Journal of Agricultural Science; Vol. 11, No. 18; 2019
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Comprehensive Perception Approach of Adoption: Experimenting Hybrid Chinese Maize Varieties in Benin

Houinsou Dedehouanou[1], Antoine Affokpon[1], Rachidatou Sikirou[2], Noël Akissoe[1], Chabi G. Yallou[2], Jean-Louis Ahounou[2], François-Xavier Akondé[3], Antoine Badou[2] & Jacqueline Sagbohan[3]

[1] Faculty of Agricultural Sciences, University of Abomey-Calavi, Benin

[2] National Institute of Agricultural Researches of Benin, Benin

[3] National Direction of Agriculture, Benin

Correspondence: Houinsou Dedehouanou, Faculty of Agricultural Sciences, University of Abomey-Calavi, 01 BP 526 Cotonou, Benin. Tel: 229-9762-1627-9542-4771. E-mail: hdedehouanou@hotmail.com

Received: September 14, 2019 Accepted: October 20, 2019 Online Published: November 15, 2019

doi:10.5539/jas.v11n18p21 URL: https://doi.org/10.5539/jas.v11n18p21

The research is financed by the West African Agricultural Productivity Program (WAAPP-Benin) under the CNS-Maïs China Project entitled "Agronomic and Technological Assessment of Varieties of Chinese Hybrid Maize Introduced in Benin".

Abstract

The probability of adoption of four Chinese Hybrid Varieties of maize is considered as a favorable perception for these varieties by actors. In order to understand the way of adoption, a panel of actors comprising producers, processors, traders, extension officers, local elected representatives and, above all, end-users, was used as enumerator to evaluate the behavior of those varieties in comparison to the reference maize varieties known as "local" in experiment plots during the vegetative, harvesting and processing phases. For each actor surveyed and for each introduced variety, the comparative index of appreciation (IA) was determined by the difference in perception scores with respect to each of the descriptors evaluated. The adoption of maize varieties within the sites surveyed was affected by the respondent' social profile (title), the number of varieties already adopted by the respondent, respondent's experience, age, educational background, membership to an association/organization and the site (research station). The estimation of adoption relative to probabilities (odds ratio) of each variety of maize from the binary logistic regression models revealed only one variety having more than one in two chances for being adopted. Unlike the adoption rate of maize varieties calculated after expensive dissemination efforts, the analysis of probabilities and determinants of adoption somewhat reduces research, pre-extension and extension efforts. The proposed approach allows for a flexible integration of research experiments and field extension concerns of the process of adoption by creating panels of stakeholders around research experiments on research stations.

Keywords: adoption probability, adoption rate, maize, China, Benin

1. Introduction

The adoption of maize varieties by the stakeholders is a major challenge given the multitude of varieties available (Shiferaw, 2013). However, isn't it another challenge to prioritize the probability of adoption on the rate or frequency of adoption? If for one, the conventional implementation approach becomes increasingly heavy and very expensive in material, human and financial resources (FAO, 1998), for the other, the "Comprehensive Perception Approach of Adoption" is rather imperceptible. Recall that what is known as agricultural technology transfer is supply driven, while adoption of agricultural technology suggests a demand driven process (Courgeau, 2004). Whether this process is a single stage, or two-stage or multistage decision process is not at stake here (Dimara & Skuras, 2003). This research underscores the process of agricultural technology transfer that it endeavors to abridge at just research stations. Indeed, a good agro-morphological, phyto-pathological and entomological behavior is a bonus for the producer, but it is not decisive in the adoption of an improved maize variety (Dedehouanou et al., 2015, 2017). For instance, a good knowledge of the descriptors whose sensitivity is high with the actors directs very precisely on the research and selection efforts to be made with respect to a given variety (Aly, 2001; Dewaminou, 2004). Moreover, the relative appreciation of certain descriptors, especially those of the vegetative, harvesting or processing phases, suggests the nature of the complementary research to be carried out: whether it concerns agronomic research in order to highlight the potential (Hononta & Agbetogan, 2002), or whether it is a genetic research for the expression or mitigation of given attributes (seed research) (Dewaminou, 2004).

Perception assessment implemented here leads to the identification of factors and probability of adoption, approach less complex than the traditional agricultural technology transfer (Ntsama Etoundi & Kamgnia, 2008; Dedehouanou et al., 2015). The pending issue is how to establish a link between probability of adoption and adoption rate; which would justify the new approach. Such an achievement leading to spared resources and time would represent a breakthrough in the process of agricultural innovation and transfer in the developing countries. Therefore, this paper endeavors to tentatively link the probability and determinants of adoption with the rate and determinants of adoption, pioneering innovative pathways to a costless and timeless approach to agricultural technology transfer.

2. Materials and Methods

2.1 Materials and Experiment Zones

Fifty Chinese hybrid varieties were introduced and tested in Benin. Four of those varieties revealed strong attributes with regard to phyto-pathological and pest concerns. They further demonstrated strong spatial and rustic fitness. That is the rationale of those four varieties being experimented and evaluated with respect to their agronomic, disease resistant, pest control and processing performance in three different and important agro-ecological zones of Benin. Experimental plots were installed at three research stations: Niaouli at CRA-Sud (site 1), Gobé at CRA-Center (site 2), and Ina at CRA-North (site 3). Four varieties were then introduced in 2014-2015 agricultural campaign. The first of those varieties was “Guidan 162” (denoted T2 variety, 84-day seed-maturity cycle, potential yield of 7 t/ha, yellow color grain, spike insertion height of 86 cm), described by Affokpon et al. (2015). The second of those varieties was “Jinguyuan 688” (denoted T3 variety, seed-maturity cycle of 77 days, potential yield of 3.7 t/ha, yellow color grain, spike insertion height of 45 cm), described by Sikirou et al. (2015). The third one was “Jinyu No.8” (denoted T4 variety, 80-day seedling-maturity cycle, potential yield of 6.5 t/ha, yellow color grain, spike insertion height of 58 cm), described by Dedehouanou et al. (2015). And the fourth one was “Xianyu 335” (denoted T5 variety, 79-day seedling-maturity cycle, potential yield of 4.3 t/ha, yellow color grain, spike insertion height of 49 cm), described by Akissoe et al. (2015). The four Chinese hybrid maize varieties were then ranked according to the decreasing weight performance of their yields as follows: T2, T4, T5 and T3. The test was installed according to the randomized block design with four replicates. As part of the comprehensive perception evaluation, respondents compared the four Chinese varieties with their own local varieties. In reality, local variety was chosen by the respondent and acted as a reference/baseline for evaluation (Dedehouanou et al., 2015, 2017).

2.2 Sampling and Data Collection

The perceptions of producers, food processors, maize traders, extension officers, local elected officials and end-users on the agro-morphological, phyto-sanitary, physico-chemical characteristics and the processing capability, packaging and storage capacities of four Chinese hybrid maize varieties were evaluated through semi-structured interviews of individual respondents.Three areas were explored known as the Guinean zone (site 1), the Sudano-Guinean zone (site 2) and the Sudanian zone (site 3). To this end, enumerators were listed according to some specific profile. For instance, gender considerations were at stake in general. So, was membership or not to a farmers’ organization for producers. The criterion of having or not participated in an assessment of maize in the past was also relevant. There were also a few purposeful biases. The first important bias was to select the chief of the village in which the research station is located. This is to smooth relationships between agricultural research stations and villagers in a Research & Development perspective. The second important bias was to select local extension officers as their role in the agricultural technology transfer is to communicate the strengths and qualities of a given technology to producers. This is to obtain their adhesion beforehand so as to prompt their willingness to transfer the new varieties. Overall thirty (30) enumerators were selected by site. The gathering of enumerators in order to investigate agricultural experiments happened three times: (1) ten days after sowing, the lifting phase; (2) at harvest, the harvesting phase; (3) after conservation and during food processing, the processing phase. One important criterion that was set in order to validate perception data was enumerators’ consistency with respect to the three research phases. If an enumerator failed to participate in one phase (maybe he/she was not available, or he/she asked relatives to answer on his/her behalf), his/her data sheet was withdrawn. This suggests a good deal of communication and motivation on both researchers and participants sides. For instance, there was a serious consideration to count upon researchers among enumerators in the beginning. Because of administrative concerns, all researchers could not be available for all three phases. Researchers were then all withdrawn in the end. Respectively 18, 18 and 19 enumerators were finally surveyed on sites 1, 2 and 3 for all three research phases. It is very illustrative to notify that the specialist of phyto-pathology recommended to slash and burn organs of variety "Jinguyuan 688"/T3 in the Sudano-Guinean zone (site 2), because of disease attacks.

The main topics of the interviews were the perceptions on: i) the lifting phase [on seedling size depending on their age, robustness of seedlings, number of organs attacked on the plant, number of diseases on the plant, number of organs damaged on the plant and number of pests on the plant]; ii) the harvesting phase [size and volume of the spike, number of spikes per plant, dimensions (length, width and thickness) of the grains, drying level of husks, phyto-sanitary state of the spikes at harvest, and attack of the extreme side of the spike at harvest, number of pests per spike at harvest, maize kernel attack on spike at harvest, vitreous nature and friability of grain, grain indentation, structural composition (pericarp, germ and endosperm) of grains and color of grains]; and iii) the processing phase [elasticity of food derivatives/paste organoleptic quality of derivatives/paste elasticity of food derivatives/organoleptic quality of paste "Gambalilifin"/elasticity of paste "Gambalilifin" food/"Akassa" paste, organoleptic quality of derivatives/akassa and Degree of culinary fitness/diversity in number of foods]. Perceptions were reported for Chinese hybrid maize varieties and for the best local varieties. The appreciation scores of each perception variable (descriptor) varied from -2 for the least appreciated variables to +2 for the most appreciated variables (-2, -1, 0, +1 and +2, respectively).

2.3 Methods: Statistical Data Processing and Analysis

The socio-economic characteristics of the respondents were first determined by means of a frequency distribution. This characterization was supplemented by a Principal Component Analysis (PCA), based on a matrix with rows, different categories of actors and for columns, variables related to the number of varieties already adopted, membership or not to a famers' association/organization, participation or not in an assessment on maize crop in the past and the exercise or not of other income generating activities (Dedehouanou et al., 2015). This statistical analysis was performed with the software MINITAB Release 14.

For each actor investigated and for each introduced variety, the index of comparative assessment (ICA) of the variety introduced and the reference variety was determined by the difference in perception scores from the two varieties ($\text{Score}_{[\text{introduced variety}]} - \text{Score}_{[\text{reference variety}]}$) for each of the variables (descriptors) of evaluated perception. For a given variable, the introduced variety is well-liked (compared to the reference variety) if ICA > 0.

The correlations between various characteristics of the varieties introduced were extracted by a step by step canonical discriminant analysis (stepwise discriminant canonical analysis) on the characteristics relating to lifting, harvesting and culinary/processing phases of the introduced varieties. This analysis was carried out with the STEPDISC procedure under SAS (version 9.2).

The discriminant canonical analysis was followed by a discriminant factorial analysis designed to describe, through a system of canonical axes, the varieties and the sites according to the relevant variables (descriptors) retained by the step by step canonical discriminant analysis. The statistical analysis was carried out, by site and for all sites, using the CANDISC procedure under SAS (version 9.2).

An index of appreciation (Ia) has been defined for given site (s), variety (k) and phase (j) (Hosmer & Lemeshow, 1989),

$$Ia_{lkji} = \frac{1}{n}\sum_{l=1}^{n}(Score_{[\text{ introduced variety }]} - Score_{[\text{ reference variety }]}) \quad (1)$$

where, i denotes the index variables (descriptors) selected from the step by step canonical discriminant analysis.

This index varies from - 4 to +4 and reflects the overall opinion of the respondents on the variety concerned. If,

$I_{alkji} < 0$, the introduced variety is less appreciated than the reference variety of the respondents;

$I_{aLkji} = 0$, respondents/actors are indifferent to the two varieties (introduced and reference);

$I_{alkji} > 0$, the introduced variety is more appreciated than the reference variety of the respondents.

An index of overall appreciation (Ig) was determined per respondent, per site and for all sites from the varieties of characteristics put to use in the step by step canonical discriminant analysis (Hosmer & Lemeshow, 1989),

$$Ig = \frac{1}{n}\sum_{i=1}^{n}(Score_{[\text{ introduced variety }]} - Score_{[\text{ reference variety }]}) \quad (2)$$

where, i denoting the index of the relevant characteristics retained.

A maize variety could probably be adopted if its Ig is greater than zero (Ig ≥ 0). It was then possible to determine who could adopt the introduced varieties in the future (probable adopter = 1 and probable non adopter = 0).

The relationship between the adoption of a variety by a person and the socio-economic characteristics of the person was then modeled using a binary logistic regression (Hosmer & Lemeshow, 1989):

$$\pi(x) = Prob(Y = 1/X = x_1, x_2, \ldots x_k) \tag{3}$$

with the dependent variable (in this case, the adoption or not of a variety: $y = 0/1$) and the independent variables (here, socio-economic characteristics: $x_1, x_2, \ldots x_k$).

The probability of adoption of a variety was of the form (Hosmer & Lemeshow, 1989),

$$Log(\frac{\pi(x)}{1-\pi(x)}) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \tag{4}$$

or,

$$\pi(x) = \frac{e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k}}{1 + e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k}} \tag{5}$$

where, β (β_1, β_2, ... β_k) represents the vector of regression coefficients and x (x_1, x_2, ... x_k) the vector of socio-economic characteristics measured by investigation.

This analysis was made for the probable adoption of all varieties without distinction and for the probable adoption of each variety by site and for all sites. It enabled to infer the probability of adoption of the varieties by the average of the individual probability of adoption of the variety by the respondents.This statistical analysis was carried out with software R version 3.0.2.

3. Results

3.1 Socio-economic Determinants of the Likelihood of Adoption of Four Chinese Hybrid Maize Varieties

The binary logistic regressions (Table 1) showed that the probability (future decision) of adoption of a maize variety would depend significantly on the maize variety and the site (agro-climatic zone). Moreover, the social profile and the number of years of experience of the enumerator determined the probability of adoption of maize varieties on sites 1 (Guinean zone) and 2 (Sudano-Guinean zone), while participation in an assessment of maize in the past determined the probability of adoption of maize varieties on sites 2 (Sudano-Guinean zone) and 3 (Sudanian zone). Membership to a farmers' association/organization and the level of education of the respondents, respectively, affected the likelihood of adoption of maize varieties on sites 1 (Guinean zone) and 3 (Sudanian zone).

Estimating the relative chances of adoption (odds ratio) of maize varieties derived from binary logistic regression models revealed that T2 variety is 0.08, 0.02 and 0.01 times more likely to be adopted than T4, T5 and T3 varieties, respectively. In addition, maize varieties on site 1 (Guinean zone) are 27.93 and 9.31 times more likely to be adopted than on sites 2 (Sudano-Guinean zone) and 3 (Sudanian zone), respectively. At each site, T2 variety has more chance of being adopted than T3, T4 and T5 varieties, in particular on the site 2 for which T2 variety is 2.03, 0.02 and 4.16 10 -10 times more likely to be adopted than T4, T5 and T3 varieties, respectively. Thus, extension agents are more likely to adopt maize varieties than local elected officials (on sites 1 and 2) and producers (on site 2), while enumerators who do not belong to a farmers' association/organization are more likely to adopt than those who belong to an association/organization on sites 1 and 2. It is the same trends for the uneducated versus educated enumerators on site 3.

The decision to adopt the different varieties of maize within the prospected sites (Table 2) was found to be significantly influenced by the social profile of the respondent (for T2 variety on each site and T4 variety on site 2, Sudanian zone), the number of varieties already adopted by the respondent (for T2 variety on site 1, Guinean zone; and T4 variety on all sites) and the respondent's experience in years (for T5 variety on site 1, Guinean zone; T4 variety on site 2, Sudano-Guinean zone and T5 on all sites). Age, level of education and membership of respondents to a farmers' association/organization and site were critical for T4 variety on site 2, Sudano-Guinean zone and all sites, T2 on Site 3, Sudanian zone and T5 variety on all sites, respectively.

Table 1. Effect of socio-economic characteristics on the overall adoption probability of the four Chinese hybrid maize varieties

Sites	Variables	Degree of freedom	Probability of adoption
Site 1	Maize variety	3	0.000
	Social profile of respondent	1	0.040
	Number of years of experience of respondent	1	0.001
	Membership to an association/organization	1	0.001
Site 2	Maize variety	3	0.002
	Social profileof respondent	2	0.030
	Number of years of experience of respondent	1	0.029
	Participation in an assessment of maize in the past	1	0.000
Site 3	Maize variety	3	0.000
	Educational background of respondent	3	0.001
	Participation in an assessment of maize in the past	1	0.004
Global	Maize variety	3	0.000
	Site	2	0.033

Note. Only significant effect variables on the adoption of maize varieties are presented;

The degree of freedom is set for the number of modalities that takes the variable minus 1;

Site 1: Guinean zone, Site 2: Sudano-Guinean zone, Site 3: Sudanian zone.

Table 2. Effect of socio-economic characteristics on the probability of adoption of the four Chinese hybrid maize varieties

Sites	Maize varieties	Socio-economic characteristics	Degree of freedom	Probability of adoption
Site 1	T2	Social profile of respondent	1	0.007
		Number of varieties already adopted	1	0.011
	T5	Number of years of experience	1	0.040
Site 2	T2	Social profile of respondent	2	0.001
	T4	Age of respondent	1	0.015
		Social profile of respondent	2	0.012
		Number of years of experience	1	0.005
Site 3	T2	Social profile of respondent	2	0.004
		Educational background of respondent	3	0.010
Global	T4	Site	2	0.000
		Number of varieties already adopted	1	0.005
	T5	Number of years of experience	1	0.049
		Membership to association/organization	1	0.003

Note. Only significant effect variables on the adoption of maize varieties are presented;

The degree of freedom is set for the number of modalities that takes the variable minus 1;

Site 1: Guinean zone, Site 2: Sudano-Guinean zone, Site 3: Sudanian zone.

The estimation of relative chances of adoption (odds ratio) of each variety of maize per site and for all sites from the binary logistic regression models generally showed that on site 1 and site 3 (Sudano-Guinean zone in particular, and Sudanian zone), T4 variety is more likely to be adopted, whereas non-membership to a farmers' association/organization implies a greater chance of adoption of T5 variety on site 3 (Sudanian zone) than membership to a farmers' association/organization. Moreover, extension agents are more likely to adopt T2 variety than local elected officials on site 1, local officials and producers on site 2, producers and food processors on site 3. They are also more likely to adopt variety T4 than local elected officials and producers on site 2.

3.2 Probability of Adoption of Four Chinese Hybrid Maize Varieties

The estimation of the probability of adoption of maize varieties by site and for all sites surveyed is presented in

Table 3. Whatever the site, T2 variety has the highest adoption probabilities (greater than 0.60) while T3 variety is granted the lowest (less than 0.06). Moreover, T4 variety has the highest probability of adoption (0.50) on site 2. The same trends are observed across all surveyed sites (Probabilities of adoption of T2 and T3 varieties: 0.5455 and 0.0182, respectively).

Table 3. Probability of adoption of maize varieties by site and for all sites

Sites	Maize varieties	Probability of adoption	Sites	Maize varieties	Probability of adoption
Site 1	**T2**	**0.667**	Site 3	**T2**	**0.632**
	T3	0.000		T3	0.000
	T4	0.000		T4	0.053
	T5	0.056		T5	0.053
Site 2	T2	0.444	Global (all 3 sites)	**T2**	**0.546**
	T3	0.056		T3	0.018
	T4	**0.500**		T4	0.146
	T5	0.111		T5	0.055

Note. Site 1: Guinean zone, Site 2: Sudano-Guinean zone, Site 3: Sudanian zone.

4. Discussion

The following two assertions should be used with discernment. These are the probability or likelihood of adoption and adoption rates or frequencies. The same holds true for their determinants, even if certain socio-economic characteristics remain neutral as much with respect to objective as well as subjective probabilities.

4.1 Probabilities and Determinants of Adoption Versus Rates and Determinants of Adoption of Maize Varieties

The results presented with regard to the probability/likelihood and the determinants are distinct from the adoption rate and the determinants of adoption found in the literature. For instance, an adoption rate of 10% (Ntsama Etoundi & Kamgnia, 2008) appears to be very far behind the likelihood of adoption of 0.50 (probability of adoption) obtained by the best Chinese hybrid maize variety at all three sites in Benin. The decision process described in the present research is rather the modeling of the revealed preferences for descriptors of introduced maize varieties, as opposed to the two-stage adoption decision process (Dimara & Skuras, 2003). By integrating the multiple constraints acting on the adopting actor, it is instructive to infer that at the phase of adoption in the fields of agricultural producers the rate of adoption would be very much reduced (Dedehouanou et al., 2015, 2017). However, actors' gender did not affect the rate of adoption as in the present case study, although consistently, Ntsama Etoundi and Pedelahore (2010) emphasized maize variety, socio-economic profile, number of years of experience and participation in an assessment on maize in the past on one side, number of varieties already adopted and age of enumerator on the other side as determinants of the adoption rates. Those findings are also established in the present case study. As expected, admitting the principle of calculating the probability, the principle of sufficient reason leading to its separation from the principle of causality between one and the other variable, is relevant to elucidate the tendency at hand (Jorland, 1993). The challenge here would stem from establishing equivalence between probability of adoption and rate of adoption, i.e. adoption performed from agricultural research stations being equivalent to the conventional mode of adoption of agricultural technology, although both processes have not benefited from the same circumstances or determinants in the outset. Therefore, predictions of adoption are likely at the research station if necessary provision is safeguarded by stakeholders of the agricultural technology transfer process. However, this is very suggestive unless authors on both sides, research stations with a comprehensive approach of adoption and real productive systems with the conventional approach of agricultural extension, reach consistent results for decision making and interventions.

4.2 Probability and Determinants of Adoption: Towards the Rate and Determinants of Adoption of Maize Varieties

On the basis of the differences between the probability/likelihood of adoption (subjective probability) and the rate or frequency of adoption (objective probability) (Courgeau, 2004), the two results cannot be equivalent. Unlike Affokpon et al. (2013), who highlighted the absence or presence of previous crop effects on maize crop yields, these results suggested to forgo such circumstances. This is not consistent with Da-Gbadji, Dedehouanou, Houngnandan, Zoundji, and Kpanou (2019), who constantly emphasized social and economic acceptability in the adoption of agricultural innovative technologies. Obviously, various circumstances are to be handled by agricultural producers before their effective move to adoption. Adegbola, Arouna, and Ahoyo (2011a, 2011b) on the one side, and Agbaka, Tano, Borgemeister, Foua-Bi, and Markham (2005) on the other side, respectively substantiated the acceptability arguments such as storage losses of maize due to the devastating pest, *Prostephanus Truncatus Horn*. It is then very relevant to note that in the ex-ante situation, enumerators could not probably pass by the multiple constraints of production services, storage and marketing of grains as for acting agricultural producers (Adegbola, Arouna, & Houedjissin, 2011b). However, various factors and circumstances could streamline the gap between probability/likelihood and rate/frequency of adoption. For example, one important favorable factor for adoption could be the market orientation of maize varieties (Ntsama Etoundi & Pedelahore, 2010; Ntsama Etoundi & Kamgnia, 2008), as the ex-ante evaluation demonstrated in two major producing zones of Benin, Sudano-Guinean zone and Sudanian zone (Dedehouanou et al., 2015; Dedehouanou et al., 2017). But still, it could not justify any kind of generalization. Another important factor in favor of an alignment of both probability and rate of adoption could be the matching of determinants. Indeed, the present findings are consistent with Ntsama Etoundi and Kamgnia's (2008), who also claimed that the determinants such as area, educational level, and membership to a farmers' organization positively affect the adoption rate of improved maize varieties, prompting to "similar causes reach similar effects". A further factor or circumstance in favor of relating probability and rate of adoption could be time length that is needed to consolidate research works on the probability of adoption. This is a missing tail of the present research, experimental observations having taken place only for one annual campaign.

Although the probability and determinants of adoption of maize varieties were obtained from the ex-ante perception evaluation of the characteristics relating to the vegetative, harvesting, processing phases of maize resulting from the experiments, the results could reveal the ex-post evaluation of the adoption rates of maize by actors. Recall that this finding was tentatively inferred elsewhere (Dedehouanou et al., 2015, 2017). It then appears that calculation of probability/likelihood of adoption could lead to tentatively predict the rate/frequency of adoption, bringing about striking possibilities such as shortening the diffusion process, saving scarce resources and catching up with times.

5. Conclusion

The expensive technology diffusion approach, which suggests a phase of research station experiments, a pre-extension phase and another phase of technology popularization, could be overshadowed in order to shorten the process. However, the innovative approach only leads to the determination of subjective probabilities of adoption of maize varieties. Nevertheless, with a closer view, many constraints could mark the adoption of varieties with a view to determining objective probabilities of adoption. These constraints are, in this case, regarding the production services, storage and marketing of the grains. The challenge, in no doubt, would be to establish tangible links between the perceptions of stakeholders at research stations and those in producers' fields. It would then be possible, from these interrelationships between probability of adoption and adoption rate, to initiate a new approach to agricultural technology transfer.

Acknowledgements

The authors thank Professor Romain GLELE-KAKAÏ for his effective involvement in the treatment and statistical analysis of the comprehensive perception evaluation data. They also thank Director Adolphe ADJANOHOUN for his facilitation as the former Director of *CNS-Maïs Project.* They further thank Dr. Yves MAGNON, who edited a draft of a French version of the document. Finally, they thank Mister Gafoudou SAKPOHO for revising the English version of the paper.

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