sector is considered as a strategic tool to achieve economic and social development. It represents 75% of exportations and contributes for 33% to Gross Domestic Product (GDP). The sector has a variety of agro-ecological areas that are still untapped, favorable to agriculture and which, when better used, can contribute to the effective fight against poverty [1,2] and [3]. Unfortunately, despite its potential in terms of land resources, the agricultural sector struggles to express its full performance. The yield are no longer proportional to the efforts made by different actors involving in agricultural development. Cropland is being depleted at an accelerated rate and crop yields are continually declining. This accelerates the process of soil fertility loss and endangers the productivity and sustainability of agricultural systems [4,5,6]. The severity of soil degradation varies across an agro-ecological zone and is one of the major constraints that hamper agricultural production [7] and thus compromises food and nutritional security ; Therefore, the need to preserve natural resources, particularly agricultural land by promoting sustainable and reproducible farming practices, has emerged as a priority in order to improve sustainably the productivity of crops.

Sustainable land management (SLM) is an approach with deals with the objective of land resources management for agricultural productivity improvement. It is defined as a comprehensive approach to obtaining long-term productive ecosystems taking into account biophysical, socio-cultural and economic needs and values. In other words, SLM is the adoption of land-use systems that enhance the ecological support functions of the land through appropriate management practices and thereby enable land users to derive economic benefits while preserving those of future generations. This is usually done by integrating socio-economic principles with environmental concerns in order to: maintain or improve production, reduce the level of production risk, protect the potential of natural resources, avoid soil and water degradation, be economically viable and socially acceptable [8] and [9]. SLM approach is based on techniques and tools adapted to changes in the components of the natural environment as well as users behavior [5]. In this context, different technologies have been promoted in

beninese rural areas through various initiatives. The Soil Protection and Rehabilitation for Food Security Project (*Projet de Réhabilitation des Sols pour la Sécurité Alimentaire: ProSOL*), one of these initiatives, is funded and implemented by German Development Cooperation. ProSol is promoting and popularizing technologies of sustainable land management, particularly in municipalities where cotton is the main crop cultivated one hand and where land is subject to a strong degradation on the other. Despite all efforts done to improve the restoration of farmland, low rates are recorded, not only in the adoption of these technologies, but also and especially in the transmission chain of these technologies [10]. An analysis of studies that examined the understanding of the phenomena of adoption of agricultural technologies in Benin reveals that most of researches focus mainly on factors explaining the low rate of technologies adoption [11,12]. Very little attention is given to the dissemination mechanism of these technologies and their adoption [13]. This process takes into account relationships not only, between a producer and an adopted technology, but also relationships of all producers between them and the adopted technology.

Given the essential role play in the flow of information in the adoption of innovation [14], communication channels appear necessary to study. Communication channels, considered as means by which information is transmitted from one person to another in a given social system [15], are distinguished into formal and informal channels. The importance of this analysis is due to the fact that communication channels or networks developed by local communities for the transmission of information in particular on agricultural technologies, can be used to disseminate information on SLM technologies at a large scale. Therefore, an association of communication channels implemented by development agency with those initiated by producers' communities, can be a key asset for a better dissemination of SLM technologies. So, this article aims at understanding how communication channels influence the diffusion of SLM technologies in the municipalities of Kandi and Savalou, two agricultural localities of in the North of Benin, facing the thorny issues of land degradation.

2. MATERIALS AND METHODS

2.1 Study Areas and Research Unit

Empirical data of the study were collected in Kandi and Savalou municipalities in Benin, West Africa. Located in the agro-ecological area of cotton production of north Benin, Kandi covers 3,421 km² and represents 13% of Alibori Department. It is characterized by a Sudanese-Sahelian tropical climate with a dry season up to seven (07) months. Being the second country of cotton production in Benin, Kandi is facing a strong soil degradation problem. In addition to crops production, Kandi is an excellent breeding locality with a constant evolution of cattle, small ruminants and poultry. Although the importance of livestock is a significant source of organic matter for sustainable soil fertility management, over-grazing contributes to increase a degradation of already very poor soils. As for Savalou, it is located in the Center of Benin and covers 2,674 km², representing 19% of Department of Collines. The economic of the Savalou is mainly based on agriculture and domestic livestock (goats, sheep, pigs, poultry) at large scale.

The research unit is constituted of producers followed by ProSOL in Kandi and Savalou and having implemented at least one SLM measure. These producers have at least two years experiences in adoption of these measures. On the base this criterion, 6 of the 15 villages of Savalou (Agbodranfo, Awiankanmè, Doyissa, Koutago, Naoudji, Zadowin) and 5 of 17 villages of Kandi (Angaradébou, Gambanè, Kassakou, Mongo, Padé) benefiting from ProSol activities were selected. In total, 151 producers were investigated in Savalou and 150 producers in Kandi. In addition, 18 opinion leaders on which 7 in Savalou and 11 in Kandi were interviewed. These leaders are persons representing farmers organizations and those chosen by ProSol to lead training classes.

2.2 Data Collected and Methods of Collection

Data were collected at producers and opinion leaders levels. At the producer level, data collected were relating to socio-economic and demographic characteristics, to farming system (access to agricultural land, type of labor used, financing agricultural activities, cropping system, cultural practices); SLM measures implemented, perceived advantages and disadvantages of

SLM measures and reasons for their use; strategies to be used for a wide dissemination of these measures, number of producers reached, channels used for disseminating information. At the level of opinion leaders, these data were complemented by leader's status in his organization, position and role in social groups, activities to promote SLM measures carried out, number of producers reached by opinion leaders, channels used for disseminating information, difficulties encountered in disseminating the measures, solutions developed. These data were collected with questionnaires and interview guides through structured and semi-structured interviews.

2.3 Methods and Tools of Data Analysis

Data collected were processed and analyzed using the R.3.5.2 software. The socioeconomic and demographic data were analyzed with parameters of descriptive statistics and the comparison test of two proportions (Chi 2 test). The relative frequencies were used to compare producers according to socioeconomic and demographic variables (age, sex, level of education, marital status, household size, etc.). As for communication channels used for the dissemination of SLM measures, they were listed and percent calculation is used to identify the types of channels mostly used. Two proportions comparison test using approximation of the normal law, was carried out for each SLM measure analyzed according to the municipalities, to determine the most widely used distribution channel (formal and informal channels). Two (2) fixed-factor variance analysis (ANOVA) was used to assess the effect of communication channels and municipalities on the number of producers reached and the number of producers having adopted SLM measures. Statistical test t of Student was used to assess the average difference between producers and leaders in terms of the number of people reached in the diffusion of measures process.

3. RESULTS

3.1 Socio-economic and Demographic Characteristics of Producers

Producers interviewed during the study are an average of 40±10 old years and are women in a relative majority (54%). Almost 95% of them are married with a low or without level of education. Among them, 74% are not educated; 13.62%

have primary school level; 11.63% secondary school level. They capitalize almost 24 ± 10 years of experience in agricultural production. Their households are relatively large with an average of 7.43 ± 3.81 persons. As for the leaders, they are mostly men (83%) with an average age of 46 ± 9.83 years. Most of them are married (89%) and relatively more educated than their peers producers: 44% have secondary school level and 6% primary school level.

3.2 Types of SLM Measures Adopted by Producers in Savalou and Kandi

SLM measures popularized by ProSOL can be classified into six (6) categories: (i) Integrated Soil Fertility Management (ISFM); (ii) Conservation Agriculture (CA); (iii) Water and Soil Conservation (WSC); (iv) Integrated Agriculture and Livestock Management (IALM); (v) Agroforestry and Individual Forests (AIF); and (vi) Climate Change Adaptation (CCA) (Table 1).

Table 1. Categories of SLM measures popularized by ProSol and adopted by producers

	SLM measures disseminated	SLM measures adopted	
		Kandi	Savalou
Integrated Soil Fertility Management (ISFM)	Management of crops' residues	x	x
	Bovine dung	x	x
	Growing leguminous plants (pigeon peas, mucuna, soya, aschynomene stylosanthes)	x	x
	Compost and animal manure	x	x
	Composting in piles, anaerobic with biogas extraction, vermicomposting		
Conservation Agriculture (CA)	Cultural Association	x	x
	Crops rotation and parcelling	x	x
Water and Soil Conservation (WSC)	Ploughing perpendicular to slope	x	x
	Technique of Zaï	x	
	Half-moon technique de demi-lune	x	x
	Green Teens		
	Drains of flood water drainage	x	x
	Fascins and Riprap		
	Filter bunds and stony cords	x	x
Integrated Agriculture and Livestock Management (IALM)	Installation of forage plots for livestock		
	Rotational parking of oxen		
Agroforestry and individual forests (AIF)	Rehabilitation of orchards	x	x
	Agroforestry based on moringa, gliricidia, enterolobium, Acacia, etc.		
	Fencing of fields with hedges	x	x
	Installation of Shelterbelts		
	Assisted Natural Regeneration		
	Private plantations with teak, gmelina, enterolobium and acacia		
	Time-spread seedlings	x	x
Adaptation to Climate Change (ACC)	Dry seeding		
	Early seeding in the shallows		
	Cultivation of drought tolerant plants	x	x

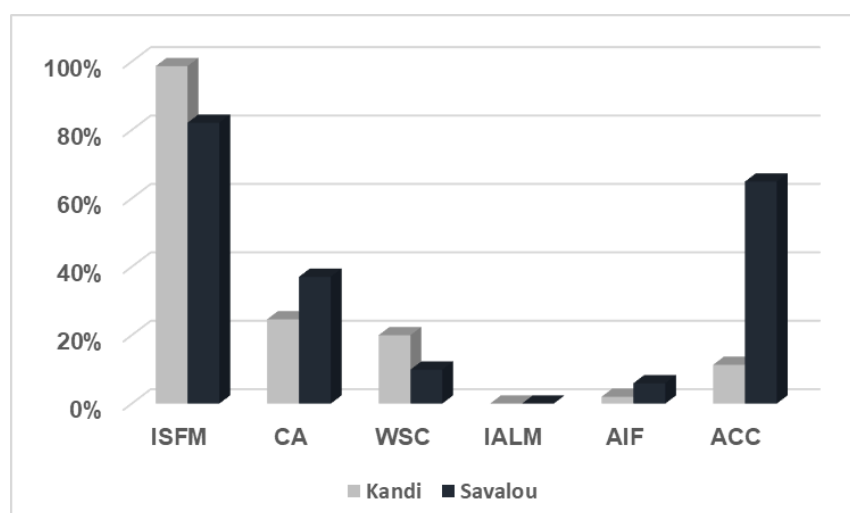


Fig. 1. Producers distribution according to SLM measures categories adopted in Savalou and Kandi

ISFM: Integrated Soil Fertility Management; CA: Conservation Agriculture; WSC: Water and Soil Conservation; IALM: Integrated Agriculture and Livestock Management; AIF: Agroforestry and Individual Forests; ACC: Adaptation to Climate Change

Five (5) categories of SLM measures are adopted by producers. However, the level of adoption varies greatly from one category to another and from one municipality to another (Fig. 1).

Overall, Integrated Soil Fertility Management (ISFM) measures are the most widely adopted by producers: 98.66% in Kandi and 82.11% in Savalou. The high rates in this category of SLM measures can be explained by the fact that these measures are the easiest and the most adapted to producers' agro-ecological conditions. As far as Conservation Agriculture (CA), the most crop associations observed are maize-peanut, maize-bean and maize- pigeon pea in Savalou, and maize-soya in Kandi. The highest adoption of Climate Change Adaptation measures in Savalou (64.9%) compared to Kandi (11.33%) is due to the fact that Savalou producers practice drought tolerant crops consisting mainly of cassava cultivation, a crop which the main processed product is called "gari", one of the specialty food of this region of Benin. The failure in Integrated Agriculture and Livestock Management (IALM) measures adoption is explained in Savalou particularly by the fact that the rearing is limited mainly to poultry and small ruminants and is done through divagation. As for Kandi, where IALM measures are expected to be widely adopted as a result of the rearing of large ruminants in this locality in Benin, the considerable distance between crops fields and

sites of organic material supply, explains the difficult to adopt these measures.

3.3 Communication Channels used to Reach Producers in the SLM Measure Adoption Process

In the process of SLM measures adoption, both formal and informal communication channels are used by ProSOL in Kandi and Savalou. The main formal communication channels implemented consist of training groups, support and advice to producers and radio broadcasts. Producers' trainings are conducted by field staff (recruited by NGO facilitators such as ALAFIA-NGO and ANaF-NGO) who, prior to their deployment on field, benefit from enhanced capabilities on communication and information tools designed and made available by ProSOL. These tools include training guides, picture boxes, technical sheets collection to facilitate the understanding of the various measures to be disseminated. In Kandi specifically, trainings are combined with radio broadcasts in local languages (*Batonu, fulubé, Monkolé and Dendi*) through local radio named "Kandi FM". The objective is to promote a collective awareness on state of environmental degradation illustrated by the decline in soil fertility, the low level of crop yield, etc. due to anthropogenic actions on the one hand and the need to undertake corrective actions to ensure better sustainable management of the environment on the other hand. As for informal

communication channels, they include informal discussions between individual producers, meetings within producers organizations, awareness-raising through public shouters and are used by producers in particular. Informal discussions take the form of occasional discussions and telephone calls. These channels promote a transfer of information to the rest of the population, a sharing of experiences between producers, problems encountered, approaches and ways to resolved them. The use of informal channels follows a logic of social proximity and it is based on affinities existing between producers. As consequence, these types of channels contribute to the reinforcement of social relations between producers and communication networks promotion. Discussions within groups are encouraged by the fact that producers belong to training groups set up by ProSOL on the one hand and to others existing producers organizations on the other hand. These producers' networks are platforms which allow stakeholders to have regular meetings to exchange and share information on SLM measures. The importance of these different channels in the dissemination of SLM measures varies from one locality to another and depends on the different categories of measures (Fig. 2).

Overall, formal communication channels are the main channels used for the dissemination of SLM measures in both Kandi and Savalou municipalities. Indeed, 60% % of the producers in Kandi, and 58.94% of producers in Savalou, access to information on SLM measures through ProSOL trainings while radio broadcasts, allowed to reach only 18% of producers in Kandi. Specifically, 69.33% of Kandi producers who are reached through formal channels and 66.22% of Savalou producers who are reached through this kind of channels adopted ISFM measures. Similarly 21.33%; 18%; 2.66% and 70.66% of producers in Kandi; 33.11%; 9.27%; 5.96% and 75.49% of producers in Savalou who adopted respectively the measures of Conservation Agriculture, Water and Soil Conservation, Agroforestry and Individual Forests and Agroforestry and Individual Forests, access to information through formal channels. Thus, the formal communication channels are those through which, most producers who have adopted SLM measures access to information on these measures. The comparison test of two proportions at the level of each SLM measure category using the approximation of the normal law reveals a significant difference between the proportions at the 5% threshold ($P<.001$).

3.4 Role of Producers in the Dissemination of SLM Measures within the Social System

Within a social system, producers represent important actors in the dissemination of innovations. In Kandi and Savalou, organizations meetings and informal discussions are the main communication channels used by producers (Table 2).

It appears that, while 88% and 75.49% of producers trained by ProSol in respectively Kandi and Savalou share information on SLM measures with their peers, about 12% and 19.20% of producers in respectively Kandi and Savalou do not share any information received. Moreover, in Savalou, meetings within producers groups constitute arenas through which almost 5.29% of the producers trained 7par ProSol exchange on SLM measures while in Kandi, no producer shares information through this channel. Thus, informal discussions are the channels most used by producers trained by ProSOL to disseminate information on SLM measures to other members of the social system. The proportion comparison test revealed a significant difference at the 5% threshold ($P=.001$ in Kandi and $P=.03$ in Savalou). According to the technical support agents, the predominance of informal channels and the lack of sharing of information would result from the fact that no requirement for the restitution of training content is made to producers trained by ProSOL. Since informal communication networks are linked to social relations, the sharing of information is based on a logic of social proximity and affinity between actors (kinship or friendship). As a result, the number of average producers reached by farmers in the process of information dissemination on SLM measures varies according to the communication channels used (Table 3).

In Kandi where only informal channels are used by producers, 22.21 ± 1.03 producers are reached per week by each producer formed by ProSOL. Among them, 10 reached representing 45.45% of producers implement SLM measures. In addition, in Savalou the average number of producers reached by each producer formed by ProSOL is 18.11 ± 1.12 and 15.13 ± 4.60 through respectively informal and formal channels. Among these producers, approximately 8.60 ± 0.54 (48%) reached through informal channels and 10.38 ± 3.53 (80%) reached through formal

channels, implement SLM measures. The type of channel used does not significantly influence the number of producers reached at $\alpha = 5\%$ threshold ($P=0.49$). However, informal channels are the most important with 18.11 ± 1.12 producers reached per week. But the type of channel used does not significantly influence

the number of producers implementing SLM measures at $\alpha = 5\%$ threshold ($P=0.41$). In short the communication channels used donot significantly influence the dissemination of SLM measures to reached producers in Kandi and Savalou municipalities.

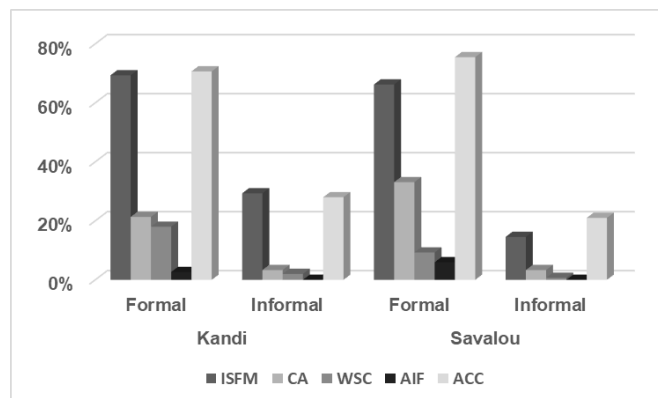


Fig. 2. Distribution of categories of SLM measures by type of communication channels used

ISFM: Integrated Soil Fertility Management; CA: Conservation Agriculture; WSC: Water and Soil Conservation; IALM: Integrated Agriculture and Livestock Management; AIF: Agroforestry and Individual Forests; ACC: Adaptation to Climate Change

Table 2. Channels used for information on SLM technologies dissemination within the social system

	Organizations meetings	Informal discussions	No information sharing
Kandi	-	88%	12%
Savalou	5.29%	75.49%	19.20%

Table 3. Average Number of farmers reached and SLM technologies adopters by types of channels

Channels		Number of farmers reached		Number of farmers adopters	
		Mean	Standard deviation	Mean	Standard deviation
Kandi	Informal	22.21	± 1.03	10.14	± 0.50
	Formal	0.00	± 0.00	0.00	± 0.00
Savalou	Informal	18.11	± 1.12	8.60	± 0.54
	Formal	15.13	± 4.60	10.38	± 3.53

Table 4. Average number of farmers reached by farmers organizations' leaders

	Number of farmers reached within groups		Number of farmers reached outside groups	
	Kandi	Savalou	Kandi	Savalou
President	21 \pm 2.08	32.5 \pm 2.5	11.33 \pm 0.67	11 \pm 1.00
Secretary	27.5 \pm 2.50	27.75 \pm 3.42	6 \pm 1.00	7 \pm 1.22
Organizer	22	-	5	-
Advisor	29 \pm 3.52	40	6 \pm 0.95	8

Note. Only one leader with organizer status in Kandi and only one advisor in Savalou was met in Kandi during the study

Overall, the leaders reach producers members of organizations more than producers not belonging to any organization. Moreover, opinion leaders with advisory and secretary status seem to impact more producers than those with president and organizer status; 29 ± 3.52 producers per leader in Kandi and 40 producers in Savalou. Indeed, leaders with status of president, not only, do not have enough technical information as advisers and secretaries but also do not have sufficient time to discuss with other members issues on SLM measures, due to the daily management tasks assigned to them.

4. DISCUSSION

Diffusion of innovations can be seen as the process by which an innovation spreads within a social group [16]. Four dimensions are sometimes considered to analyze diffusion process, including the innovation, the social system, the time and the communication channels. This study analyze communication channels focusing on formal and informal channels, interpersonal and masses channels, leadership and relational network. The Innovation is gradually communicated to the members of the social system through communication channels (mass media and interpersonal channels) and in this respect cannot be considered as an isolated phenomenon operating at the level of a single individual but a social fact which involves a whole range of actors belonging to a community.

According to [14], mass communication being a form of communication where the audience is a set of receivers that cannot respond through the same channel, it constitutes the fastest and the most efficient way to inform a broad audience of users of an innovation. This is in line with the results obtained in this study, in relation to the formal channels that enable the majority of producers to be informed on SLM measures disseminated. Therefore, it can be said that formal communication channels have a positive effect on the dissemination of innovations compare to informal channels. However, informal channels are more effective in persuading an interlocutor to adopt an innovation, especially since the context of communication brings together interlocutors who are peers or who share the same values. Thus they are more effective in dealing with the resistance of receivers because they allow an exchange of ideas in both directions and can allow interlocutors to form or modify attitudes deeply. The receiver can therefore obtain clarification

and more information about the innovation from the individual source. In view of the results obtained, formal and informal communication channels have no significant influence on the dissemination of SLM measures conducted by producers, but it is noted the informal channel has a positive effect on the diffusion of technologies. These results are in line with [17] who explain that the diffusion of innovation depends on interpersonal relations between farmers through proximity and neighborhood networks. [18] believes that the diffusion of an innovation is a process that takes place between individuals belonging to a social environment and whose interactions create situations of influence where the behaviors of some can be conditioned by others behaviors. This is due to the fact that innovation spreads through imitation, some individuals being inspired by the attitude of the early adopters.

One of the important questions to answer is if a precise identification of communication networks is necessary? Daily practice of dialogue lead structures or people involved to refine their contacts, to choose their interlocutors and to understand the networks that support formal relationships or voluntary organizations. In the case of Massaroca in Brazil, it is appeared that social relations being fairly well known by the technicians after eight years of intervention, the analysis of local networks showed that the intervention was not working on the right scale with the right interlocutors; researchers and technicians all have their blinkers [19]. Therefore, it is important to take an interest in the process of innovation translation [20] or innovation interpreting [21] and how it is appropriated. It would be necessary to meet all members of the studied social group and formulate very personal, even intimate, questions on the one hand and very nuanced on the other hand [22]. This would facilitate the precise and individualized qualification of interpersonal and intergroup relations.

Moreover, several theories have addressed the importance of leader role in the dissemination of innovations. With regard to the theory of the diffusion of innovations, it emphasizes the dual role of the leader, who is both a transmitter of information and an influencer. But it is important to point out that in the case of our study, interpersonal contacts are at the origin of leaders influence of on producers implementing SLM measures. This results is in accordance with [23] findings, who shows that the nature of

interpersonal contacts and the context of their realization have an impact on the scope of the message and therefore on the probability of a change in attitude or behavior. Similarly many authors like [24] and [25] demonstrate that people trust the information shared by opinion leaders on innovations. Thus, information shared by leaders to producers penetrates the minds better: knowing the person delivering the message is perceived as less intrusive, is interpreted as advice regarding measures and not as an obligation. These different ideas reflect the results of this study which reveals that opinion leaders are more influential in the diffusion of SLM measures in the study areas. Moreover, as shown by [26], the position of a leader within the dialogue network corresponds well to social status. This is reflected in the results of the study on the different numbers of people reached by opinion leaders according to their different status in their social groups.

In spite of the importance of opinion leaders in the process of innovations adoption, producers should not be viewed as followers and passive individuals but as individuals who are fully engaged in interpersonal communication [27]. Therefore, a leadership is not a one-way process; a dual mechanism of influence is in action [28]. In other words, opinion leaders would be influenced by others and should not be seen as dominant individuals who would influence a set of passive followers [29,30].

5. CONCLUSION

Formal and informal communication channels have enabled producers to be informed about SLM measures and to implement them, both in Kandi and Savalou level. However, formal communication methods are the most widely used and informal communication channels are more important in Kandi compared to Savalou. Concerning the influence of communication channels on SLM measures dissemination, the channels used do not significantly influence the dissemination of these measures. However, informal channels are the most important used by producers to share information on SLM measures among the social system. This type of channel is therefore not to be overlooked and must be more taken into account in the dissemination of innovations, particularly in a context of sustainable soil management. In addition, leaders with their position within producers organizations share information with the rest of the actors who are not enrolled in the

ProSOL system, despite the fact that this activity is not included in criteria of this system. They contribute to the dissemination of SLM measures according to their different status and enable a significant number of producers to be reached in their community. As a result, leaders play important roles in raising awareness of innovations in rural settings and are, therefore, to be taken into account in scaling-up initiatives for SLM measures and in general technological innovations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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