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Innovation and the Diffusion of Technology in Agriculture in Floodplains in the State of Amazonas

Inovação e Difusão de Tecnologia na Agricultura de Várzea na Amazônia

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Resumo

A literatura sobre a inovação e a difusão de tecnologias no agronegócio é vasta e a explicação dominante para a disseminação de inovações enfatiza o processo de influência e fluxo de informações através de um sistema social. Questões de pesquisa relativas à inovação e difusão de tecnologias ultrapassam os limites disciplinares convencionais. Este artigo tem como objetivo investigar a inovação e a difusão de tecnologias no contexto da agricultura em áreas de várzea no interior do Estado do Amazonas. Um conjunto de proposições foi desenvolvido com foco nos fatores que influenciam na concepção do processo de inovação e difusão. Através de uma pesquisa qualitativa, foram feitas entrevistas semiestruturadas. Os estágios de análise do processo mental de difusão não determinam a adoção de inovação na presente pesquisa. Os resultados sugerem que o ambiente competitivo do lado da oferta, bem como a influência das indústrias de agronegócio, assistência técnica, agenda política de desenvolvimento, projetos universitários e prática de campo podem favorecer a difusão de tecnologias. O artigo busca ampliar o atual paradigma na compreensão de inovações e na difusão, incorporando fatores operantes em um contexto peculiar de agricultura, sugerindo elementos que, se estimulados, podem ser comunicados e assimilados dentro de um sistema social.

Palavras-chave: inovação e difusão de tecnologias; adoção de tecnologias; produção agrícola de povos ribeirinhos; agricultura de várzea; Amazônia – Brasil.

Abstract

There is a vast literature on innovation and diffusion of technology in Agribusiness. The dominant explanation of dissemination of innovations emphasizes processes involving information flows through a social system. Research questions on innovation and diffusion of technology transcend conventional disciplinary boundaries. This article's objective is to investigate innovation and diffusion of technology in the context of agriculture in floodplains in provincial Amazonas, Brazil. A set of propositions were defined, focusing on factors that impact on the conceptualization of the process of innovation and diffusion. A qualitative research approach was employed, based on semi-structured interviews. In this study, the analytical stages of the mental process of diffusion do not determine adoption of innovation. The results suggest that the supply-side competitive environment, in conjunction with the influence of agribusiness, technical support, a development-oriented political agenda, university projects, and practices in the field can facilitate diffusion of technologies. This paper seeks to extend the current paradigm of understanding of innovations and diffusion, incorporating factors that apply in a specific agricultural context, suggesting elements that, if stimulated, can be communicated and assimilated within a social system.

Keywords: innovation and technology diffusion; adoption of technology; agricultural production by riverine people; agriculture in floodplains; the Amazon – Brazil.

JEL Code: O32, O33, N56.

Introduction

The managers of the small-scale agricultural areas that are characteristic of family farming face an increasingly dynamic and complex decision-making scenario. This ever-increasing complexity demands a range of different innovation tools for decision-making in an ever-more challenging environment (Fisher, Norvell, Sonka, & Nelson, 2000). Studies of diffusion of innovations in agriculture have their roots in sociology and go back to a study of the diffusion of hybrid seed corn among the farmers of Iowa, a state in the United States' Midwest (Ryan & Gross, 1943).

The characteristics of the agricultural business environment increase the degree of complexity even more, beginning with the seasonal nature of agriculture. Very often, the results of decisions to adopt new practices are not immediately evident. The results of decisions related to planting and use of chemicals generally take months or even years to materialize and the same is true of investments, new technologies, new supplies, and new seed. Nevertheless, innovation is seen as one of the primary drivers of productivity, profitability, and competitiveness for family agriculture practiced by small-scale farmers (Organisation for Economic Cooperation and Development [OECD], 2013), which, in turn, casts diffusion and adoption of agricultural innovation as important measures in agricultural development (Peshin, Vasanthakumar, & Kalra, 2009).

Research in the area has investigated the technological changes that have taken place in agriculture over recent years because they have a decisive role to play in meeting future demand for agricultural produce (Dietrich, Schmitz, Lotze-Campen, Popp, & Müller, 2014; Hertel, Baldos, & Mensbrugghe, 2016). The rapidly-changing technological scenario tends to influence small-scale farmers, who sometimes find it difficult to assimilate both the technology and the business models of the economic system. Despite such difficulties, agricultural innovation has shown a strong correlation with increased agricultural production (Runge et al., 2003). Increases in agricultural production have resulted from technological changes driven by investment in research and development (R&D) (Dietrich et al., 2014).

The literature on innovations in agriculture is diverse and has developed its own vocabulary. One line of research investigates creation of innovations (Adenle, Manning, & Azadi, 2017; Kassie, Teklewold, Jaleta, Marenya, & Erenstein, 2015; Pound & Conroy, 2017), while another avenue focuses on promotion of adoption and implementation of innovations in agribusiness (Kassie et al., 2015; Morrone, 2017; Petry & Machado, 2014). This is an area of investigation that makes distinctions between innovations that are incorporated into goods or products such as tractors, fertilizers, seeds, and other supplies. In counterpoint, there is another investigative approach that deals with promotion of rural innovation, for example, programs for promotion of integrated pest management, technical training, fieldwork days, technical meetings, and technical visits, i.e., programs founded on investment in promotion and diffusion of rural innovation (Morrone, 2017; Sunding & Zilberman, 2002). However, intensification of generalized adoption of innovations without technical supervision and/or support from specialized public bodies can have negative consequences, such as depletion and contamination of the water table and degradation of soil fertility (Kassie et al., 2015).

Adoption and diffusion of agricultural technologies comprehend a certain degree of complexity in the decisions taken by small-scale farmers. To a certain extent, the complexity lies in the lack of certainty with relation to the benefits of such technologies before they are adopted. Farmers who are potential adopters and those who have already adopted find out about these benefits through a process of feedback of information to which they have access because they are part of a community. Learning about the benefits of technologies has an influence on the process of adoption of these technologies. The process of diffusion takes place through adoption of technologies by members of the community; therefore, the decision to adopt a new technology is based on the potential results achieved by the adopter (Fisher et al., 2000; Noltze, Schwarze, & Qaim, 2012).

Empirical evidence shows that farmers learn about new technologies after adoption of these new technologies by their neighbors (Bandiera & Rasul, 2006; Munshi, 2004; Pratiwi & Suzuki, 2017; Suri, 2011). The literature also shows the importance of social learning after adoption of a new technology. Adoption and diffusion of technologies in agriculture are processes of social learning (Feder & Umali, 1993). Empirical evidence

also shows that adoption of innovations in agriculture reaps greater financial gains and greater productivity from the area under cultivation, especially through reduction of wastage of supplies and utilization of new practices and/or technologies (Coromaldi, Pallante, & Savastano, 2015; Petry & Machado, 2014; Teklewold, Kassie, Shiferaw, & Köhlin, 2013) and also leads to greater financial returns (Khonje, Manda, Alene, & Kassie, 2015; Manda, Alene, Gardebroek, Kassie, & Tembo, 2016). A study by Petry and Machado (2014) investigated the process of diffusion of innovations in agriculture in the green belt of greater Florianópolis, Brazil. However, agricultural areas cultivated by ribeirinhos (traditional peoples living near rivers) who live in the provincial areas of the Brazilian state of Amazonas have not been investigated. There is, nevertheless, a need to understand how the process of innovation and diffusion of farming technologies takes place in the context of ribeirinho farming populations living along the rivers in the interior of Amazonas and to investigate whether such a process of innovation and diffusion actually takes place at all. Adoption of new agricultural technologies is a phenomenon that remains poorly understood (Bandiera & Rasul, 2006; Conley & Udry, 2010; Pratiwi & Suzuki, 2017), which leads us to pose the following research question: what factors prompt floodplains farmers to adopt a new agricultural technology?

The objective of this article is to provide evidence on innovation and diffusion of technologies in a floodplains agriculture setting and its relationship with floodplains farming practices in the Alto Solimões region of the state of Amazonas. This will help us to determine the true social effects of adoption of innovations (technologies) by farmers in floodplains areas located along the rivers in the Alto Solimões region. Evaluation of the adoption of technological innovations into the farming practices employed in floodplains areas can provide suggestions for design of agricultural policies dealing with projects for rural development and of public policies focused on these isolated communities.

Including this introduction, this paper is divided into five sections. Section following is devoted to the conceptual structure and explanation of the agricultural system. Later section discusses the methodological decision that informs this study. In the later section presents the analysis and discussion of the data and is followed by the Final Comments and the bibliographic references.

Theory and Proposals

Agricultural innovation and diffusion

The concept of innovation is normally associated with a new combination of existing knowledge and resources (Fagerberg, Fosaas, & Sapprasert, 2012). In the context of agriculture, innovations are related to increasing production of food, improving the quality of products, cultivation conditions, and production processes (Van Der Veen, 2010).

The theory of diffusion, which deals with the process of innovation and development (Rogers, 2003), is the theory that provides the principle foundations for understanding diffusion in agriculture (Peshin et al., 2009). Its theoretical assumptions play a central role in the practice of rural extension as a vehicle for diffusion of agricultural innovations globally (Roling, 1988). The theory of diffusion provides an adequate explanation of the relationship between technological innovations and social relations. Diffusion is the process by which an innovation is communicated within a social system. It consists of a mental process of acceptance of an idea or new practices which passes through stages of awareness, interest, evaluation, trial, and adoption (Beal & Bohlen, 1957). The theory understands innovation as diffusing through a social system by means of its adoption by individuals and groups (Peshin et al., 2009).

This subject has attracted considerable attention from economists and researchers interested in agriculture in developing economies (Carrer, Souza, & Batalha, 2017; Feder, Just, & Zilberman, 1985; Noltze et al., 2012). Investigations into diffusion of innovations have a long history in sociology, going back to an initial study of diffusion of hybrid seed corn among farmers in Iowa (Ryan & Gross, 1943). In that study, the researchers found

that the rate of adoption of agricultural innovations followed an S-shaped curve over time – the S-shaped curve describes the self-limiting growth of a population, inducing correct measurement of the growth process to quantitatively identify natural growth and reveal the upper limit of growth and the growth slope (Kucharavy & De Guio, 2011). The study contributed to a definition of diffusion of technology in agriculture in developed settings (Rogers, 2003).

Rogers (2003) defines diffusion as a process through which innovation is disseminated over time among the members of a social system. In agriculture, it is when farmers use their neighbor's experience to guide their decision-making (Bala & Goyal, 1998; Mühlenbernd, 2011). Diffusion requires that farmers are educated for adoption and must take account of their requirements, perceptions, restrictions, objectives, and complex demands (Peshin et al., 2009). A farmer's final adoption is defined as the degree of utilization of a new technology when a long-term equilibrium is reached and occurs when the farmer has sufficient information and is convinced of the new technology's potential (Feder et al., 1985). This, therefore, is how an innovation is accepted and diffused (Rogers, 2003).

In Indonesia, Pratiwi and Suzuki (2017) investigated the effects that farmers' social networks have on knowledge acquisition. Their empirical study found that technologies are transferred via information sharing during social interactions. The bonds between farmers in the community, in the neighborhood, is what determines their capability to acquire information. The social situations that affected information acquisition abilities were friendship networks, counseling, and formal training meetings in exemplary cultivation areas. Pratiwi and Suzuki's (2017) conclusive results showed that educational trips to exemplary cultivation areas, when several farmers were brought together at a single property, were associated with the best learning results, whereas networks of friendship ties were not as important for diffusion of technologies, while also showing that a person's position in their local community was strongly related to their ability to request and access information.

An empirical study conducted in the North of Mozambique by Bandiera and Rasul (2006) found an ambiguous relationship between decision and adoption of agricultural technologies. The same study also found evidence about how farmers' decisions to adopt a new technology is related to the adoption choices of their family and friendship networks. Their results revealed an inverse, U-shaped relationship. They suggested that social effects are positive while the number of adopters in the network is small and negative when there is a large number of adopters. They concluded that the technology adoption decisions of farmers who have better information are less sensitive to the adoption choices of producers who do not have the technology and also that technology adoption decisions are more correlated with the influence of the family and of friends than of religious networks and individuals of different religions who encourage diffusion of agricultural technologies.

The relationship between the effects of training farmers and knowledge acquisition was tested by Yang et al. (2008), observing pest management in vegetable farming in the Yunnan province in China, from 2003 to 2007. The results of that study showed that small-scale farmers achieved significant gains in knowledge about pest control when trained in the field, whereas there were no significant improvements in knowledge among farmers trained conventionally with lectures in the classroom. Field trips and training in the field enabled the farmers to acquire simple and complex knowledge. In contrast, the group of farmers trained in the classroom with lectures only mastered simple notions.

These studies appear to converge on the understanding that diffusion requires a strategy planned to transmit knowledge, skills, and active learning to achieve effective adoption of this knowledge and skills by farmers (Peshin et al., 2009).

Access to information related to agricultural knowledge is essential to develop farmers' capacity to maintain and increase agricultural productivity (Pratiwi & Suzuki, 2017). The way in which societies are organized and how they interact socially can impact on diffusion of technologies and agricultural productivity (Conley & Udry, 2001). The greater the interaction between community leaders and other individuals in the local agricultural community, the more it would be expected that knowledge will be diffused. Additionally, it is expected that official programs or other mechanisms for interchange of knowledge and research organs and technical support agencies act as intermediaries, facilitating dissemination of knowledge (Spencer, 2008).

In general, the ribeirinho communities whose leaders are more active, interacting widely with other farming communities and seeking out agricultural knowledge and innovations, contribute more to knowledge diffusion than less active communities. Nevertheless, communities involved in official programs or other knowledge exchange mechanisms may have a greater propensity for knowledge diffusion. In view of the above, the following propositions are proposed:

Proposition 1: The greater the involvement of ribeirinho community leaders in associations for promotion of agricultural development, the greater will be the innovation and knowledge diffusion in the community over the long term.

Proposition 2: The more integrated the exchange mechanisms for promotion of agribusiness are with the ribeirinho communities, the greater will be the adoption and diffusion of farming practices by the ribeirinhos over the long term.

Proposition 3: Exposure of rural ribeirinho communities to knowledge through the effects of demonstration, the effects of local ties, or effects originating in the external context brought about by companies, projects, and technical support organizations, will increase the level of adoption and diffusion of technologies in the adoption setting.

Understanding the agricultural system in Brazil and the Alto Solimões region

In Brazil

In 2016, Brazil's Gross Domestic Product (PIB) from agriculture grew by 4.48% (Centro de Estudos Avançados em Economia Aplicada [CEPEA], 2017). Despite the recessionary scenario that the country was facing, Brazilian Agribusiness exported US$ 85.0 billion in 2016, a 3.7% fall compared to the previous year (Federação das Indústrias do Estado de São Paulo [FIESP], 2017). The states of São Paulo, Mato Grosso, Paraná, Rio Grande do Sul, Minas Gerais, Santa Catarina, Goiás, Mato Grosso do Sul, and Bahia account for 90.21% of agribusiness exports. The state of Amazonas makes a small contribution to this statistic, with just 0.26% of exports (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2017).

Agriculture has become a strategic sector for economic growth in Brazil, in particular the soy complex, the sugar/ethanol complex, coffee, and tobacco and its products. Fruit and vegetable products, including pulses, roots and tubers, account for 29.93%, 13.36%, 6.44%, 2.5%, 1.0%, and 0.12% respectively; a total of 53.5% of the agribusiness chain. Agriculture is therefore an important actor and the primary driving force in Brazil's trade balance (MAPA, 2017). This is the result of development of an agricultural system recognized worldwide for its role in domestic economic growth and in expansion of exports (Martinelli, Naylor, Vitousek, & Moutinho, 2010).

Development and adoption of technology has contributed to the success of Brazil's agriculture, in conjunction with the efficacy of science and technology policies that are developed and disseminated by networks of agents working in the industry (Ekboir, 2003). Because agriculture is a key sector in the economy of a country that is still in development, and one with great political and strategic importance, it will remain at the top of the strategic agenda (Saritas & Kuzminov, 2017). Therefore, adoption and diffusion of new technologies in agriculture is considered of great importance as offering opportunities for increasing production and revenues and providing employment and sustenance for a large contingent of people involved in the process (Feder et al., 1985).

In the Alto Solimões region

In the Alto Solimões region, farmable areas are generally located along the large rivers and are lowlands. In other words, geographically, these are areas along a fluvial corridor with floodplain characteristics (seasonal ebb and flow) (Tockner, Malard, & Ward, 2000). As such, inundation is the driving force in the lives of local farming people (Junk, Bayley, & Sparks, 1989), since it is the regular rise and fall in the levels of the rivers that has enabled human occupation, as its sequential sedimentation has made an ancient agricultural horizon possible (Piperno, 1990). The process of inundation is known for its physical and biological effects, including erosion and deposition

of sediments and transport and processing of organic material (Tockner et al., 2000). This phenomenon led to the emergence of small rural communities along the fluvial corridors.

The use of land for agriculture in the Amazon basin, in the Alto Solimões region, has been a controversial subject. On one side of the debate, there are studies that argue that ribeirinho farmers should practice traditional agriculture (empirical practices, with traditional knowledge), without access to new farming techniques or technologies (seeds, supplies, fertilizers, management methods, etc.) (Noda & Noda, 2016; Rodrigues & Noda, 2013).

On the other side are studies showing that the dry land in the Amazon is known for its low fertility, which is an environmental limitation to development of agriculture (McMichael et al., 2012). Farming the land in the floodplains is a technique employed to exploit the advantages provided by the inundations that fertilize the land, enabling small-scale farmers to occupy these areas in the Amazon summer only (Kawa, Michelangeli, & Clement, 2015), soon after the waters recede. The floodplain lands are rich in sediment and organic material deposited during the high waters, which makes the soil suitable for farming (Tockner et al., 2000). Farming activities are carried on in small areas of floodplain land, the crops receive little or no agrochemicals, the techniques employed are normally primitive, the seeds do not undergo any kind of improvement treatment, and management practices are very often inadequate (Altieri, 1999), with the result that many communities engage in subsistence farming (Peña-Venegas, Stomph, Verschoor, Echeverri, & Struik, 2016).

Some practical investigations in floodplain regions in Amazonia report that promotion and implementation of new farming practices enables communities to produce better quality agriculture, producing better yields for families that engage in farming activities in floodplain lands (Abizaid, Coomes, Takasaki, & Arroyo-Mora, 2018; Miltner & Coomes, 2015), which in turn reduces destructive practices (for example, illegal logging and predatory hunting and fishing) and improves families' means of subsistence (Cotta, 2015).

Study Location, Sampling and Data

The Alto Solimões region is one of the microregions of the state of Amazonas, encompassing the municipal districts of Amaturá, Atalaia do Norte, Benjamim Constant, São Paulo de Olivença, Santo Antônio do lçá, Tabatinga, and Tonantins (Constituição do Estado do Amazonas, 2014), and it is characterized in the Köppen-Geiger classification system as having an equatorial climate with abundant rainfall and rivers with large water volumes (Rubel, Brugger, Haslinger, & Auer, 2017). The region can also be characterized as having soils of low fertility for large-scale, dry-land agriculture (McMichael et al., 2012) and it is inhabited by a rural population with a predominantly subsistence lifestyle (Baye, 2017). The soils of the floodplains are formed by sedimentation and are subject to the cycles of the movements of water (Alfaia, Souza, & Fajardo, 2009). Cultivation systems are dominated by short-cycle crops such as cowpea beans, rice, corn, watermelon, collard, cackrey, cassava, and squash. Farming is only carried on in periods when the river levels are low. The seeds used for planting crops have not been genetically improved and are sourced from previous harvests and/or bartering between farmers. Traditional activities like fishing, fruit farming, timber extraction, and dry-land livestock farming are normal practices (Alfaia et al., 2009).

The construct used to measure diffusion and innovation in agriculture was developed to fit the theoretical framework and the Propositions presented above, taking innovation as the foundation, adapting work by Damanpour, Szabat and Evan (1989), (Rogers, 1976; 2003; Stephenson, 2003) and comprised eleven questions to be used as a semistructured interview script. The questions cover the origins of innovation, such as farming supplies, seeds, fertilizers, tools, management practices, and also the influence of research and technical support agencies or external supply-side factors as facilitators of knowledge dissemination (Spencer, 2008) and the existence of any relationship between the social system and the process of assimilation of innovations. The sample was non-probabilistic, selected by convenience and accessibility (Alencar & Gomes, 1998). The data for the study were obtained from a non-probabilistic sample of 25 rural farmers who were surveyed during 2018. Five of these farmers had taken part in a fieldwork experiment in 2012 based on the study of diffusion and innovation conducted

by Ryan and Gross (1943), in which the idea was to determine adhesion to and diffusion of new farming processes and whether adhesion and diffusion would spread over time among the members of a social system, as in the study by Rogers (2003). Interviews were recorded and transcribed to facilitate analysis.

The study covers two distinct blocks of research. The first is an extension activity performed in 2012, conducting a fieldwork experiment in the context of learning, enrolling 20 farmers from the São José community, on an island that is part of the municipal district of Benjamin Constant. The fieldwork experiment involved introduction of a hybrid watermelon variety to explore the effects of personal networks on the learning performance of the farmers (Pratiwi & Suzuki, 2017). Activities were conducted with the farmers from planting to sale of the harvest. Five rural farmers who had taken part in this intentional fieldwork experiment were interviewed in July 2018 with the objective of discovering whether the hybrid watermelon variety seeds had been adopted alongside the crops grown by these farmers and what mechanisms had been employed to communicate the innovation. Second, 20 rural farmers were surveyed in the municipal district of São Paulo de Olivença, which is a long distance from São José in the municipal district of Benjamin Constant, so they do not have any contact with the farmers there (the distance is 235km, and it is estimated that the boat journey takes 46 hours).

Our analytical proposal is to attempt to understand innovation and diffusion of technologies in the context of floodplains agriculture in the Alto Solimões region, which is a rich investigative scenario that could generate practical and theoretical insights into the phenomenon. In order to determine the interviewees' diffusion stages, the five-stage mental process proposed by Beal and Bohlen (1957) was adopted (shown in Table 1).

Table 1

Stages for Analysis of the Interviewees' Mental Processes of Diffusion

Stages	Sequence of stages	What happens in the field of research?
Awareness stage	The farmer becomes aware of a new idea. He knows about the existence of the idea, but he lacks details. For example, the farmer knows the name of a new product, technology, or seed, but does not know how this information works, or what he should do.	Normally, awareness is the result of specific television programs. Rural extension programs are sporadic.
Interest stage	At this stage, the farmer wants more information about the idea, product, or seed, etc. He wants to know how it works and what its potentialities are. He is convinced that this idea might help him increase his income, or help him control pests or diseases, or improve farming or home life in some way.	Farmers identify what the specific product, seed, or technique is.
Evaluation stage	The farmer makes a mental judgment of the idea, He applies the information obtained in the previous stages to his own situation. This stage involves questions such as "Can I do this and if I do it, will it be better than what I am doing now— will it increase my income, or will it help to maximize any other values that I hold important ?"	What is the new idea for? Fifteen farmers interviewed in the municipal district of São Paulo de Olivença did not provide any information that indicated they had proceeded to the next two stages.
Trial stage	This is a stage in which the farmer decides that the idea has possibilities; he will adopt it. The trial stage is characterized by small-scale experimental use, and by a need for specific information to deal with: "How do I do it? How much do I use? When do I do it? How can I make it work for me?" The farmer needs to test the new idea even though he has thought about it for a long time and has collected information about it.	A small number of interviewees managed to proceed to the trial stage. The interviewees from the area where the trial of the hybrid water melon seed was conducted only managed to progress to this stage because they were involved in an extension project. For other crops and techniques they had stagnated at stages 1 and 2.

Continue

Table 1 (continued)

Stages	Sequence of stages	What happens in the field of research?
Adoption stage	This is the final stage in the process. This stage is characterized by continued large-scale use of the idea and, more than anything, by satisfaction with the idea. This does not mean that a person who has accepted an idea must use it constantly. It means that the farmer has accepted the idea as good and that he intends to include it in his on-going program.	While interviewees from the municipal district of São Paulo de Olivença did report adoption of new ideas, this was not observed in practice. In order to avoid interviewer biases, a neighbor was invited to check the information, which was not confirmed. The exception was the group that took part in the experiment with the hybrid watermelon seed. All of the farmers on the island of São José had already accepted the idea and had abandoned the traditional seeds and practices.

Note. Source: Adapted from Beal, G. M., & Bohlen, J. M. (1957). The diffusion process (Special Report Nº 18, Agricultural Experiment Station). *Iowa State College*, Ames, Iowa.

All 25 interviewees were male, aged from 30 to 55 years. All were married and had from 3 to 5 children and had attended school for a minimum of 3 years. Mean monthly income is estimated at R$ 250.00 to R$ 500.00, which was the equivalent of 26% to 52% of the prevailing national minimum wage. Their income is derived from fishing, agriculture, and collecting fruit in the forest. Mean interview duration was 40 minutes. The interviewees were unable to estimate the area of the land they were cultivating and stated that they did not hold deeds to these areas.

Some agricultural produce, such as cassava, is processed into flour to provide food when the rivers are in flood. Surplus is transported in small boats to the center of the municipal district and is generally taken up by intermediaries who provide the link between farmers and end consumers. As such, agriculture in the tropics can be described as low-income, as illustrated by the World Bank (2003) and by Marenya and Barrett (2007).

Analysis and Discussion of Data

Innovation occurs via a process through which a **thought**, **behavior**, **or thing** that is **qualitatively different from existing forms** is conceived of and brought into existence (Barnett, 1953). In agriculture, innovations are primarily concerned with the need to increase production, with improving the quality of production, and with production processes and cultivation conditions (Van Der Veen, 2010). In turn, the process of diffusion is a mental process consisting of five stages of acceptance of an idea or new ideas and/or new practices (Beal & Bohlen, 1957), as illustrated in Table 1 showing the analytical stages of the interviewees' mental process of diffusion.

For Rogers (2003), the process of adoption of an innovation in agriculture is a mental process that extends from the first auditory or visual contact with an innovation up to its final adoption. In other words, it is an ordered sequence of events. However, in addition to the stages shown in Table 1, economic, social, cultural, ideological, and psychological conditions can also play a significant role in the process of diffusion (Van Der Veen, 2010).

For ribeirinho communities, diffusion of innovation has the potential to provoke changes leading to utilization of new farming techniques or technologies that could improve specific problems affecting their communities (Mayer & Davidson, 2000). The roles played by community leaders can facilitate transfer of innovations (originating in the external context) and diffusion through social interactions (Pratiwi & Suzuki, 2017). This prompted us to venture and test Proposition 1, stating that if there was greater involvement of community leaders in associations for promotion of agricultural development, there would be greater diffusion of innovations over the long term in that community. To test this, data were collected from the interviewees' experiences with the community and their understanding of stimuli for agricultural development.

When the interviewees were asked where they acquired knowledge about farming innovations, they reported that they watched specialist TV programs such as Campo e Lavoura (Field and Harvest) and Globo Rural (Globo is the largest TV network in Brazil and Globo Rural is a program aimed at rural viewers) and other programs that provide this type of information. Three participants mentioned the influence of children living in the state capital Manaus or studying at a university in the interior of the state. In terms of the Beal and Bohlen (1957) awareness stages of the mental process of diffusion, shown in Table 1, the interviewees were aware of the new idea (the awareness stage) and some had even sought more information about the idea (the interest stage). However, the third stage, evaluation, which consists of evaluation of the **idea**, appears to be the final mental stage for the majority of the interviewees. The trial and adoption stages of the mental process were not identified in diffusion of technological innovations in this floodplains agriculture setting.

The way in which communities are organized and interact socially may have an impact on diffusion of information and agricultural productivity (Conley & Christopher, 2001). The type of pattern of relationships in a social network can have a significant impact on how its actors behave and can have implications for the challenge of managing diffusion of innovations and technologies in an agricultural context (Bodin & Crona, 2009). Furthermore, as mentioned above, social and economic conditions can also affect the diffusion process (Van Der Veen, 2010). This prompted us to explore Proposition 2, which postulates that if there is greater integration of exchange mechanisms for promotion, there will be greater results in terms of diffusion of innovations and technologies in the long-term agricultural context. The questions put to the respondents did not provide a basis for confirming this Proposition. In contrast, assimilation of the new hybrid watermelon seed was observed among all of the farmers from the community that had participated in the fieldwork experiment conducted in 2012.

Access to information related to agricultural knowledge is essential to develop farmers' skills and maintain and increase agricultural productivity (Pratiwi & Suzuki, 2017). In relation to this characteristic, Proposition 3 was ventured to verify exposure of rural communities to external sources of information such as field days and trips to see demonstrations, the influence of multinational firms, or of farming supplies shops, or technical support. This proposition results from a study conducted in the South of Brazil by Petry and Machado (2014). The community that took part in the fieldwork experiment using introduction of hybrid watermelon seed to intentionally explore the effects of personal networks on the learning performance of farmers only exhibited evidence to confirm innovation and diffusion of technologies over time with relation to the hybrid watermelon. Other interviewees complained about barriers such as a lack of access to resources, knowledge, and institutional support.

When the interviewer mentioned other possible means of accessing information, such as state or municipal government extension agencies, specific farming supplies shops, and campaigns run by global companies and NGOs, the respondents mentioned the existence of an Amazonas Farming Development Institute (IDAM) office. However, communities a long way from the administrative center of the municipal district are only followed-up occasionally. The majority of interviewees stated that they did not know of any work undertaken to foster farming innovation and diffusion. According to the farmers' reports, some political initiatives run by the state of Amazonas had distributed hybrid seed corn, farming tools such as machetes, hoes, and scythes, and boat motors. These initiatives are normally restricted to election campaigns, with no follow-up in the field and do not involve, according to the interviewees, elements that contribute to diffusion of farming technology innovations.

"I think it will take many years for the community to learn new practices, and for neighbors to copy them, because we are still using the traditional farming methods". This utterance comes from an interviewee (I3) who defined innovation and diffusion in the study area. The primitive methods referred to are methods that are handed down from generation to generation or, possibly, fostered by researchers such as Rodrigues and Noda (2013) and Noda and Noda (2016), who argue in favor of maintaining traditional knowledge and suggest that external innovations should be ignored, which is, apparently, the dominant idea in the setting investigated.

The influence of friends and neighbors, or even the church, on the process of innovation and diffusion is insignificant. Theory understands that an innovation is diffused within a social system through its adoption by individuals and groups (Peshin et al., 2009). The interviewees' narratives did not provide substantive evidence of innovations transferred from friends or neighbors and the church was not mentioned. The effects of social networks

are minimal in the setting investigated and these results are compatible with the findings of studies by Bandiera and Rasul (2006) and Pratiwi and Suzuki (2017).

The transcripts reveal a lack of interest and the absence of large multinational firms that produce agrochemicals, fertilizers, and/or seeds, which is a completely different scenario to that revealed by the results of an investigation by Petry and Machado (2014) in the green belt of Grande Florianópolis, in Santa Catarina in South Brazil, where the revolution in innovation is driven by large multinational firms (who make initial investments in agricultural areas with key farmers, and in seeds, supplies, and innovative practices) and diffusion followed the S-shaped model of dissemination among the members of a social system over time, as described by Rogers (2003).

The supply-side competitive configuration, such as multinational firms and farming products stores, exhibits little or no interest and this lack of business interest in floodplains agriculture in the Amazon setting investigated is reflected in the low level of innovation and diffusion in the sector. Compounding this, the long distances from the main centers of consumption, the absence of roads, the difficulties of river travel, and the high cost of fuel increase the difficulty of farming, all of which are factors related to economic, social, and psychological conditions, as identified by Van Der Veen (2010).

Farmers' demotivation in relation to the peculiarities of Amazonian floodplains agriculture are well known. Communities further from the administrative center of the municipal district that engage in floodplains farming prioritize crops with short cycles that can be processed into foods to support them when the rivers are running high, such as cassava flour. Even so, changes could take place through microinventions, such as modifications to practices and tools, consisting of adaptations to already existing technologies rather than innovations in recent technologies (Van Der Veen, 2010). Nevertheless, this phenomenon was not identified in the great majority of interviewees' utterances.

Farmers closer to the administrative center of the municipal district – which is normally where the largest numbers of consumers are concentrated – are unhappy with their farming model and practices, but are unable to get past the interest and evaluation stages shown in Table 1. Careful analysis of the transcripts reveals certain elements that make progression through the stages shown in Table 1 difficult. In first place is the influence of students who are disciples of the beliefs of the Noda and Noda school – which was evident in the community in which the hybrid watermelon seed was introduced. The results achieved with these seeds were clearly superior to those with watermelon seeds sourced from previous years' harvests – in that the **traditional** fruit were malformed and productivity per unit area under cultivation was low. However, other practices and/or crop varieties were not spontaneously successful in the same community. In second place, the distances and difficult access by river create barriers to transport of produce, discouraging farmers from attempting to change. And finally, the state and municipalities are neglectful of technical support for floodplains agriculture. Technical consultants engaged in rural extension activities could play a crucial role in development of agriculture and the community (Brunier, 2016). However, such proactivity remains in the realm of imagination in the setting investigated.

Final Comments

Research into and knowledge about innovation in agriculture have grown over recent decades in Brazil. A great deal of this knowledge is related to innovation in different contexts, such as large-scale crops (soy, maize, wheat, among others) and in specialist agriculture (horticulture and fruit farming) around large cities, known as green belts. In contrast, little effort has been focused on understanding farming innovation and diffusion, especially in agriculture in floodplains areas in the interior of the state of Amazonas, which has low agricultural productivity, since it relies on traditional and rudimentary knowledge. This study was intended to understand innovation and diffusion of technologies in the context of agriculture in floodplains areas in the Alto Solimões region, in the state of Amazonas, more specifically, among farmers who farm in areas subject to seasonal inundation. Innovations are considered critical to improving the efficiency, productivity, and efficacy of agriculture (Mutsvangwa-Sammie, Manzungu, & Siziba, 2017).

Three propositions were ventured to explain how the model of agricultural innovation and diffusion works. The propositions were organized to explain the central concepts of agricultural innovation and diffusion in the setting of farming in an area of floodplains. These propositions were not intended to encompass all factors associated with innovation and diffusion. Rather, they offer certain important examples that demonstrate how innovation and diffusion in the context of agriculture in the interior of the state of Amazonas in floodplains areas helps to improve understanding of how subjects (farmers) understand the questions raised by innovation and how a social system may help to disseminate it, thereby contributing to improving revenues and productivity.

The results of this article offer a series of contributions that extend knowledge about innovation and diffusion of technologies in agriculture. First, the discoveries provide certain insights into the complexity of the process and the factors that impact on methods of innovation and diffusion, highlighting how the concept of innovation is not universal in agriculture. In a floodplains settings not even small incremental or spontaneous variations, such as modifications to tools, improved seeds, or new management practices, were identified. This contradicts the idea that tendencies in the competitive context spontaneously lead to innovation. This was not the case in the floodplains farming setting that was studied.

Second, it must be recognized that the socioeconomic characteristics of the region and the industry investigated affect innovation and the mental scale of diffusion, as does interest from the supply-side competitive configuration, such as domestic or multinational firms, researchers, extension and development agents, and other actors. The same is true on the demand side, with buyers, markets, and intermediaries.

Thirdly, the study provides certain guidance, demonstrating how extension through specialist technical support (universities, agricultural engineers, farming technicians) facilitates innovation and its dissemination through the system social over time, as was observed in the fieldwork experiment conducted intentionally in 2012 with introduction of the hybrid watermelon seed.

Conceptual limitations should be acknowledged, creating opportunities for empirical and qualitative evaluations and theorizing in greater detail. This study focused on innovation and diffusion of technologies and not on the social structure of the ribeirinho communities with relation to the social learning process.

Future studies of innovation and diffusion should consider inclusion of additional factors to understand the peculiarities of floodplains agriculture in the interior of the Brazilian Amazon, such as the cultural, economic, and psychological factors that could affect the process of innovation and diffusion. Additional studies are needed to explore applications of specialist technical support as an agent of innovation and promotion of diffusion.

Finally, the results observed appear to indicate that an important factor in understanding agricultural change involves adaptations that fit in with the local circumstances, which is a route involving the role of technical personnel who take responsibility for knowledge transfer (innovations). The task of drawing up a political agenda to promote this revolution falls to universities.

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2nd author: Substantial contributions to conception and design. This author participates in drafting the article and revising it critically for important intellectual content.

3rd author: This author had substantial contributions to conception and design. Participates in the research and the final review.

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