HEC MONTRÉAL

Factors that influence the adoption of precision agriculture technologies with Quebec farmers

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Summary

The research question addressed in this study is: What are the factors that influence the adoption of precision agriculture technologies with Quebec farmers?

This study examines which factors are facilitating or impeding the diffusion of precision agriculture (PA) technologies in the province of Quebec. It uses the theory of "Diffusion of innovation" (DOI) (Rogers, 1962). Knowing the factors that influence the adoption of PA technologies can lead to specific actions in order to reduce the adoption barriers that operators are facing. This may take the shape of better educational programs, the creation of better financial support programs etc. Increasing adoption of PA will help resolve the problems such as growing farms, shrinking rural population, environmental constraints, traceability issues and productivity challenges. A secondary objective is to assess the current adoption rate of precision agriculture technologies among Quebec's largest farms.

This research indicates that for both "large" and "small" farms the following factors positively affects the number of PA technologies adopted: *non-voluntariness*, *perceived resources*, *employee knowledge*, *compatibility* and *visibility* On the contrary, i*mage* and *trialability* negatively affect the number of PA technologies adopted. The number of PA technologies adopted by "larger" farms is more specifically and positively affected by *employee knowledge*, *perceived resources* and *compatibility*. It is also negatively affected by *quality of support*. And finally, the number of PA technologies adopted by "smaller" farms is more specifically and positively affected by compatibility, *operator innovativeness*, *perceived usefulness* and *visibility*. It is also negatively affected by *relative advantage*.

The following summary in French will present an overview of the English article.

French Summary

Introduction

L'agriculture a toujours été un élément important pour la survie de l'économie et de la culture québécoise. Depuis le début des années 2000, l'agriculture connait de nouveaux défis (AAFC, 2008) : l'agrandissement des fermes de 169% entre 1996 et 2001 (Statcan, 2007), la diminution de la population agricole de 16,4% entre 1996 et 2001 (Statcan, 2007), les préoccupations environnementales avec la détection d'algues bleues dans plus de 151 lacs du Québec en 2007 (MDDEP, 2007), la traçabilité des aliments avec 61 rappels de produits alimentaires dans les sept premiers mois de 2008 (CFIA, 2008) et les défis de la productivité face aux agriculteurs américains (AAFC, 2008). Avec un marché mondial de l'agriculture qui se libéralise de plus en plus, la pression sur les agriculteurs augmente continuellement.

L'agriculture de précision est la combinaison du concept de « site-specific management » et des technologies de l'information. Cette combinaison permet aux agriculteurs de faire de la micro gestion de champs aux caractéristiques hétérogènes, qui auparavant étaient traités comme un tout. Selon de nombreuses études, les technologies d'agriculture de précision (AP) permettent une amélioration de la traçabilité (Godwin, Earl, Taylor, Wood, Bradley, Welsh, Richards, Blackmore, Carver, Knight et Welti, 2002), une diminution du besoin en main-d'œuvre (Amenozima, Ismail et Jusoff, 1997), une amélioration significative de la productivité (Robert, 2002), une réduction manifeste de l'utilisation d'intrants et donc une diminution de coûts (Bongiovanni et Lowenberg-Deboer, 2004) tout en minimisant l'impact environnemental des activités agricoles (Whitley, Davenport et Manley, 2000). Cependant, peu d'études se sont intéressées aux facteurs d'adoption de ces technologies et aucune d'entre elles n'a ciblé les agriculteurs.

Les objectifs de cette étude sont doubles : premièrement, il s'agit d'identifier les facteurs qui influencent l'adoption des technologies d'agriculture de précision des agriculteurs au Québec et deuxièmement, de constater l'état actuel du phénomène d'adoption de ces technologies au Québec.

Revue de littérature

Les technologies d'agriculture de précision

Les technologies d'AP peuvent être classifiées en deux familles : les technologies diagnostiques et les technologies applicatives (McBride et Daberkow, 2003). Les technologies diagnostiques servent à collecter des données sur les champs. Parmi les plus connues, on retrouve : le « geographic position system » GPS, les capteurs de rendement, les systèmes d'information géographique (SIG), les cartes de rendement et la télédétection. Les technologies applicatives telles que les applicateurs à taux variables et les systèmes de navigation servent à effectuer des modifications directement dans les champs. Une revue de littérature en 2000 sur l'utilisation des technologies d'agriculture de précision a identifié que 69% des études faites sur le sujet mentionnaient des retours sur investissement positifs suite à l'adoption de ces technologies innovantes (Lambert et Lowenberg-DeBoer, 2000).

Diffusion et adoption d'innovation

Une innovation est une nouvelle idée. Cette idée peut être une combinaison d'idées existantes appliquée dans un nouveau contexte, un acte qui bouleverse l'ordre présent, une formule ou une approche unique qui est perçue comme étant nouvelle pour l'individu (Zaltman, Duncan et Holbek, 1973; Rogers, 2003).

Deux grands courants de recherche en adoption d'innovation TI existent: les modèles basés en psychologie et les modèles basés sur la diffusion d'innovation (DOI) (Nah, Tan et Teh, 2004). Puisqu'il n'a pas de modèle généralement accepté (Benbasat et Barki, 2007), que ces deux types de modèle se ressemblent (Nah, Tan et al., 2004) et que la théorie DOI a été développée dans le domaine de l'agriculture, elle constituera une base théorique appropriée pour cette recherche. Aussi, cette étude va revoir tous les facteurs d'adoption ayant été cités dans la littérature du domaine des systèmes d'information (SI) et de l'agriculture de précision (AP) afin d'incorporer les construits qui pourraient être pertinents dans le contexte de cette étude. Sur les 44 facteurs d'adoption identifiés, 23 facteurs d'adoption ont été identifiés dans la littérature en SI tandis que 21 facteurs d'adoption ont été relevés dans littérature en AP. Après avoir identifié tous les facteurs d'adoption des littératures respectives, 15 variables ont été finalement retenues.

Quatre variables indépendantes ont été utilisées dans cette étude. La première est la variable binaire d'utilisation, oui ou non (Tornatzky et Fleischer, 1982; Fichman, 1992; Thong, 1999). Les deuxième et troisième relèvent du type de technologie adoptée : diagnostique ou applicative (McBride et Daberkow, 2003). Finalement, la quatrième variable indépendante est l'intensité d'adoption et a été opérationnalisée par le nombre de technologies utilisées par l'opérateur de l'exploitation (Thong, 1999).

Le modèle d'adoption pour les technologies d'agriculture de précision est présenté dans la Figure 1.

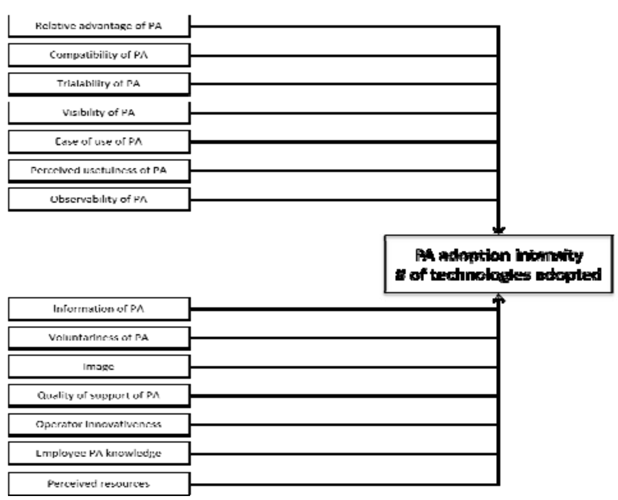


Figure 1: Modèle d'adoption des technologies d'AP

Méthodologie

La question de recherche de cette étude est la suivante : Quels sont les facteurs qui influencent l'adoption des technologies d'agriculture de précision au Québec? Pour y répondre, une étude rétrospective transversale a été conduite au moyen d'un questionnaire papier pour collecter les données. Les règles méthodologiques habituelles, ont été respectées lors du développement du questionnaire. Premièrement, lorsque requis, les facteurs d'adoption ont été adaptés au contexte de l'étude. Les mesures opérationnalisant les facteurs d'adoption regroupaient un nombre minimal de trois items (Aubert et Hamel, 2001), maximal de six items (Compeau, Meister et Higgins, 2007) avec un alpha de Cronbach supérieur à 0,7 (Hair, Anderson, Tatham et Black, 1995). Puisque 90,8% de la population agricole du Québec est francophone (Statcan, 2007), le questionnaire a été administré en français et les items ont été traduits par le chercheur. Des variables de contrôle ont été incluses dans le questionnaire. Elles sont les suivantes : âge, sexe, niveau d'éducation complété, habileté linguistique, technologies d'AP utilisées, âge moyen de la machinerie, grosseur de la ferme et utilisation de données historiques.

Le questionnaire a subi deux pré-tests à des fins d'amélioration. Le premier avec deux agronomes de l'université Laval et le second avec trois agriculteurs. Concernant le reste de la collecte, les données ont été recueillies auprès de 2000 membres de la FPCCQ, « fédération des producteurs de cultures commerciales du Québec ». Les opérateurs ont reçu le questionnaire anonyme par l'intermédiaire de leur fédération et l'ont ensuite renvoyé au chercheur.

L'envoi a été effectué le 17 février 2009. En date du 1er avril 2009, 421 questionnaires ont été retournés au chercheur ce qui représente un taux de réponse de 21,07%. 415 questionnaires ont pu être soumis à des analyses statistiques. Ce sont majoritairement les plus grandes exploitations de l'échantillon qui ont répondu à l'enquête. L'âge moyen des répondants est de 48,7 ans, ce qui est très similaire à l'âge moyen des agriculteurs de la province (49 ans). Les répondants de l'enquête sont en moyenne plus éduqués que la population agricole du Québec puisque 34,5% ont un diplôme d'études collégiales versus 22,2% pour la moyenne provinciale. Un biais de non-réponse a été constaté entre les premiers répondants et les derniers. Il a des différences significatives entre les résultats des 30 premiers répondants et les 30 derniers répondants. Sur les 71 items, 15 items étaient significativement différents: une variable de contrôle sur cinq ainsi que six construits sur quatorze étaient significativement différents. Ceci indique que les répondants ne sont pas complètement représentatifs de la population générale (Armstrong et Overton, 1977).

La fiabilité de l'instrument a été évaluée selon plusieurs méthodes : une analyse factorielle exploratoire, le calcul de l'alpha de Cronbach et une analyse factorielle confirmatoire où l'item devait afficher une saturation supérieure à 0,5 pour être admissible (Aubert et Hamel, 2001). Ces analyses ont conduit à la division du facteur d'adoption *connaissance de l'opérateur* en trois variables de contrôle. Également, neuf facteurs au total ont été éliminés pour des raisons de fiabilité. Les facteurs finaux ont tous affiché un alpha de Cronbach supérieur à 0,788 sauf pour *utilisation volontaire* et *observabilité*.

Pour démontrer la validité discriminante du modèle, deux méthodes ont été utilisées : la corrélation et AVE (average variance extracted). Aucune des variables n'avaient une corrélation entre elles supérieure à 0,7 (Garson, 2009). Cependant la méthode AVE a indiqué qu'il y avait un problème de validité discriminante au niveau des facteurs *facilité d'utilisation* et *capacité d'innovation de l'exploitant.* Ils n'ont pas été éliminés du modèle, car leur retrait n'a pas eu d'impact significatif sur les résultats du modèle, cependant les conclusions tirées sur ces facteurs d'adoption doivent être interprétées avec prudence.

Résultats

Cette étude a permis de répertorier plusieurs technologies utilisées par l'industrie des grandes cultures au Québec. Ces technologies sont présentées dans le Tableau 1 (Tableau 9 de l'article en anglais).

Tableau 1: Distribution des technologies d'AP par groupe d'adopteurs

Type de technologie	Nom de la technologie	Adopteurs de technologies diagnostiques % (n) (n=159, 38.3% de l'échantillon, 56.8% des adopteurs) (A)	Adopteurs de technologies applicatives % (n) (n=121, 29.2% de l'échantillon, 43.2% of adopteurs) (B)	Adopteurs des technologies d'AP % (n) (n=280, 70.2%) (A+B)
Diagnostique	GPS (« geographic positioning system »)	56,6% (90)	72,7% (88)	44,6% (178)
Diagnostique	SIG (système d'information géographique)	9,4% (15)	14,0% (17)	8,0% (32)
Diagnostique	Capteurs de rendement	76,7% (122)	76,0% (92)	53,6% (214)
Diagnostique	Cartographie (carte de rendement)	42,1% (67)	55,4% (67)	33,6% (134)
Diagnostique	Télédétection	3,8% (6)	9,9% (18)	4,5 % (18)
Applicative	Technologies à taux variables	0% (0)	61,2% (74)	18,5% (74)
Applicative	Système de navigation (autopilote)	0% (0)	62,8% (76)	19% (76)

Les Tableaux 2 et 3 (10 et 11 de l'article en anglais) présentent les moyennes des facteurs d'adoption et des variables de contrôles pour chaque groupe d'adoption.

Tableau 2: Moyenne des facteurs d'adoption

Facteurs	Non-adopteurs (n=119, 29.8%)	Diagnostique (n=159, 38.3% de l'échantillon, 56.8% des adopteurs)	Applicative (n=121, 29.2% de l'échantillon, 43.2% des adopteurs)	Adopteurs (App or Dia) (n=280, 70.2%)
	A	**B**[1]	**C**[2]	**D**[3]
Capacité d'innovation de l'exploitant	3,69	3,93*	4,24***	4,07***
Ressources perçues	3,01	3,36**	3,77***	3,54***
Avantage relatif de l'AP	3,91	3,85	4,26***	4,03
Utilité perçue de l'AP	3,48	3,81**	4,17***	3,97***
Compatibilité de l'AP	3,22	3,56**	4,08***	3,79***
Facilité d'utilisation de l'AP	3,05	3,30*	3,80***	3,52***
Caractère volontaire de l'AP	3,86	3,32***	3,19	3,26***
« Observabilité » de l'AP	3,48	3,44	3,75**	3,57
Information de l'AP	3,38	3,67*	3,82	3,74**
Qualité du support de l'AP	3,23	3,44	3,64	3,53**
Visibilité de l'AP	2,46	3,08***	3,31	3,18***
Image de l'AP	2,20	2,30	2,56*	2,41*
« Expérimentabilité » de l'AP	3,57	3,45	3,55	3,50
Connaissance des employés	2,11	2,44*	2,96**	2,67***

Si la différence est significative, le niveau est indiqué dans la colonne initiale de la comparaison. Ex: Quand la colonne D est comparée à la colonne A; la colonne D contient le niveau de la différence.

1- La colonne B est comparée à la colonne A

2- La colonne C est comparée à la colonne B

3- La colonne D est comparée à la colonne A

p <0.05*

p <0.01**

p <0.001***

Tableau 3: Moyenne des variables de contrôle

Facteurs	Non-adopteurs (n=119, 29.8%)	Diagnostique (n=159, 38.3% de l'échantillon, 56.8% des adopteurs)	Applicative (n=121, 29.2% de l'échantillon, 43.2% des adopteurs)	Adopteurs (App or Dia) (n=280, 70.2%)
	A	**B**[1]	**C**[2]	**D**[3]
Connaissance de l'opérateur 1 (connaissance générale de l'AP)	2,83	3,29***	3,78***	3,50***
Connaissance de l'opérateur 2 (capacité d'utilisation des logiciels)	2,92	3,17	3,50**	3,31**
Données historiques	3,67	3,68	4,22***	3,91
Habileté linguistique	1,79	2,01*	2,43*	2,19**
Âge de l'opérateur (années)	3,45 (44,5)	3,28 (42,8)	3,25 (42,5)	3,27 (42,7)
Éducation de l'opérateur	2,47	2,52	2,62	2,56
Âge de la machinerie (années)	10,37	9,63	7,94**	8,91**
Temps d'ordinateur (par jour)	41,44	39,32	50,48*	44,13
Grandeur de la ferme (revenu)	4,66 (199 000$)	5,06** (265000$)	5,34 ** (335 500$)	5,18*** (295 000$)

Si la différence est significative, le niveau est indiqué dans la colonne initiale de la comparaison. Ex: Quand la colonne D est comparée à la colonne A; la colonne D contient le niveau de la différence.

1- La colonne B est comparée à la colonne A

2- La colonne C est comparée à la colonne B

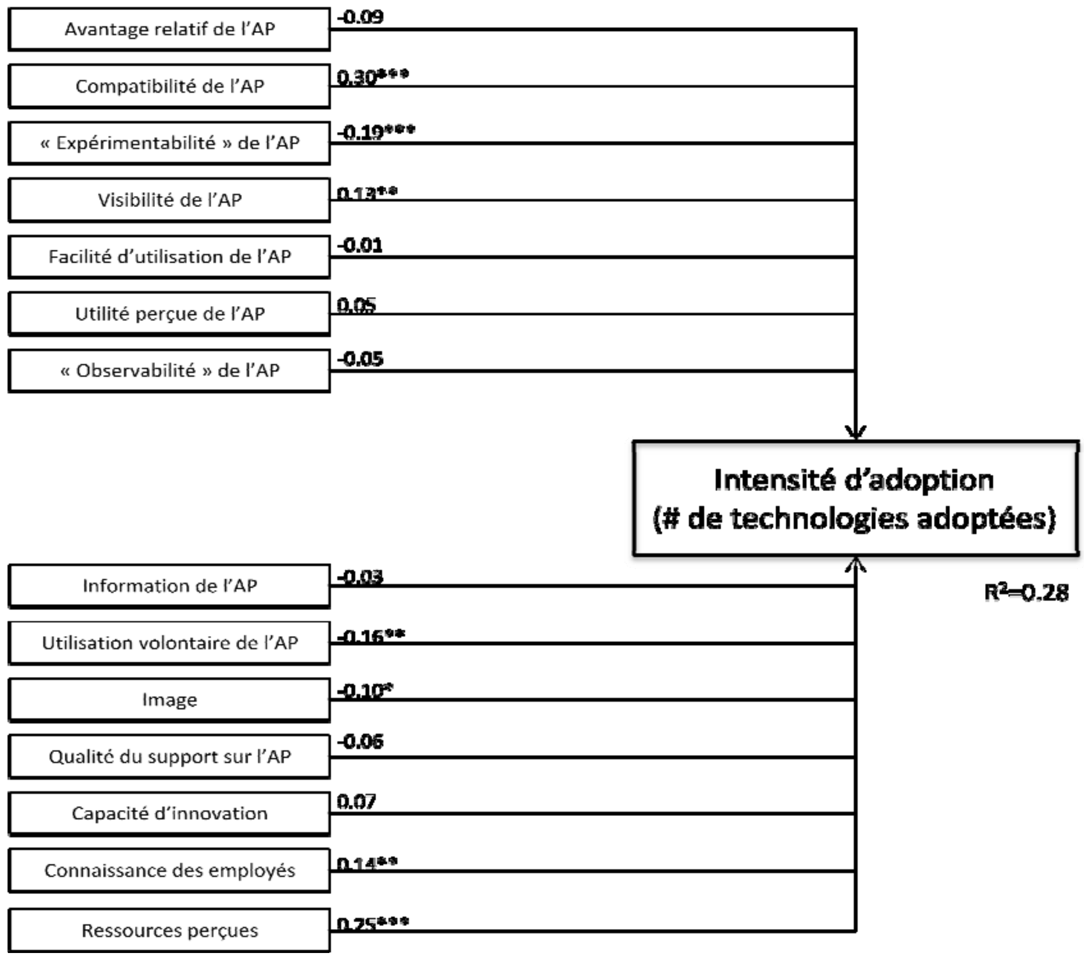
3- La colonne D est comparée à la colonne A

p <0.05*

p <0.01**

p <0.001***

Les résultats du modèle global d'adoption (l'adoption étant mesurée par l'intensité d'adoption) sont présentés dans la Figure 2.



Goodness of fit (Chi-square) = 4150.901
Root Mean Square Error of Approximation (RMSEA) = 0.079
Comparative Fit Index (CFI) = 0.716
p <0.05*
p <0.01**
p <0.001***
Résultats obtenus avec AMOS (voir annexe 18 de l'article)

Figure 2: Modèle d'adoption des technologies d'AP

Hypothèses

Le Tableau 4 (12 de l'article en anglais) indique les résultats des tests d'hypothèses.

Tableau 4: Résultats des tests d'hypothèses pour les facteurs d'adoption

	Résultats du modèle	Résultats des catégories d'adoption		
Facteur d'adoption	**Modèle global (# de techn. adopter)**	Adoption des technologies applicatives	Adoption des technologies diagnostiques	Adoption des technologies d'AP (oui/non)
	d	**c**	**b**	**a**
Avantage relatif de l'AP		H1c		
Compatibilité de l'AP	**H2d**	H2c	H2b	H2a
Visibilité de l'AP	**H4d**		H4b	H4a
Facilité d'utilisation de l'AP		H5c	H5b	H5a
Utilité perçue de l'AP		H6c	H6b	H6a
« Observabilité » de l'AP		H7c		
Information de l'AP			H8b	H8a
Caractère non volontaire de l'AP	**H9d**	H9c		H9a
Qualité du support de l'AP				H11a
Capacité d'innovation de l'exploitant		H12c	H12b	H12a
Ressources perçues	**H14d**	H14c	H14b	H14a
Connaissance des employés	**H15d**	H15c	H15b	H15a
« Expérimentabilité » de l'AP	**N-H3d**			
Image de l'AP	**N-H10d**	H10c		H10a

La présence du code de l'hypothèse dans le tableau indique que la relation est significative et affecte positivement la variable dépendante, ce qui confirme l'hypothèse.
Si le code de l'hypothèse est précédé par N-, la relation est significative, mais affecte négativement la variable dépendante, ce qui rejette l'hypothèse.
Une cellule vide indique que l'hypothèse n'est pas confirmée.
Connaissance de l'opérateur a été divisée en trois variables de contrôle qui ne sont pas présentées dans ce tableau.
Caractère volontaire est renommée *caractère non volontaire* puisqu'il affecte négativement l'intensité d'adoption.

Synthèse des résultats

Cette étude a identifié sept facteurs qui affectent l'intensité d'adoption. Cinq facteurs d'adoption affectent le nombre de technologies adoptées positivement : *connaissance des employés*, *ressources perçues*, *caractère non volontaire*, *visibilité* et *compatibilité* tandis que deux facteurs l'affectent négativement : *image* et « *expérimentabilité* ». La grandeur de la ferme est une variable de contrôle qui crée une différence significative dans le modèle. Les plus grandes fermes de l'échantillon sont particulièrement et positivement affectées par les facteurs *connaissance des employés*, *ressources perçues* et *compatibilité* et négativement affectées par *qualité du support*. Les plus petites fermes sont plus particulièrement et positivement affectées par *visibilité*, *compatibilité*, *utilité perçue* et *capacité d'innovation de l'exploitant* ainsi que négativement affectées par *avantage relatif*.

Discussion

Contributions pratiques

Quatre acteurs du secteur de l'agriculture peuvent avoir de l'influence sur certains facteurs d'adoption en vue d'encourager l'adoption des technologies d'AP : l'opérateur, le gouvernement, les associations et l'industrie de l'AP. Les contributions pratiques de cette étude consistent en des recommandations qui s’adressent à chaque acteur vis-à-vis des facteurs d’adoption qui se sont révélés significatifs. Ainsi, les opérateurs pourraient notamment adopter des styles de travail et acheter des équipements qui sont compatibles avec les technologies d’AP. Les gouvernements pourraient encourager la formation des employés. Les associations quant à elles, pourraient avoir des ressources humaines pour aider les opérateurs et répondre à leurs questions concernant l’AP. Finalement, l’industrie d’AP pourrait augmenter la visibilité de ces technologies par des pancartes affichées sur les exploitations qui utilisent ces technologies.

Contributions théoriques

Cette étude apporte une contribution théorique au niveau méthodologique, au niveau de la théorie de diffusion de l’innovation ainsi que pour la littérature en AP. Plus spécifiquement, il est possible de mentionner deux contributions importantes. Premièrement, l’impact de la taille de la ferme sur les facteurs qui influencent l’intensité d’adoption a été identifiée et devra être considéré dans les recherches futures sur le sujet. Également, cette recherche a permis de reconnaître la pertinence de huit nouveaux facteurs d’adoption qui n’étaient pas inclus dans la littérature d’AP : *compatibilité, visibilité, caractère non-volontaire, qualité du support, capacité d’innovation de l’opérateur, utilité perçue, avantage relatif* et « expérimentabilité ».

Limites

Trois limites importantes doivent être spécifiées. Premièrement, étant donné qu’il y a eu une prépondérance de répondants provenant de grandes fermes, cette étude peut difficilement être transposée au contexte des plus petites fermes de la province sans une nouvelle validation du modèle pour les plus petites fermes. Deuxièmement, le modèle qui a guidé l’étude ne comportait pas l’item *facilité de travail* comme composante du facteur d’adoption *avantage relatif* puisque ce dernier a seulement été identifié via la question ouverte du questionnaire. Finalement, la causalité des variables indépendantes qui affectent la variable dépendante pourrait être inversée puisque l’adoption pourrait influencer positivement *connaissance des employés* donc l’inverse du modèle théorique. Une étude longitudinale pourrait venir éclaircir cette possibilité d’une causalité inversée.

Conclusion

Cette étude vise à répondre à la question de recherche suivante: quels sont les facteurs qui influencent l’adoption des technologies d’AP des agriculteurs au Québec? Les résultats indiquent que cela dépend de la taille de l’exploitation. Un objectif secondaire de cette étude est d’évaluer l’état actuel du phénomène d’adoption au Québec. L’étude révèle qu’il y a un taux d’adoption de 70,2% dans les plus grandes fermes du Québec.

Cette étude a contribué à enrichir trois domaines de recherches : la littérature d’adoption et d’innovation, la littérature d’adoption en SI et la littérature en AP. Aussi, plusieurs contributions pratiques ont été formulées afin de faciliter l’adoption de ces technologies prometteuses mais au taux de pénétration très lent.

Acknowledgements

Writing a master's thesis: Key success factors

(NB: read with a sense of humor)

Success factors have been part of every researcher's publications at one time or another. That being said there are no articles explaining to novice researchers the key success factors for successfully finishing a master's thesis.   This brief page of acknowledgement will outline potential avenues for future research.

Key success factors (for this research): subject, methodology, thesis director, support group and family.

The right subject is the first success factors. Choosing a subject that you find motivating and interesting is the only thing that will keep you from staying in bed in the morning. Your subject has to be a part of you and your passions.

> "The subject of PA technologies has been a culmination of my passions in my first quarter century. I want to thank my Nonno, Giacomo Grimaudo, for introducing me at an early age to everything on a farm. This was the first step in this master's thesis and it started 20 years ago. Thank you"

The methodology chosen will more than likely determine the time you spend on your thesis. Don't use questionnaires if you don't want to wait around for others.

> "Because I wanted and needed to go straight to the source (producers) I required a great deal of support from outside HEC Montréal. I need and want to thank the "Fédération des Producteurs de Cultures Commerciales du Québec" for generously allowing me to send questionnaires to their members and being by far the most efficient federation I have ever seen. Without them this research would never have been possible. Thank you."

A good thesis director is the foundation for a successful paper. He must push you without breaking you, he must give constructive criticisms, he must give you the impression that you aren't wasting your time and he must acknowledge your priorities.

> "Benoit, you have done all this and more. I can't imagine this work if you hadn't given me such valuable input whenever I submitted something to you. Thank you"

A support group is there when your director has gotten under your skin☺. They are there to vent your frustrations, give you a heads up when you can't see the light at the end of the tunnel, go camping when you can't read another article and help you put together 2000 questionnaires for mailing.

"Jerome, Nicolas, Jerry, Jonathan P, Ariane, Remi, Genevieve, Gaëlle, Mathieu, Claire, Alex and Julie, without all of you these past 2 years would not have been nearly as enjoyable or as enriching. It was a delight to be surrounded by such phenomenal friends".

Family is a funny thing. They have no idea what you are actually doing and are rather jealous that you "seem" to be doing nothing all day but despite that, they are always there for you.

"I want to thank my Nonno and Nonna for lifting part of the financial burden of university. Thank you for making all this possible by making my education a priority".

"I want to thank my mom, Lyne Millette, who never thought I would make it to university or even read for that matter. I want to thank her for allowing me to stay at home until I finished my schooling, for always encouraging me no matter what, for having supper when I'd get home late, for putting on the headset to watch TV when I was reading articles at 10PM on a Sunday night, for just being there and for all the little things you've done to make this possible. Thanks mom".

"And last but not least, to the one person who quite literally has been with me 24 hours a day, 7 days a week for the past 3 years, my North Star, Claire. You have been my companion for all these adventures and hopefully for many more yet to come. To the most fantastic woman I know. Thank you for everything".

I hope this contribution will guide future generations of researchers ☺

Sincerely,

Jonathan

Table of contents

List of Figures

List of Tables

Section 1 - Introduction

Context of Quebec's agriculture

An important part of Quebec history resides in the family farms that exploited the land before the industrial revolution. It has been a crucial element in Quebec's economic, cultural and social survival. Quebec farmers have always had the task of feeding their province's population. Now they must not only provide food for the population of Quebec but they must do so in a global and competitive environment. To accomplish this task, Quebec farmers have become specialized and far more productive. Throughout this transformation, farms have been getting larger. Their productivity and environmental impact has increased accordingly (Feder et Umali, 1993; Ferguson, 2002; MENV, 2003; Fountas, Blackmore, Ess, Hawkins, Blumhoff, Lowenberg-Deboer et Sorensen, 2005).

In the 2008 report, AASBF (Agriculture and Agrifood: Securing and Building the Future), written by the CAAAQ, "Commission sur l'Avenir de l'Agriculture et de l'Agroalimentaire Québécois" identified other challenges that Quebec's agriculture industry is facing. The challenges are diverse: growing farms, shrinking rural population, environmental constraints, traceability issues and productivity challenges.

It is well documented that there are less and less farms in Canada and Quebec. The number of farms in Quebec has dropped from 41 448 to 30 675 from 1986 to 2006 which represents a reduction of 25.99%. However, the land being used for crop production has increased from 1 744 396 hectares to 1 933 274 representing a 10.83% increase. The average farm size for crop production has thus increased from 48 hectares to 81 hectares in the same time span (Statcan, 2007), which represents a 169% increase. The rural population has decreased from 1 541 170 to 1 420 330 (7.8%) and the farm population has decreased from 109 460 to 91 455 (16.4%) from 1996 to 2001 (Statcan, 2007). Fewer farms and less people are working a greater territory. This trend has been present since the 1960's and shows no signs or reasons for stopping according to the AASBF report (CAAAQ, 2008). There are now fewer pairs of eyes capable of identifying diseases, infestations, need for fertilization and other yield decreasing instances in specific areas of a crop, which can lead to outbreaks.

The environmental constraints in Quebec have also been discussed in the public circles especially since the contamination of many lakes in Quebec rural areas with "algue bleue", cyanobacteria. In September of 2007, Quebec was dealing with over 151 lakes and rivers contaminated with cyanobacteria (MDDEP, 2007). This is about twice as much as in 2006. This contamination is not solely a consequence of agricultural production around these lakes but it does have a significant impact. Phosphorus compounds are used to fertilize nearby fields and some of it ends up in the lakes and rivers. While society cannot entirely ban agricultural activity around these areas, it can attempt to lower the impact of farms on local environments.

Traceability is becoming a key challenge in the food industry. Traceability is the ability to trace the history, application, or location of a product (GDT, 2006). In the agricultural context, this definition encompasses all products fit for human consumption. In the 1990's, cattle was the main focus of traceability over concerns of mad cow disease. Legislation was put in place that required every animal to be tagged and tracked throughout its useful life cycle. This can lower human risk when diseases are identified. Crops will be no exception to this new trend. The outbreak of salmonella in US produced tomatoes in 2008 is an example of the risk. Reducing the economic impact of recall and human safety are the biggest advantages of traceability of food products. In Canada, there was over 61 recalls or allergen warnings in the first eight months of 2008 (CFIA, 2008).

Finally, productivity is an ongoing battle that operators must continually wage in order to stay competitive. US productivity still slightly outpaces Canadian and Quebec farmers (AAFC, 2008). This has been the norm for well over 40 years. There is also an ongoing international debate on the reduction of western agricultural subsidies. Should these discussions lead to concrete actions then Quebec's farmers will have to compete with developing countries without public support.

These are not problems that can be overcome easily and there doesn't seem to be a single answer to solve these problems but a combination of legislative and technological approaches are probably a means to a solution. This study will focus on a potential technological solution, precision agriculture technologies (PAT). These technologies have shown promise to help on these fronts.

Context and definition of precision agriculture (PA)

Agriculture is a field of activity that has not ceased to evolve throughout human history. Mechanization in the 20th century revolutionized agriculture. In more modern times, the 90's, technological advance has to a certain extent, pushed productivity while minimizing the environmental impact of the industry. This has been accomplished by reducing inputs such as fertilizer, pesticides and other inputs (Stan G Daberkow and al., 2006). The term PA (precision agriculture) was popularized in the 90's at a time when information technologies (IT) began making its introduction in the agricultural industry. The use of precision agriculture technologies allows the collection and analysis of large quantities of information from the crops and then to act accordingly. This allows for better decision making with less manpower over much greater territories. The overall goal of PA is "to increase the number of (correct) decisions per unit area of land per unit of time with associated net benefits'' (McBratney, 2006). An operator must make multiple decisions in the course of a growing season. These decisions pertain to a great many aspects of the work: the quantity of fertilizer to use depending on soil type, the type of culture to plant according to current soil conditions, the quantity of pesticides to use on a specific crop etc. Making a decision based on a specific location, thus a specific soil type, crop type etc., is the concept of site-specific management (SSM). Fertilizer use, crop choices and pesticide use are but a few examples of decisions that an operator must make. These are not simple questions; they require important quantities of information and analysis in order to make the right decisions. These decisions will, in the end, affect the environmental impact of the exploitation, the quantity of goods produced, the quality of the crop produced and the profitability of the crop. The literature indicates that PA is the combination SSM and information technologies. This combination gives operators the ability to effectively micro-manage fields that have been, up until the adoption of PA technologies, managed as a whole. In order to do this, specific technologies are required to collect data and act on it. These technologies can be either diagnostic or applicative in nature. This concept and these technologies are explored and explained later in this paper.

The literature suggests that PA can help resolve some of the challenges that Quebec faces in its agricultural industry: productivity can be increased (Robert, 2002), costs can be minimized by diminishing inputs (Bongiovanni et Lowenberg-Deboer, 2004), the impact on the environment can be reduced due to diminishing input (Whitley, Davenport et al., 2000), traceability can be improved (Godwin, Earl et al., 2002) and a reduction of manpower made easier (Amenozima, Ismail et al., 1997). Despite these advantages PA is not widely used in Quebec. About 5% of farms used precision agriculture technologies in the form a GPS system in 2000 (Jacques, 2007). This study will try to identify which adoption factors are behind the adoption of this technology, and try to explain what appears to be a low adoption rate.

Research objectives and contributions

Adoption of PA technologies is a problem that has already been presented in the literature (Daberkow et McBride, 2003). Despite this presence in the literature very little has been done specifically for Quebec and unfortunately U.S. studies can't be easily transferred to Quebec since the geographical, climate, structural and political specificities affect the industry directly. Certain conditions have been identified as being important in the adoption and profitability of PA. These conditions include farm size, specialization of the operation, computer familiarity, operator's age and education (McBride et Daberkow, 2003). This study examines which factors are facilitating or impeding the diffusion of PA technologies in the province of Quebec. It uses the theory of "Diffusion of innovation" (Rogers, 1962).

PA technologies are important and are present in the literature but there is a gap in the literature from a methodological stand point. There is not a full understanding of why individual operators adopt or not PA technologies. The diffusion of innovation literature can help fill part of that gap. This will lead to an understanding of the factors that influence the adoption of PA technologies. Once they are identified, specific actions could be put in place to reduce the adoption barriers that operators are facing. This could take the shape of better educational programs, the creation of better financial support programs etc. Increasing adoption of PA will help resolve the problems that are indentified in the report "Agriculture and Agrifood: Securing and Building the Future".

A secondary objective is to assess the current adoption rate of precision agriculture technologies among Quebec's largest farms. Since Quebec has a different environmental and structural context from the U.S., the conditions that lead to adoption may differ as well. This study will help identify these conditions.

Research question

What are the factors that influence the adoption of precision agriculture technologies with Quebec farmers?

Section 2 - Review of literature

Review of literature on precision agriculture (PA)

Introduction

The goal of this section is to present the major themes associated with precision agriculture (PA). This section begins with a definition and an explanation of PA and its relationship with traditional methods. This is followed by the goals and benefits associated with PA and finally, the classification of PA technologies.

Context and definitions

Precision agriculture and PA technologies have been available since the 1990's (Daberkow et McBride, 2003). There is no real consensus about the agricultural enterprises concerned by this technology (McBratney, Whelan, Ancev et Bouma, 2005). For example, there are diverging views about whether PA is restricted to field crops or if it also encompasses herd management. This study looks solely at crop management.

The first element required to understand PA is the concept of SSM (site specific management). Site specific management is the micromanagement of a crop defined as ''matching resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field" (Wheland et McBratney, 2000 : 265). In the past it was known as "plant by soil" (Robert, 2002). Unlike the predominant agricultural practices that treat a single crop as a single field, SSM treats the field and not the crop. This allows the operator to optimize soil conditions throughout an entire field despite the variations from one part of the field to another such as: water retention, fertilizer effectiveness etc. (Wheland et McBratney, 2000). This practice optimizes field conditions but it requires a great deal of observations from the operator. This was possible in the early stages of agriculture since an operator would deal with a field that was exploitable by man or cattle power. This situation disappeared during the mechanization of agriculture where it was more cost effective to treat entire fields as a whole (Stafford, 2000). IT now gives us the chance to apply this concept in modern with the automation of SSM practices (Bongiovanni et Lowenberg-Deboer, 2004). This automation allows operators to collect the required data from the field, analyze that data and react accordingly. It is the ''electronic monitoring and control applied to data collection, information processing and decision support for the temporal and spatial allocation of inputs for crop production'' (Lowenberg-DeBoer et Swinton, 1997 : 371)

Technology

There are different types of technologies required in PA. They can be separated into two families: diagnostic and applicative (McBride et Daberkow, 2003). The automation of SSM requires two steps. The first part is the gathering and analysis of field data. This falls into the diagnostic technique family. The second part is the allocation of inputs on the field, this falls in the applicative technique family.

Diagnostic techniques

Diagnostic techniques can be defined as "methods of gathering data and analyzing spatial variability at the sub-field level, including such technologies as yield monitors and soil and plant attribute sensors"(McBride et Daberkow, 2003 : 24). They are necessary to determine spatial variability in fields, nutriment requirements and other field imbalances before variable rate techniques can be adopted. Operators can use diagnostic techniques without applicative techniques. This could be perfectly appropriate if the field is homogenous. If the field is not homogenous, then the use of applicative techniques could be beneficial to the operator (McBride et Daberkow, 2003).

Applicative techniques

Applicative techniques are "computer controlled devices which vary input applications as machines move across the field"(McBride et Daberkow, 2003 : 24). The use of applicative techniques requires the prior use of diagnostic techniques. Therefore, this study will look at both families of techniques. An adopter of applicative technologies is necessarily an adopter of diagnostic technologies.

PA technologies

The technologies used are the tools required make PA work such as GPS, GIS, yield monitors, variable rate application, crop scouting and remote sensing, guidance and navigation. A brief description and their classification are presented in Mackay (1997) and is summarized in Table 1.

Table 1: List and description of PA technologies

Name	Description	Category
GPS:	The global positioning system is used for topographic surveying or in conjunction with other sensors to provide geo referenced (x, y coordinate) maps of yield, salinity, or anything else which can be measured and would require mapping within a field crop.	Diagnostic
GIS:	Geographic information system is a database of information in which can be stored data such as soil type and other location specific information.	Diagnostic
Yield monitors:	These devices collect data from small and various areas in crop fields to measure potential variations. They can also collect protein and moisture data in the soil. These monitors are available for most grain and bulk crop harvesters, either as an add-on or pre-installed.	Diagnostic
Variable Rate Application:	These devices can apply fertilizer, seed, and pesticides using controllers to vary the rate on the go. This can be computer controlled according to a prescription map or varied manually. They are installed on the sprayer, either as an add-on or pre-installed, in order to treat the crop field.	Applicative
Crop Scouting and Remote Sensing:	These devices are used to identify problems in the crop and make records of sloughs, field boundaries, rocks, etc.	Diagnostic
Guidance and Navigation:	These systems using differential GPS can be used for parallel tracking while spraying or swathing. The GPS navigation system can be used to return to a point with known coordinates to spot spray, soil sample at the same location, or return to a rock to pick it up.	Applicative

Name	Description	Category
Software:	These programs are used with almost every other technology for PA. GPS uses software to record speed, paths and other location specific information. Variable rate applicators use software to calculate and control the quantity of input required. Etc.	Applicative and/or diagnostic

These technologies are for the most part modular, so they can be mixed to fit the producer's needs and create a system (Mackay, 1997). However, they are made to be used together. When interconnected to form a whole, they offer net returns by using resources more effectively (Mackay, 1997). This relationship is especially true between the two technology groups: diagnostic technologies and applicative technologies. Diagnostic technologies can identify specific areas that require corrections. Even though this in itself can help the producer identify problems early on, it cannot reduce the cost of inputs required to treat the problem. Diagnostic techniques alone cannot lower the operators total consumption of inputs because the operator would have to spray the same amount inputs over a far greater area than he would actually need according to the data collected by the diagnostic technologies. To do this he would require technologies from the applicative category that would vary the quantity of inputs prayed in different areas of the crop field. Using both of these in concert will reduce cost and maximize profit more efficiently than using them alone (Young, Kwon, Smith et Young, 2003).

The technologies seen above are classified under map based technologies since they all require the use of GPS to know where they are and where to take the appropriate actions. They could be merged into single units that would diagnose and treat fields as they advance. This is known as the "on the go" concept. This new type of unit has not yet achieved maturity and is not used in the industry. This may change as this type of technology progresses (Zhang, Wang et Wang, 2002).

Profitability

PA can help reduce costs and increase revenue for operators. It can reduce costs by reducing the inputs required such as fertilizer, pesticides, herbicides and fungicides. It can also reduce costs by reducing the manpower required on the farm (Amenozima, Ismail et al., 1997). It can increase revenue and productivity (Robert, 2002) by increasing crop yield and crop quality by better managing field variability. PA technologies provide operators with opportunities to change the distribution and timing of fertilizers and other agrochemicals based on spatial and temporal variability in fields. For example, operators can make economic analyses based on the variability of a crop yield in a field to obtain an accurate assessment of profitability. "A farmer could verify that, for 70% of the time, 75% of the barley grown in a field would yield 3.8 tones. By knowing the cost of inputs, farmers can also calculate the cash return over the costs for each hectare. Certain parts within a field, which always produce below the breakeven line, can be isolated for the development of a site-specific management plan" (Zhang, Wang et al., 2002 : 117).

A profitability review of the literature in 2000 revealed that two thirds of all studies showed benefits, while a quarter showed mix results (Lambert et Lowenberg-DeBoer, 2000). Of the 108 studies that reported economic results, 69% indicated positive net returns for a given PA technology, while 12% indicated negative returns. There were 21 articles indicating mixed results (19%).

Environment

PA technologies are tools that can help the industry achieve sustainable agriculture. By enabling the operators to use only the inputs necessary, they can limit their environmental impact on the surrounding lands. This is of growing concern in Western countries. New legislation may go as far as to limiting quantities of agrochemicals or forcing operators to transfer all data relevant to chemicals (Zhang, Wang et al., 2002). PA was indeed shown to reduce water contamination and reduce erosion (Schumacher, Lindstrom et Schumacher, 2000; Whitley, Davenport et al., 2000). In fact, most of the literature on the subject concludes that PA can contribute in many ways to long term sustainability of agricultural production (Bongiovanni et Lowenberg-Deboer, 2004).

Current adopters

Operators that have adopted PA technologies are so far mostly utilizing map based approaches (Zhang, Wang et al., 2002) that use a combination of specific technologies such as: GPS for guidance and positional data, GIS for soil mapping, yield monitors for yield mapping and VR (variable rate) fertilizer applicators. The use of these technologies does not seem to be affected by geographic location of the operator (Fountas, Blackmore et al., 2005). A study comparing the use of PA in the US Corn Belt and Denmark concluded that operators use essentially the same technologies and face similar problems such as: lack of technical knowledge, time constraints and cost. A similar situation should be found with operators in Quebec, since Quebec seems to share certain attributes with both countries. The supply of PA services resembles the US. Quebec's farm size is similar to those of Denmark. Denmark's average farm size was evaluated at 57 ha in 2004 (Levin, Langer et Frederiksen, 2006) versus Quebec's average farm size of 81 ha in 2006 (Statcan, 2007), whereas the State of New-England average farm size was 143 ha in 2003 (USDA, 2006).

Review of literature on the diffusion and adoption of innovations

Introduction

Diffusion and adoption has been explored by researchers for over 70 years. It is present in fields such as: anthropology, sociology, education, agriculture etc. Diffusion and adoption of innovation theories are not new in the agricultural field. In the 1940's, Ryan and Gross (1943) published a study on the diffusion of hybrid seed among Iowa farmers. The following section reviews the current body of knowledge on diffusion and adoption of innovations. This section will first present the core concepts of adoption and diffusion. And then, present the main theories of adoption and diffusion of innovation in IS.

Definitions and concepts

An innovation is a new idea. This idea can be a recombination of old ideas, a scheme that challenges the present order, a formula, or a unique approach which is perceived as new to the individuals involved (Zaltman, Duncan et al., 1973; Rogers, 2003). The idea doesn't need to be universally new, only perceived as new by the group in question (Ven, 1986). An innovation is normally perceived as useful. For this to be true, it must be an idea that is profitable, constructive, or solve a problem.

The innovation-decision process is a mental process through which an individual passes from first hearing about an innovation to final adoption (Rogers, 2003). In order for the innovation-decision process to happen, the information relative to the innovation must be diffused throughout the given population. There are different theories on how this process is accomplished.

Rogers defines diffusion as a process by which an "innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003 : 5). Diffusion occurs within a society or a group, adoption pertains to an individual (Rogers, 2003). This study will focus on the individual level, thus the adoption of the innovation.

IT adoption theories

There are two lines of research for IT adoption theories : models based on psychology and models based on the diffusion of innovation (Nah, Tan et al., 2004). The first type is based on psychology, like the Theory of reasoned action TRA (Ajzen et Fishbein, 1980), the theory of planned behavior (TPB) (Ajzen, 1985; Ajzen, 1991) and the technology acceptance model (TAM)(Davis, Bagozzi et Warshaw, 1989; Davis, 1989). The second line of research is based on the diffusion of innovation (DOI)(Rogers, 2003).

Despite the differences in the origin of TAM and DOI, these two adoption models are quite similar (Nah, Tan et al., 2004). When TAM was originally created, it proposed two constructs: perceived usefulness (PU) and perceived ease of use (PEOU). Both of these constructs are among the perceived characteristics of innovations (Rogers 2003). Since TAM was suggested in 1989, it has been adapted in order to stay relevant with changing technologies (Benbasat et Barki, 2007). Constructs such as trust, top management support, innovativeness etc. have been added to the model. Since there are no commonly accepted adoption models in IS (Benbasat et Barki, 2007), this study will review the adoption factors in the IS and PA technologies literature and incorporate constructs that could be relevant in a PA technologies adoption model.

It is important to note, that the "context to which the theory is being applied matches well with the context in which the theory was developed" (Fichman, 1992 : 18). The context could not be more appropriate since Rogers developed the core of his adoption theories using the agricultural sector. Therefore, DOI is an appropriate theoretical foundation on which to base this study.

Limits of DOI

There are four limits that have been identified in the IS adoption literature that could impact this study: the unit of study, the interdependence of users, the absence of distinction between different types of innovation and finally, the comparison of different studies and models that do not refer to the same stages of adoption. These four limits will be discussed below.

The first limit is the unit of study. This limit will not be a concern in this research since the adoption of the innovation is made on an individual basis and are negligibly influenced by organizational factors. Farms are operated by owners who are making decisions individually. Rogers's classical theory of diffusion mostly applies when the innovation is an individual adoption, and/or an independent-use technology (Fichman, 1992). This model will therefore fit the unit of study well.

The second limit is the interdependency of users. There are two ways interdependency could have an impact. First, it may depend on other users to use it in order to make the innovation useful for the adopter. This is not the case for PA technologies. The second way interdependency could be relevant is if the use of a technology is integrated into organizational routine (Nelson and Winter, 1982). In the case of PA technologies there is no organizational process to adhere to and thus is not a constraint (Fichman, 1992).

The third limit is the type of innovation. Comparing adoption factors when innovations are different is problematic. Innovations can be classified in many different ways but the literature presents three different typologies based on innovation complexity, distinction between a product innovation and a process innovation, and finally on the field of application of a technology (Paré et Trudel, 2007). PA technologies can easily qualify as a type 3b technologies according to Swanson (1994) since the impact of the innovation is on the operations in the fields. However, these typologies were created on the organizational level and not the individual level. Therefore, this study will integrate the factors that Swanson puts forward in the literature since they are at least partially relevant in this context. Rogers classical theory of diffusion mostly applies to simple technologies, as opposed to complex ones (Fichman, 1992). PA technologies are not complex since they rely solely on the knowledge of the operator and not on an existing network of users (Fichman, 1992). Therefore, Roger's classical theory of diffusion is likely to apply.

The final limit is the comparison of factors linked to specific periods of the adoption process. According to certain authors (Zaltman, Duncan et al., 1973; Eveland et Tornatzky, 1990) factors influencing the "initiation" period are different from those affecting the "adoption" period. This study will not limit itself to the list of factors that are identified for the adoption period. It will consider other adoption factors because the unit of study and the context of the study are different to those of previous studies (Zaltman, Duncan et al., 1973; Eveland et Tornatzky, 1990).

Adoption of innovation factors

There are many factors in the literature that can impact the rate of adoption of an innovation. The core factors, the perceived characteristics of the innovation, which generally account for at least half the variance of an innovation rate of adoption (Rogers, 2003) are described in Table 2.

Table 2: Perceived characteristics of the innovation

Characteristics of the Innovation	*Description (Rogers, 2003)*
Relative advantage	Is the innovation that we are thinking of adopting superior to prior practices or technologies?
Compatibility	Is there a fit between the innovation and the culture and methods?
Complexity	Refers to the difficulty in understanding and using the innovation.
Trialability	Being able to use the innovation before adopting it.
Observability	Can the results from others be seen by others?

Since Rogers (1962) introduced these adoption factors, other authors have added or subdivided these adoption factors to try to get a more specific view of different industries and technologies. Relative advantage was divided into relative advantage and image, observability was divided into visibility and result demonstrability, voluntariness of use was added and complexity was renamed into ease of use (Moore et Benbasat, 1991). A model was tested where compatibility was broken into prior experience, preferred work styles and values, and where result demonstrability was broken down into communicability and measurability (Compeau, Meister et al., 2007). Because of these attempts at specifying the factors a single model was not retained. All factors identified in the IT literature are presented in Table 3 in order to build a model specific to PA adoption.

Factors influencing the adoption of IT

PA needs to be treated as a systems approach since PA is information intensive (Blackmore, 2000). For this reason, all factors identified in the IT and small business literature that affects adoption of innovation can be relevant to PA. Both large and small farms management resemble small businesses since even large farms are operated by few individual and have single decision makers. A summary of all adoption factors identified in the IT and the small business literature can be found in Table 3.

Table 3: Factors influencing the adoption of IT innovations

IT and small business adoption factors	**Description of the adoption factors**	**Sources in the IT and small business literatures**
CEO's innovativeness (Risk attitudes)	To which level is the CEO considered innovative (Thong, 1999).	(Thong, 1999; Rogers, 2003; Bang Nam, Kyeong Seok et Myung Jin, 2006; Bhatti, 2007)
CEO'S IS knowledge	To which level does the CEO have IS knowledge (Thong, 1999).	(Thong, 1999; Bang Nam, Kyeong Seok et al., 2006)
Relative advantage of IS	The level to which an innovation is perceived as superior to the technology it is replacing (Aubert et Hamel, 2001).	(Meyer et Goes, 1988; Thong, 1999; Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et Beomsoo, 2003; Wee, 2003; Craig Van, France et Christie, 2004; Ilie, Slyke, Green et Lou, 2005; Bang Nam, Kyeong Seok et al., 2006; Syed Shah, Ali, Mohd Ismail Sayyed et Hishamuddin Bin, 2007)

IT and small business adoption factors	Description of the adoption factors	Sources in the IT and small business literatures
Compatibility of IS	Quality of an innovation that fits easily into values, culture and routine of an individual (Aubert et Hamel, 2001).	(Meyer et Goes, 1988; Thong, 1999; Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et al., 2003; Wee, 2003; Craig Van, France et al., 2004; Ilie, Slyke et al., 2005; Bang Nam, Kyeong Seok et al., 2006; Syed Shah, Ali et al., 2007)
Ease of use (Complexity)	Perception of the ease with which the innovation can be made usable (or integrated) in daily tasks (Aubert et Hamel, 2001).	(Meyer et Goes, 1988; Thong, 1999; Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et al., 2003; Wee, 2003; Craig Van, France et al., 2004; Ilie, Slyke et al., 2005; Bang Nam, Kyeong Seok et al., 2006; Bhatti, 2007; Syed Shah, Ali et al., 2007)
Business size	Size of the business adopting the innovation (Thong, 1999).	(Ein-Dor et Segev, 1978; Thong, 1999; Bang Nam, Kyeong Seok et al., 2006)
Employee' IS knowledge	Employee's knowledge of the IS or innovation in question (Thong, 1999).	(Thong, 1999; Bang Nam, Kyeong Seok et al., 2006)
Information intensity	The degree to which information is present in the product or service of a business reflects the level of information intensity of that product or service (Thong, 1999).	(Kwon et Zmud, 1987; Meyer et Goes, 1988; Thong, 1999)
Competition	The business environment in which the business operates (Thong, 1999).	(Kwon et Zmud, 1987; Meyer et Goes, 1988; Thong, 1999; Bang Nam, Kyeong Seok et al., 2006)
Observability (Result demonstrability)	Can the results from others be seen by others (Rogers, 2003)?	(Meyer et Goes, 1988; Thong, 1999; Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et al., 2003; Wee, 2003; Craig Van, France et al., 2004; Ilie, Slyke et al., 2005; Syed Shah, Ali et al., 2007)
Trialability	Being able to use the innovation before adopting it (Rogers, 2003)?	(Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et al., 2003; Wee, 2003; Craig Van, France et al., 2004; Syed Shah, Ali et al., 2007)
Quality of support	Perception of accessibility, rapidity, and how the support is provided (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001; Bang Nam, Kyeong Seok et al., 2006)
Image	Perception of the prestige and the value of the innovation (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001; Wee, 2003; Craig Van, France et al., 2004)
Information	Perception of the availability, quality and the value of the information produced by the innovation (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001)
Membership	Sense of belonging to the professional association (promoting the adoption) (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001)
Involvement	Mechanisms through which an individual feels part of the development, design, or implementation process of an innovation (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001; Mohammed et Glenn, 2007)
Perceived usefulness	Perception of the innovation's utility in the individuals routine (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001; Sangjo, Joongho et al., 2003; Bhatti, 2007)
Satisfaction	Evaluation of the fulfillment of the individual's expectation after a tryout of an innovation (Aubert et Hamel, 2001).	(Aubert et Hamel, 2001)
Voluntariness	The degree to which adoption of the innovation is viewed as a matter of personal choice, rather than external pressure (Compeau, Meister et al., 2007).	(Craig Van, France et al., 2004; Bhatti, 2007; Compeau, Meister et al., 2007)
Subjective Norms / Norms of the social systems	A person's subjective norm is determined by his or her perception that salient social referents think he/she should or should not perform a particular behavior (Ajzen et Fishbein, 1980 p.320).	(Aubert et Hamel, 2001; Bhatti, 2007)
Visibility	The perception of the actual visibility of the innovation itself as opposed to the visibility of outputs (Craig Van, France et al., 2004).	(Sangjo, Joongho et al., 2003; Craig Van, France et al., 2004; Ilie, Slyke et al., 2005)
Perceived resources	Extent to which an individual believes that he or she has the personal and organizational resources needed for using an information technology (Mathieson, Peacock et Chin, 2001).	(Sangjo, Joongho et al., 2003; Bang Nam, Kyeong Seok et al., 2006)
Perceived risk (Security / confidentiality)	Perceived risk increases with higher levels of uncertainty or with an increased chance of negative consequences (Campbell et Goodstein, 2001).	(Wee, 2003; Craig Van, France et al., 2004; Syed Shah, Ali et al., 2007; Kent, Katri et Daniel, 2008)

Review of Literature on the Diffusion and Adoption of Precision Agriculture

Introduction

The adoption factors associated with IT have been identified in the previous section. In order to make sure that there are no additional adoption factors in the PA literature, a review of literature on the adoption of precision agriculture technologies was done.

Adoption factors

There is a significant amount of literature that discusses or evaluates factors that influence the adoption of PA technologies (Feder and Umali, 1993; McBride and Daberkow, 2003; Baerenklau and Knapp, 2007). Factors will be grouped in the following categories: farm factors, operator factors, innovation factors and information source factors.

Farm factors such as farm size increases the probability of adoption of both diagnostic and applicative techniques at a decreasing rate (McBride et Daberkow, 2003). Location also has a positive impact on the probability of adopting diagnostic and applicative techniques. This is probably due to a higher concentration of vendors in a given area (McBride et Daberkow, 2003). The specialization of crop, importance of livestock (McBride et Daberkow, 2003) and age of capital stock (Baerenklau et Knapp, 2007) impacts the adoption of PA techniques.

Operator factors that impact adoption are: operator's education, major occupation, off farm employment, relationship to the land (tenants or owners) (McBride et Daberkow, 2003), training, education (Auernhammer, 2001; Kitchen, Snyder, Franzen et Wiebold, 2002; Fountas, Blackmore et al., 2005), borrowing capacity and risk management tendencies (McBride et Daberkow, 2003; Syed Shah, Ali et al., 2007). Education also impacts the adoption of diagnostic and applicative techniques. Greater education increases the likelihood of adoption (McBride et Daberkow, 2003). An increase in the operator's age reduces the likelihood of adoption of diagnostic and applicative techniques. Computer familiarity influences the adoption of diagnostic techniques (McBride et Daberkow, 2003).

The only innovation factor that impacts awareness is the use of complementary technology (McBride et Daberkow, 2003). Irreversibility is an innovation factor that negatively affects adoption of PA techniques (Baerenklau et Knapp, 2007). This article uses irrigation systems to build the model and like irrigation systems, tractors and harvesters need replacing after a certain amount of years. Water is the input of an irrigation system and seeds, fertilizers and other chemicals are the inputs of PA technologies. Both PA inputs and water (in certain geographic areas) have variable costs. Unlike an irrigation system, precision agriculture technologies are more easily disposable trough the sale of the equipment.

Information source factors such as: the use of crop consultants, special events, input suppliers, associations, mass media (McBride et Daberkow, 2003), research publications, conference preceding, newsletters, extension bulletins, industry guides, worldwide web, compact discs (Ferguson, 2002) and the use of extension services (McBride et Daberkow, 2003) also impact adoption. Keeping computer records increases the likelihood of awareness and adoption (McBride et Daberkow, 2003). Extension services increase the likelihood of adoption. Extension services are adult education programs that were established in 1914 by the Smith-Lever Act consisting of federal, state and county level of government. The main objectives of extension services is to help people acquire the understanding and skills essential for solving farm, home, and community problems. This is done through educational programs that make use of research findings emanating primarily from the U.S. Dept. of Agriculture and the state land-grant colleges and universities land-grant colleges and universities (Columbia, 2007).

Synthesis of factors in PA literature

Table 4 presents a list of factors identified in the PA literature that affects the adoption of PA.

Table 4: Synthesis of factors in the PA literature

PA literature adoption factors	Description	Sources in the PA literature
Training and Education	Education refers to the various forms of documentation, conferences, course available etc to the industry (Ferguson, 2002).	(Ferguson, 2002; Fountas, Blackmore et al., 2005)
Capital availability / Borrowing capacity	Capital availability and borrowing capacity relates to the operators access to capital (Daberkow et McBride, 2003).	(Feder, Just et Zilberman, 1985; Feder et Umali, 1993; Daberkow et McBride, 2003)
Risk attitudes / Risk management tendencies	Risk attitude is the way operators address risky situations (Bard et J.Barry, 2000)	(Feder, Just et al., 1985; Harwood, Heifner, Coble, Perry et Somwaru, 1999 ; Daberkow et McBride, 2003; Baerenklau et Knapp, 2007)
Farm size	The size of the exploitation (Daberkow et McBride, 2003)	(Feder et Umali, 1993; Daberkow et McBride, 2003)
Age of capital stock	This refers to the lifespan of the equipment, how close are we to a reinvestment in the capital stock (Baerenklau et Knapp, 2007).	(Baerenklau et Knapp, 2007)
Employee training	Knowledge that the employee has of PA (Kitchen, Snyder et al., 2002).	(Kitchen, Snyder et al., 2002)
Specialization of crop	The operator re-sows the same crop year after year (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Importance of livestock	Proportion of revenue obtained with livestock (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Operator's age	The age of the operator(Daberkow et McBride, 2003)	(Daberkow et McBride, 2003)
Operator's education	The number of years of academic education the individual has completed (Daberkow et McBride, 2003).	(Feder et Umali, 1993; Daberkow et McBride, 2003)
Major occupation	The main occupation of the operator is farm work or off farm employment (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Off farm employment	Does the operator have some sort of off-farm employment (Daberkow et McBride, 2003)?	(Daberkow et McBride, 2003)
Use of historical records / Computer record	The use of computerized historical data on yield and other operating data is kept and used (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Relationship to the land	An operator may be a tenant of the land or the owner of the land (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Use of extension services (Source of information)	Any extension services used by the operator(Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Use of crop consultants (Source of information)	Any crop consultants used by the operator (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)

PA literature adoption factors	Description	Sources in the PA literature
Special events (Source of information)	Event such as conferences and information sessions on new technologies (Daberkow et McBride, 2003)	(Daberkow et McBride, 2003)
Input suppliers (Source of information)	The supplier of the technology is the source of information (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Associations (Source of information)	These are associations that are forums of discussion for operators (Daberkow et McBride, 2003).	(Daberkow et McBride, 2003)
Irreversibility	In the advent that the operator changes his mind after having invested can the investment reversed ex: trough the sale of the equipment (Daberkow et McBride, 2003).	(Baerenklau et Knapp, 2007)
Mass media (Source of information)	Information acquired trough mass media (television, radio, internet etc.) (Daberkow et McBride, 2003)	(Feder et Umali, 1993; Daberkow et McBride, 2003)

Mapping of factors identified in the IT and PA literature.

Table 5 presents a list of adoption factors identified from the IT literature and small business literature (column 1). These adoption factors were sometimes adapted for use in the agricultural industry (column 2) and finally, the sources in the PA literature where the adoption factors were identified (column 3).

Table 5: Mapping of factors identified in the IT and PA literature.

Adoption factors from IT and small business literature	Factors contextualized to agriculture	PA literature sources
1	**2**	**3**
CEO's innovativeness	Operators' innovativeness (risk attitudes)	(Feder, Just et al., 1985; Baerenklau et Knapp, 2007)
CEO'S IS knowledge	Operator's knowledge	Not identified
Relative advantage of IS	Relative advantage of PA	Not identified
Compatibility of IS	Compatibility of PA	Not identified
Ease of use (Complexity)	Ease of use of PA	Not identified
Business size	Size of the farm	(Daberkow et McBride, 2003)
Employee IS knowledge	Employee PA knowledge	(Kitchen, Snyder et al., 2002)
Information intensity	Information intensity	Not identified
Competition	Competition	Not identified
Observability	Observability	Not identified
Trialability	Trialability / Reversibility	(Baerenklau et Knapp, 2007)
Quality of support	Quality of support	Not identified
Image	Image	Not identified
Information	Information	Not identified
Membership	Membership (Not necessary since they are all members of the "Fédération des Producteurs de Cultures Commerciales du Québec")	(Daberkow et McBride, 2003)
Involvement	Involvement (Proportion of operators working in partnership or in direct collaboration with the PA industry is insignificant and will not be integrated in the questionnaire)	(Daberkow et McBride, 2003)
Perceived usefulness	Perceived usefulness	Not identified
Satisfaction	Satisfaction	Not identified
Voluntariness	Voluntariness	Not identified
Subjective Norms / Norms of the social systems	Subjective Norms / Norms of the social systems	Not identified
Not identified	Training and education	(Ferguson, 2002; Kitchen, Snyder et al., 2002; Fountas, Blackmore et al., 2005)
Socioeconomic characteristics	Age of operator (Control factor)	(Daberkow et McBride, 2003)
	Age of capital stock (Control factor)	(Baerenklau et Knapp, 2007)
	Operators education (Control factor)	(Daberkow et McBride, 2003)
	Use of historical records (Control factor)	(Daberkow et McBride, 2003)
Perceived resources	Borrowing Capacity	(Feder, Just et al., 1985; Daberkow et McBride, 2003)

Adoption factors from IT and small business literature	Factors contextualized to agriculture	PA literature sources
1	2	3
Perceived risk (Security and confidentiality)	Perceived risk (Security and confidentiality)	(Fountas, Blackmore et al., 2005)

Table 5 indicates that many of the standard IT adoption factors are not present in the precision agriculture literature. Relative advantage, compatibility, ease of use etc. are not found in the PA literature. Thus, there is an interest in undertaking this study using IT adoption factors.

Research model and research questions

The research model is based on other IS adoption model (Thong, 1999; Aubert et Hamel, 2001). These models are the basis for the model created for this study. The model was built iteratively during the literature review during which the items and the adoption factors that would form the questionnaire were identified. During this process, independent variables that were not relevant to this study were discarded. Those that were relevant were included in the model. Some variables were merged with others when there was concept overlap and when the items measuring the construct were appropriate.

From the list of 23 IS adoption factors in Table 3 and 21 PA adoption factors in Table 4, 15 adoption factors were selected for the model. These adoption factors were selected because they were appropriate to this study's context and its focus on applying DOI for this type of innovation.

The following adoption factors were retained in the model: CEO's IS knowledge was renamed operators PA knowledge but was eliminated from the model during the analysis of the model. *CEO's innovativeness* was renamed to *operator's innovativeness* and combined with *risk attitudes*. *Risk attitudes* and *operators innovativeness* were merged since they conceptually overlap. An innovative operator is an operator that is willing to take risks. *Risk attitudes* and *risk management* was also identified in the PA literature and was thus included in *operator innovativeness*. *CEO's IS knowledge* was renamed to *operator's PA knowledge*. *Compatibility of IS* was renamed to *compatibility of PA*. The adoption factor *ease of use/complexity* was named *ease of use of PA*. *Employee IS knowledge* was renamed *employee PA knowledge*. The PA literature identified *employee training* as an adoption factor and it was thus merged with *employee knowledge*. The adoption factor *observability/results demonstrability* was named *observability of PA* and was included in the model. *Trialability and reversibility* were merged into *trialability*. Acquisitions that can be sold off are reversible investments. PA technologies are investments that can be sold with relative ease. A reversible decision is very similar to the concept of *trialability*. This was also identified as *irreversibility* in the PA literature. Since the two concepts were similar in this context it was decided to merge them in order to reduce the number of variables in the model. *Quality of support* was renamed to *Quality of support of PA*. *Image* was also integrated into the model. *Information* was renamed *information of PA*. *Perceived usefulness* was renamed into *perceived usefulness of PA*. *Voluntariness* was renamed to *voluntariness of PA*. *Subjective norms/norms of the social systems* were merged with *voluntariness*. Despite the fact that *voluntariness* and *subjective norms* are not exactly the same construct, they are similar (Compeau, Meister et al., 2007). A construct was identified that would cover both *voluntariness* and *subjective norm*, see the section "Measurement of adoption factors" and see Appendix 17. *Visibility* was renamed *visibility of PA*. *Perceived resource* was also included into the model. This adoption factor was merged with *capital availability/borrowing capacity* that was identified in the PA literature. *Relative advantage of IS* was renamed *relative advantage of PA*. This variable was considered an independent variable like in Thong (1999) but unlike Aubert (2001) who used it as an intermediary variable. It was decided to use *relative advantage* as an independent variable because the items constructed to measure *relative advantage* did not measure whether or not the technology was better than its predecessors directly. It measured whether PA technologies achieved their goals and therefore were better than their predecessors. Because of this difference it seemed that relative advantage could not easily be an intermediary variable and thus was integrated into the model as an independent variable.

The following factors were not retained in the model or as a control variable: *Information intensity* was not included in the model because this variable is meant to compare organizations in different industries. Since all the organizations in this sample are in the same industry this adoption factor was not relevant. *Competition* was not integrated in the model because, like *information intensity*, this adoption factor is used to compare organizations in different industries. *Membership* was not retained because all the organizations in the sample are part of the same professional association. *Involvement* is another adoption factor that was not retained because the quantity of organization in the sample that could have been involved in the development of PA technologies is too small to make them statistically significant. *Satisfaction* was not retained in the model because the study in which it was used (Aubert et Hamel, 2001) was a pilot study for an innovation that studied the intention to adopt not the intensity of adoption. Also, s*atisfaction* was not significant in Aubert et Hamel (2001) thus, this adoption factor was not included in order to reduce the amount of independent variables in the model. *Perceived risk (security and confidentiality)* was not included in the model because the only confidentiality and security issue that operators could have with precision agriculture technologies is with the ownership and location of data relative to their crops and fields. This data is almost always owned and housed by the operator and is therefore not applicable in this context. *Specialization of crop* is another variable that was identified in the PA literature but was not included because the majority of the organizations targeted are specialized in specific crops. *Importance of livestock* was not retained in the model because these organizations are in the oleaginous sector and have very little dependency on livestock. The *major occupation*, *off farm employment* and r*elationship to the land* were not included because their impact had already been demonstrated in prior studies (Daberkow et McBride, 2003), thus reducing the questions and focusing on the DOI adoption factors. This also applies for *use of extension services, use of crop consultants, special events, input suppliers, associations and mass media.*

The following factors are not in the theoretical model but are present as control variables: *Business size* was not retained in the model but was included as a control variable. In the PA literature, *farm size* was identified as an adoption factor. *Training and education* was also identified in the PA literature as having an impact on PA adoption. *Education* was not included in the model but was included as a control variable. *Age of capital stock* is another adoption factor that is present in the PA literature and was included as a control variable. *Operator age* was identified in the PA literature and was included as a control variable. *Education* and *Use of historical data / computer records* were also included as control variables.

There are four sub questions integrated within the model of this study: What factors impact the decision of a producer to adopt precision agriculture technologies? Second, what factors will influence the adoption of diagnostic technologies? Third, what factors will influence the adoption of applicative technologies? And fourth, what factors will impact the quantity of PA technologies adopted (adoption intensity)?

The dependant variables

The dependant variable is "adoption of precision agriculture technologies". Adoption is defined by an operator using a technology that the literature generally accepts in the precision agriculture family. This implies that the technology is used and not just owned by the producer. The first measure of adoption is a dichotomous one: whether or not a producer uses precision agriculture technologies. This measure is often used in innovation diffusion research (Tornatzky et Fleischer, 1982; Fichman, 1992; Thong, 1999). Following the examples of Thong (1999) and of Alpar and Reeves (1990) an operator will be considered an adopter if he uses and indicates this use by selecting one of the precision agriculture technologies available in the questionnaire (see Appendix 1). Other measures of PA adoption consider the type of technologies that are implemented, diagnostic or applicative (McBride et Daberkow, 2003). A final measure of PA adoption is operationalized by the number of technologies that the adopter uses, thus the sum of the technologies used. This is similar to the operationalization of extent of adoption for small businesses where the number of personal computer is counted (Thong, 1999). The dependent variable "Extent of adoption" or "adoption intensity" takes into account all the PA technologies and the functionalities available to the operators. Since the entire scope of the technologies is included in this variable, it is deemed appropriate for capturing "global adoption". The model presented in Figure 1 uses "adoption intensity" as the dependent variable for the PA Global Adoption Model.

PA Global Adoption Model

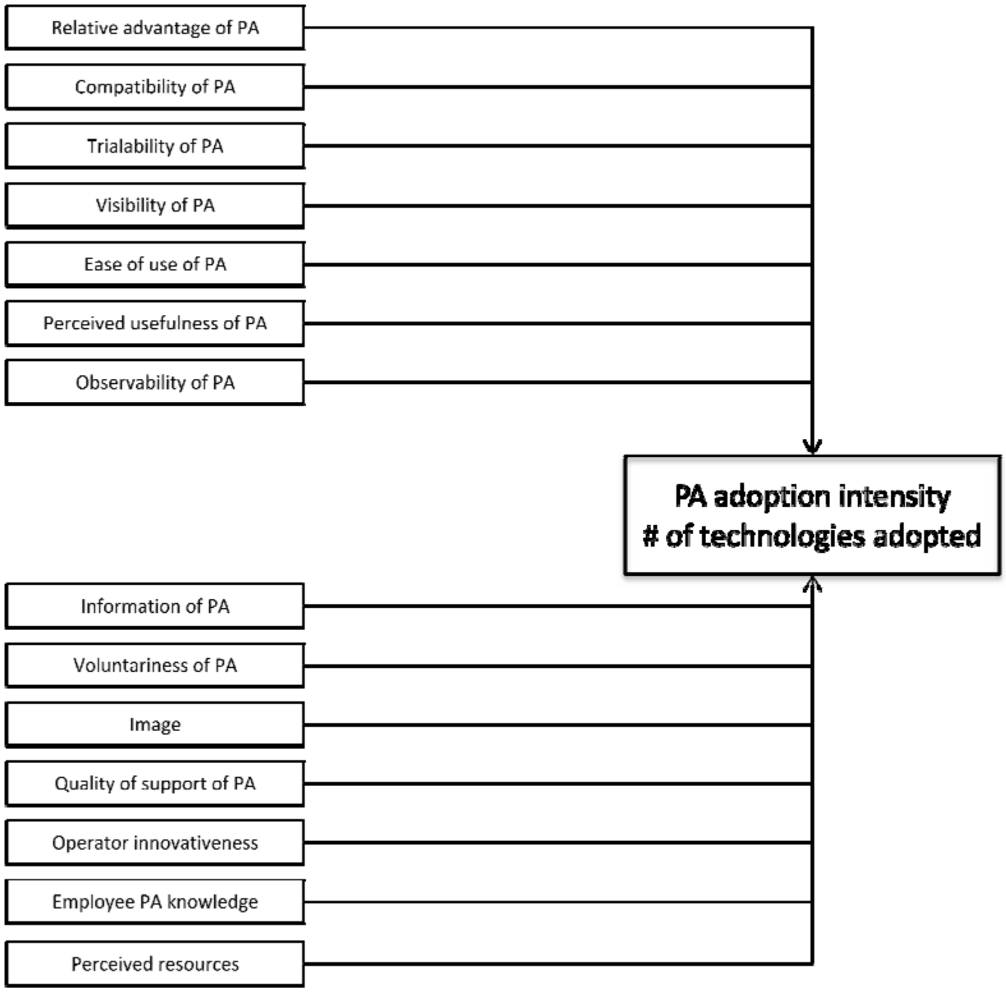


Figure 1: PA global adoption model

Hypotheses

The hypotheses contained in Table 6 will be tested in this research.

Table 6: Hypotheses

H#	Factor	Anticipated effect on the dependant variable
H1a,b,c,d:	Relative advantage of PA	The relative advantage of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H2a,b,c,d:	Compatibility of PA	Compatibility of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H3a,b,c,d:	Trialability of PA	Trialability of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H4a,b,c,d:	Visibility of PA	Visibility of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H5a,b,c,d:	Ease of use of PA	Ease of use of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H6a,b,c,d:	Perceived usefulness of PA	Perceived usefulness of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H7a,b,c,d:	Observability of PA	Observability of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.

H#	Factor	Anticipated effect on the dependant variable
H8a,b,c,d:	Information of PA	Information of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H9a,b,c,d:	Voluntariness of PA	Voluntariness of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H10a,b,c,d:	Image	Image is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H11a,b,c,d:	Quality of support of PA	Quality of support of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H12a,b,c,d:	Operator's innovativeness	Operator's innovativeness is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H13a,b,c,d:	Operator knowledge of PA	Operator knowledge of PA is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) extent of adoption, (e) global adoption.
H14a,b,c,d:	Perceived resources	Perceived resources are positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.
H15a,b,c,d:	Employee PA knowledge	Employee PA knowledge is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption.

Expected relationships of the control variables

Table 7: Expected relationships of the control variables

H#	Factor (single item)	Anticipated effect on the dependant variable
E16a,b,c,d:	Use of historical data	Use of historical data is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption
E17a,b,c,d:	Age	Age is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption
E18a,b,c,d:	Education	Education is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption
E19a,b,c,d:	Size of farm	Size of farm is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption
E20a,b,c,d:	Age of the machinery	Age of the machinery is negatively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption
E21a,b,c,d:	Language skills	Language skills is positively related to (a) adoption of PA technologies (yes/no), (b) adoption of diagnostic technologies, (c) adoption of applicative technologies, (d) global adoption

Section 3 - Methodology

In order to answer this research question "What are the factors that influence the adoption of precision agriculture technologies with Quebec farmers?" a non-experimental retrospective cross sectional study was performed and a paper questionnaire mailing approach was chosen to collect the data.

A retrospective approach was used since the adoption decision must be made before the researchers can ask the respondent what influenced that particular decision. Since the respondent is only asked to answer the questionnaire once, this is a cross-sectional study. This is a non-experimental study since the outcome is known, the effect is present and the causes need to be determined (Kumar, 2005).

A questionnaire approach to collect the data instead of an interview was chosen for three reasons: the nature of the investigation, the geographical distribution of the study's population and the type of study population (Kumar, 2005). The nature of this investigation is a simple case of adoption, in a rather specific context. No information is excessively personal or sensitive. Therefore, there is no need to use interviews since they are known to yield better results in those circumstances (Kumar, 2005). The geographic distribution of the study population is relevant since the respondents are spread across vast areas and will not leave their farm for the purpose of the study. A mailed questionnaire avoids the problems associated with the respondents being spread over a large geographic area. The study population should not be a discriminating factor; the median age of operators is 49 years (Statcan, 2008) and have operated their farms for many decades. They are literate and have filled out questionnaires before. A web questionnaire thought less costly than mailing a paper questionnaire could not be retained since 24.6% of respondents do not have internet access (Statcan, 2007). Response rate was expected to be 20% (Kumar, 2005). At least 310 usable questionnaires are needed since there are 62 items in the questionnaire and at least five times the number of items is required to make an acceptable exploratory factor analysis (Laroque, 2006). 2000 questionnaires were sent to compensate for the risk of a low response rate.

A common problem with survey based research methodology is the possibility of a self-selecting bias since the study might only interest those who have already adopted the technology. Another common problem is the inability to have direct interaction with the respondents. This leads to the inability to get spontaneous responses and an inability to have the questionnaire's information supplemented. The meaning of the questions must be as clear as possible to allow the respondents to answer the questions in the context envisioned by the researcher (Premkumar et Roberts, 1999). Therefore, five pre-tests were done to refine the instrument to make the items self-descriptive.

Measurement of the adoption factors

In order to properly measure the associated factors in this study, standard measurement tools were used whenever possible in the development of the instrument. All items were measured using a five point Likert-type scales ranging from “strongly agree” to “strongly disagree”, “never” to “always”, or “low” to “excellent”.

The following section is a review of the measures used in the literature. The most appropriate ones were identified and adapted to build the questionnaire. When identifying the list of items that would measure a specific factor, the following elements were taken into account: number of items, initial context of the items versus context of the present study and finally, the quality of the items.

The measures that were chosen to measure the adoption factors have a lower limit of three items since the constructs should be measured by multiple items (Aubert et Hamel, 2001) and constructs with two items or less tend to be problematic (Compeau, Meister et al., 2007). They have an upper limit of 6 items to minimize the number of questions while giving us the flexibility to remove an item to improve reliability (Compeau, Meister et al., 2007). The gap between the initial context of the items and the current context was evaluated by the researcher. Finally, the measure’s Cronbach’s alpha of the measure needed to be over 0.7 to qualify as reliable (Hair, Anderson et al., 1995) .

The questionnaire was administered in French since 90.8% of Quebec’s agricultural community is French speaking (Statcan, 2007). All the questions were translated by the researcher. Special attention was given to retain the exact meaning of the initial items while adapting it to the context.

Every measure used in the questionnaire is presented below. The initial wording of the items, the adaptation of the items to the context, the translation of the items, the quality of the measures and the sources of the measures can be found in Appendix 17.

To measure *operator knowledge,* two measures were identified: Bang Nam, Kyeong Seok et al. (2006) and Thong (1999). Bang Nam, Kyeong Seok et al. (2006)’s three item measure was used. Thong (1999) was not used since it’s Cronbach’s alpha was considerably lower at 0.64 compared to 0.860. Thong (1999) also contained two items as opposed to three in Bang Nam, Kyeong Seok et al. (2006) .

To measure *operator innovativeness,* three measures were identified: Bhatti (2007), Bang Nam, Kyeong Seok et al. (2006) and Thong (1999). Bhatti (2007) was used since the number of items fall within the recommended three to six items, with five items and has good Cronbach’s alpha. Bang Nam, Kyeong Seok et al. (2006) was not used since it only has two items and Thong (1999) was not used because it is based on KAI and has far too many items. It is also important to note that *operator innovativeness* includes *risk attitude*. *Risk attitude* was removed as a potential factor, since the items found in the construct *operator innovativeness* incorporates the *risk attitude*. “En general” was added at the beginning of every question of the *operator innovativeness* construct after the pretests because the respondents tended to directly associate the question to the topic of the questionnaire. This construct is meant to gather a general sense of innovativeness and not tie it to the specific subject.

To measure *relative advantage,* eight measures were identified: Wee (2003), Craig Van, France et al. (2004), Syed Shah, Ali et al. (2007), Thong (1999), Bang Nam, Kyeong Seok et al. (2006), Sangjo, Joongho et al. (2003), Aubert and Hamel (2001), and Ilie, Slyke et al. (2005). All these measures were context specific. A context specific measure was therefore considered for this study. In order to create the measure for relative advantage, the review of literature was used. There are four dimensions that can represent the relative advantage of this technology: increased productivity (Silva, Ribeiro do Vale, Pinto, Muller et Moura, 2007), decrease inputs costs (McBratney, Whelan et al., 2005), better information on which to base decisions (McBratney, Whelan et al., 2005) and reduces environmental impact of the exploitation (Zhang, Wang et al., 2002). They were used to create the four items of the measure (see Appendix 17). The possessive form of the *relative advantage* questions was dropped to make them appropriate for adopters and non-adopter without weighing down the sentence with multiple verb tenses.

To measure *compatibility,* seven measures were identified: Wee (2003), Craig Van, France et al. (2004), Thong (1999), Bang Nam, Kyeong Seok et al. (2006), Sangjo, Joongho et al. (2003), Aubert and Hamel (2001), and Ilie, Slyke et al. (2005). Wee (2003) was not used because it was context specific. Thong (1999) only provided two items so this measure was not used. Craig Van, France et al. (2004), Aubert and Hamel (2001) and Ilie, Slyke et al. (2005) respected the conditions but the items were also context specific. Bang Nam, Kyeong Seok et al. (2006) combined compatibility and complexity, thus had only one item measuring compatibility. Finally, Sangjo, Joongho et al. (2003) was kept in order to measure compatibility since it had the right number of items and a good Cronbach's alpha.

To measure *ease of us*e, nine measures were identified: Wee (2003), Craig Van, France et al. (2004), Syed Shah, Ali et al. (2007), Thong (1999), Bang Nam, Kyeong Seok et al. (2006), Sangjo, Joongho et al. (2003), Aubert and Hamel (2001), Bhatti (2007) and Ilie, Slyke et al. (2005). Bhatti (2007) was not used since the fourth item measures *compatibility*. Wee (2003) and Craig Van, France et al. (2004) are context specific. Thong (1999) and Bang Nam, Kyeong Seok et al. (2006) have only two items in the construct. Finally, Sangjo, Joongho et al. (2003) was kept because the Cronbach's alpha is greater than the measures of the other studies. There are more items and the items are more easily adaptable to the context than the others. In the first version of the translated items, one of the questions contained the term "inflexible"; this was translated by "rigide" but was then modified to "inflexible" (in French) when the pretests identified "rigide" as a difficult term to conceptualize. Furthermore, in order to make these questions appropriate for adopters and non adopters the verb of the sentence was added in the present conditional tense for the questions that required it.

To measure *employee PA knowledge,* two measures were identified: Thong (1999) and Bang Nam, Kyeong Seok et al. (2006). Bang Nam, Kyeong Seok et al. (2006) has only two items in the construct. Therefore, Thong (1999) was used in order to satisfy the three item minimum while having an acceptable Cronbach's alpha. Family labor was included in the items of Thong (1999) to complement employees in the *employee knowledge* measure because an important source of labor in Quebec agricultural industry is family members (CRAAQ, 2004).

To measure *trialability,* two measures were identified: Wee (2003) and Sangjo, Joongho et al. (2003). Sangjo, Joongho et al. (2003) was used since Wee (2003) is context specific. The trialability questions were modified in order to fit both adopter and non-adopter by adding the verb in the present conditional tense.

To measure *observability,* four measures were identified: Wee (2003), Craig Van, France et al. (2004), Sangjo, Joongho et al. (2003) and Ilie, Slyke et al. (2005). Sangjo, Joongho et al. (2003) was used since it had a better Cronbach's alpha compared to Craig Van, France et al. (2004). Wee (2003) is context specific and Ilie, Slyke et al. (2005) is very similar to Sangjo, Joongho et al. (2003) with four items in the measure. The *observability* questions were modified in order to fit both adopter and non-adopter by modifying and adding the verb in the present conditional tense.

To measure *visibility,* three measures were identified: Craig Van, France et al. (2004), Sangjo, Joongho et al. (2003) and Ilie, Slyke et al. (2005). Ilie, Slyke et al. (2005) was used since the Cronbach's alpha was the best and provided the clearest items for the study's context. Sangjo, Joongho et al. (2003) has a Cronbach's alpha that is adequate and has the right number of items in the required interval but the items are not clear given the context. Craig Van, France et al. (2004) was not used because it does not have enough items and it's Cronbach's alpha is inadequate. The *visibility* questions verb tense was changed to the present tense. This was done to measure the current visibility, to within a few weeks, of PA technologies.

To measure *perceived usefulness,* three measures were identified : Bhatti (2007), Sangjo, Joongho et al. (2003) and Aubert and Hamel (2001). Aubert and Hamel (2001) was used. Sangjo, Joongho et al. (2003) and Bhatti (2007) appears to be conceptually closer to relative advantage and since this study's construct will be using both concepts these must stay distinctly separate.

To measure *information,* the only measure identified was Aubert and Hamel (2001) and was adequate for use in this study. For these questions, the possessive pronouns were removed in order to make these questions compatible for adopters and non-adopters alike.

To measure *quality of support,* two measures were identified : Aubert and Hamel (2001) and Bang Nam, Kyeong Seok et al. (2006). For this measure Aubert and Hamel (2001) was used. The measure from Bang Nam, Kyeong Seok et al. (2006) was not used because it does not have enough items.

To measure *image,* three measures were identified : Wee (2003), Craig Van, France et al. (2004) and Aubert and Hamel (2001). Craig Van, France et al. (2004) was chosen. Wee (2003) is too context specific and Aubert and Hamel (2001) have too few items.

To measure *perceived resources,* two measures were identified : Bang Nam, Kyeong Seok et al. (2006) and Sangjo, Joongho et al. (2003). Sangjo, Joongho et al. (2003) was used, since there are too few items in Bang Nam, Kyeong Seok et al. (2006).

To measure *voluntariness*, two measures were identified : Compeau, Meister et al. (Compeau, Meister et al., 2007) and Bhatti (2007). Bhatti (2007) has too few items and the items also measure *perceived resources*. Compeau, Meister et al. (2007) was used since the items provided a construct that combined *subjective norms* and *voluntariness*. Despite the fact that *voluntariness* and *subjective norms* are not exactly the same construct, they are similar (Compeau, Meister et al., 2007). This construct was chosen to cover *voluntariness* and *subjective norm* since some items fit with the description of *subjective norms* (items 1 and 5).

General questions

The following control variables are included in the questionnaire: age, gender, level of education, language skills, PA technologies used, level of use of their PA technologies, average age of their machinery, size of farm and use of historical data. These questions can be found in the questionnaire (See Appendix 1). A final open question is included in the questionnaire in hopes that if certain adoption factors are omitted from the questionnaire, respondents may bring them forward.

Data collection procedures

The questionnaire underwent two phases of testing. The first phase was done with two agriculturists from Université Laval in Quebec City who validated the questions and the questionnaire as appropriate from a precision agriculture point of view. The second phase was done with three operators who currently operate farms and are part of the “Fédération de producteurs de culture commerciales du Québec” (FPCCQ). These two phases were done in order to refine the questionnaire before sending it out to the 2000 operators chosen by the FPCCQ. The researcher was present during the tests of the instrument in order to answer questions and receive feedback.

The data was collected from the members of the FPCCQ. The details of the respondents were not supplied to the researcher. The researcher brought the envelopes to the federation who applied the address and mailed the questionnaires to 2000 of their members. Once completed, the questionnaire was sent to the researcher via pre-paid envelopes included in the package. Anonymity was thus ensured.

Sample

The mailing was sent out to 1998 respondents on the 17th of February 2009. Out of those 1998, 421 were returned by the 1st of April for a 21.07% return rate and 444 were returned by the 8th of June for a 22.22%

return rate. The respondents had over a month and a half to complete the questionnaire in order to be included in the sample; the return chart can be found in Appendix 21. Of the 421, six were discarded because they were returned empty. There were 415 usable questionnaires for statistical analysis.

There are 10 000 registered members of the FPCCQ; of those, 3674 farms are registered in the cereal and oleaginous sectors. 1998 questionnaires were sent to the largest farms of the cereal and oleaginous population. The respondents of this study represent the largest farms of the cereal and oleaginous sector. There appears to be a response bias based on size. Farms with revenue over 500 000$ had a 41% return rate. Compared to the 250 000$ to 500 000$ segment where only 29%, returned the questionnaire. Larger farms were more likely to fill out and return the questionnaire (see Table 8).

Table 8: Cereal and oleaginous members of the FPCCQ by revenue and respondents by revenue.

	Members of the FPCCQ		Respondents in sample	
Farm revenue (size)	**# farms**	**% of farms**	**# farms**	**% of farms**
$10-50,000	1205	33%	7	2%
$50-99,999	740	20%	18	5%
$100-249,999	980	27%	93	23%
$250-499,999	514	14%	113	29%
$500 000+	235	6%	161	41%
Total	3674	100%	392	100%

Source: L'Institut de la Statistique du Québec, 2006

Age and education data on members of the FPCCQ was unavailable; therefore provincial data was used.

The median age of farm operators in Quebec is 49 years of age. 88.7% of operators were over the age of 35 in 2006 (Statcan, 2007). In this study, the median age falls within the 40 to 49 range with a cumulative percentage of 54.4. 79.8% of the respondents are over the age of 40 (see Appendix 2). Under the assumption that the distribution of operators in the 30 to 39 interval and 40 to 49 intervals (they account for 15.9% and 34.3% of respondents respectively) is equally distributed, it can be calculated that 87.75% of respondents are over the age of 35. The median age of operators in the sample is 48.7 years of age. The average age of respondents is not significantly different from the provincial average.

The education variable was measured by the highest level of education achieved by the operator. The comparison is based on the completion of a university degree or Cegep equivalent degrees (apprenticeship or trades certificates or diplomas). 7.2% of operators in Quebec in 2006 had an collegial or a graduate degree (Statcan, 2007) compared to 10.4% respondents for this study. 22.2% of operators in Quebec, in 2006, (Statcan, 2007) had a Cegep degree versus 34.5% in this study. With a 12.3 percent difference in operators who have a Cegep degree there might be an education bias.

Non-response bias potential was assessed by comparing late respondents and early respondents. This procedure is recommended by Armstrong and Overton (1977) since late respondents are likely to have similar characteristics to non-respondents. The test was done with the first 30 respondents of the sample and the last 30 questionnaires returned, 23 of which are not part of the sample and are used for the analysis. A non parametric two independent sample test, the Mann-Whitney and Wilcoxon test, was used. The advantage over the independent-samples t test, is that Mann-Whitney and Wilcoxon does not assume normality and can be used to test ordinal variables (Field, 2005). Results indicate that there are some significant differences between early respondents and late respondents. 15 items out of 71, 1 control variable out of 5, (see Appendix 3) and 6 constructs out of 14 (see Appendix 4) came back as significantly different. These were: computer time, ease of use, visibility, information, quality of support, perceived resources and observability. Thus indicating that the responses are not totally representative of the larger population (Armstrong et Overton, 1977). Responses might have been different because the late respondents did not feel that the subject affected them.

Instrument validation

Reliability

To ensure that analyses would not be negatively affected by skewness and kurtosis (Field, 2005) their values were extracted from the items and factors. Suggested skewness and kurtosis values are under two and seven respectively (Field, 2005). 69 of the 71 items met the criterions; only two items were above the suggested values and differed significantly from the normal distribution pattern. These items are: *Operators knowledge 2* and *computer time*. These items were adjusted to make sure they would have no negative impact on the analysis. All adoption factors respected the skewness and kurtosis interval.

An exploratory factor analysis was done on every group of items to check if the items loaded directly on their hypothesized factors and did not split the factor into separate components. Another exploratory factor analysis was done on all the items to see if the items loaded on the appropriate construct (see Appendix 6). The Cronbach's alpha was calculated (Aubert, Rivard et Patry, 1996) for every factor to see if the reliability of the scales could be increased by dropping items with insufficient loading values (see Appendix 5). A confirmatory factor analysis (CFA) was done on the new factors to reassess reliability. Loading values needed to be above 0.5 to show sufficient shared variance between the item and the variable (Aubert et Hamel, 2001). Eight variables met these criteria and seven had to be modified (see Appendix 14).

The *operator knowledge* items did load unto their respective initial grouping but the quality of the factors was insufficient with a Cronbach's alpha of 0.26 (see Appendix 5). These three items will be treated individually for the rest of the statistical analyses.

The adoption factor *image* (see Appendix 5) had one of its three items, image 1 (im1), removed since its CFA loading was below 0.5 and the Cronbach's alpha was significantly higher from 0.724 to 0.843 when the item was removed. This came as little surprise since the verb “to differentiate” had been misinterpreted in three out of five pre-test. The term was not replaced because no adequate replacement was found. However, it is clear that the question should be modified in order to clarify it.

The adoption factor *visibility* (see Appendix 5) had one of its five items removed. The loading was considerably lower than the other items and had a CFA loading value below 0.5. The Cronbach's alpha went from 0.838 to 0.859 when visibility 2 (vi2) was removed. Visibility 2 was the only reversed item out of the 5, this could be a potential reason why the item did not load as well as the others. This item was negatively worded using the equivalent of "not" in French « ne…pas ». According to Spector (1992) the use of the word "not" to create the negation is not recommended. The negation should be constructed using other means.

The adoption factor *ease of use* had two of its six items removed. This adoption factor constructed from six items was separated into two factors during the factor analysis. The *ease of use* item 3 (eu3) and *ease of use* item 5 (eu5) (see Appendix 5) was the cause for this. If removed, all remaining items load onto a single factor and the Cronbach's alpha goes from 0.773 to 0.859. The ease of use item 3 (eu3) proved problematic during the pre-tests. The question had been partially modified once because respondents did not understand the term "rigidity". This term was changed to "inflexible". "Inflexible" was more comprehensible to the respondents during the pre-tests. However, the problem may have come from the term, "interaction". During the pre-tests, two of the five respondents did not understand how a person "interacts" with a technology. This concept may be too specific to IS research to be properly used in a questionnaire destined for an industry such as agriculture. The items were also reversed. Item 3 did not use the word "not", however, item 5 did. This is not a suggested practice (Spector, 1992). It may be the reason why the item did not load correctly.

The adoption factor *voluntariness* was also modified. This factors was composed of five items, two measuring *voluntariness* directly and three measuring *non-voluntariness* (reversed). These items loaded onto two separate factors: items 1, 4, and 5 onto one factor and, 2 and 3 onto another factor. Upon closer inspection, there are conceptual differences between the two groups of items that can explain this separation. Item 2 and 3 focuses on an internal vision of *voluntariness*. These questions asked if the respondent felt the decision to adopt was theirs to make. The items 1, 4 and 5 took an external approach and asked if these technologies are being forced upon them by external sources. Since the quality of the adoption factor *voluntariness* composed of items 2 and 3 is well below acceptable limits with a Cronbach's alpha of 0.35, it was decided to use voluntariness composed of items 1 and 5 to measure non-voluntariness with a Cronbach's alpha of 0.668. Item 4 was dropped since its CFA loading value was below 0.5 (see Appendix 5).

Finally, the last modification made to the adoption factors was on *observability*. The items that compose observability loaded on two separate factors. A potential explanation for this is an instrumentation effect.

The fact that the questions were mixed tightly together (see Appendix 1) and were complex to read because of the two verb tenses may have triggered the problem. In the exploratory factor analysis (see Appendix 5) the items 1 and 3, which form the first factor, loaded on *trialability*. Another exploratory analysis was done to all the items of *observability* and *trialability* and the distribution of the items on the factors were identical, items 1 and 3 of *observability* loaded onto *trialability* (see Appendix 7). It was decided to therefore use the items 2 and 4 to create the *observability* factor.

All of the factors Cronbach's alpha are over 0.788 except *voluntariness* at 0.668 and *observability* at 0.588. Both these factor are composed of only two items. Cronbach's alpha is biased to a small number of items (Thong, 1999). Therefore, the Cronbach's alpha values were considered acceptable.

Discriminant validity

Two methods were used to ensure discriminant validity of the constructs. Discriminant validity is the extent to which one construct differs from another construct. The first method used to demonstrate discriminant validity is the correlation comparison between constructs. The correlations were extracted and compared (see Appendix 15). As a rule of thumb, if the correlation between two constructs is greater than 0.7 than there is the possibility of concept overlap (Garson, 2009). None of the construct pairing showed a correlation above 0.7, thus showing signs of discriminant validity. However, since this is a less stringent test of discriminant validity (Garson, 2009) a second method was also used. The second method used is the average extracted variance (AVE) (Fornell et Larcker, 1981), this compares the AVE to the shared variance of the constructs. AVE is calculated as follows:

$$AVE = \frac{\sum[\gamma_i^2]\, Var(X)}{\sum[\gamma_i^2]\, Var(X) + \sum[Var(\varepsilon_i)]}$$

Where:
$\gamma_i = loading\ of\ x_i\ on\ X$
$Var = variance$
$\varepsilon_i = measurement\ error\ of\ x_i$

The average extracted variance should be greater than the squared correlations (shared variance) in order to demonstrate satisfactory discriminant validity (see Appendix 16). All the pairings showed a squared correlation below the average variance extracted, except for a three construct pairing. The AVE for *operator innovativeness* is 0.256 and is inferior to the squared correlation between *compatibility* and *operator innovativeness* (0.336). The AVE for *ease of use* is 0.336 and is inferior to the squared correlation between *ease of use* and *compatibility* (0.446) and is also inferior to the squared correlation between *ease of use* and *perceived resources* (0.439). *Ease of use* and *operator innovativeness* were not removed because the changes in the model's results were not significant. However, any recommendation or conclusion drawn from these two adoption factors must be taken with caution.

Open question

Included in the questionnaire was an open question asking the operators why they choose to adopt or not precision agriculture technologies. There was a 64% response rate for this question. This question was asked to identify any important factors that were missed by the researcher. This also gave an opportunity for respondents to include anything that they thought was lacking in the questionnaire. This data was coded into 52 binary variables. These variables were grouped together by theme and used to analyze the qualitative data.

Statistical procedures

A non-parametric two-independent sample test was conducted on the means to see which factors were significantly different between adopters and non-adopters. This test was also done to compare non-adopters with adopters of diagnostic technologies and to compare adopters of diagnostic technologies and adopters of applicative technologies. The advantage over the independent-samples t test is that Mann-Whitney and Wilcoxon does not assume normality and can be used to test ordinal variables (Field, 2005)

The dependent variable "PA adoption intensity" was analyzed using AMOS, a structural equation modeling tool. Structural modeling with AMOS requires that there be at least 15 respondents per measured variable (Benter et Chou, 1987). The number of variables is 14; therefore the suggested number of respondents is 210. The number of respondents exceeded this.

Section 4 - Results

Descriptive statistics

Adoption, type of technology and technology

An important aspect of this study was to assess the adoption of precision agriculture technologies in the large-scale grain farms of Quebec. Large farm operators who are members of the FPCCQ have a 70.2% adoption rate of at least one precision agriculture technology. Out of the 399 respondents who answered the technology section of the questionnaire 280 respondents utilize some form of precision agriculture technology. Of these 280 respondents, 159 (56.8%) use diagnostic technologies such as GPS systems and 121 (43.2%) use applicative technologies such as variable rate application and tractor auto-pilots. The technology breakdown by adoption groups is presented in Table 9.

Table 9: Technology distribution of adopters of precision agriculture technologies by adoption group

Type of technology	Technology	Adopters of Diagnostic technologies % (n) (n=159, 38.3% of sample, 56.8% of adopters) (A)	Adopters of Applicative technologies % (n) (n=121, 29.2% of the sample, 43.2% of adopters) (B)	Adopters of PA technologies % (n) (n=280, 70.2%) (A+B)
Diagnostic	GPS (geographic positioning system)	56.6% (90)	72.7% (88)	44.6% (178)
Diagnostic	GIS (geographic information systems)	9.4% (15)	14.0% (17)	8.0% (32)
Diagnostic	Yield monitor	76.7% (122)	76.0% (92)	53.6% (214)
Diagnostic	Cartography technologies (yield maps)	42.1% (67)	55.4% (67)	33.6% (134)
Diagnostic	Teledetection	3.8% (6)	9.9% (18)	4.5 % (18)
Applicative	Variable rate application systems	0% (0)	61.2% (74)	18.5% (74)
Applicative	Navigation systems (auto-pilots for tractors)	0% (0)	62.8% (76)	19% (76)

There is also a 3% use of “other” PA technologies; these are leveling technologies such as Real Time Kinematic (RTK) satellite navigation based on GPS and laser leveling technologies. Laser leveling technologies are not considered in the precision agriculture technologies group in this study since they make no use of GPS systems. RTK leveling was taken into account and was integrated in the use of GPS. This was done since users of RTK leveling technologies use GPS systems and there are only four occurrences of RTK leveling technologies.

Adoption factor results and control variables

The variables that differentiate adoption groups are presented in this section. The adoption factors and the control variables are presented in Table 10 and 11 respectively. The adoption factors and the control variables are compared by adoption groups in order to identify the differences between them. Firstly (1), operators who have not adopted precision agriculture technologies are compared with adopters of diagnostic or applicative technologies, known as adopters. Secondly (2), adopters of diagnostic technologies are compared with non-adopter. Finally (3), adopters of diagnostic technologies are compared with adopters of applicative technologies, as illustrated by Figure 2.

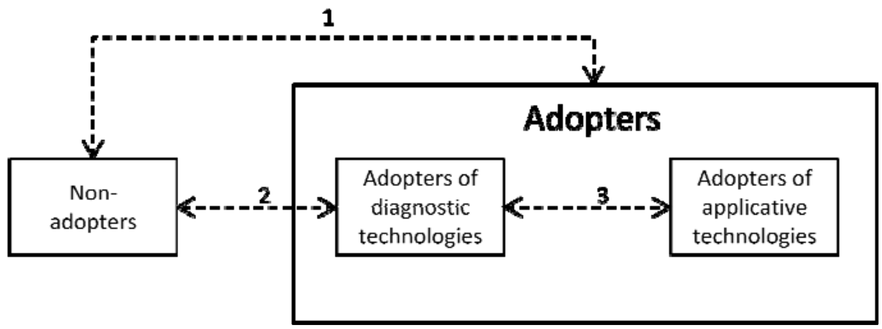


Figure 2: Comparison diagram

The Tables 10 and 11 present the mean for every variable measured by adoption group and whether or not the difference is significant using a non-parametric two-independent sample test.

Table 10: Means of adoption factors (multiple item variables)

Factors	Non-adopters (n=119, 29.8%)	Diagnostic (n=159, 38.3% of sample, 56.8% of adopters)	Applicative (n=121, 29.2% of the sample, 43.2% of adopters)	Adopters (App or Dia) (n=280, 70.2%)
	A	B[1]	C[2]	D[3]
Operator innovativeness	3.69	3.93*	4.24***	4.07***
Perceived resources	3.01	3.36**	3.77***	3.54***
Relative advantage	3.91	3.85	4.26***	4.03
Perceived usefulness	3.48	3.81**	4.17***	3.97***
Compatibility	3.22	3.56**	4.08***	3.79***
Ease of use	3.05	3.30*	3.80***	3.52***
Voluntariness	3.86	3.32***	3.19	3.26***
Observability	3.48	3.44	3.75**	3.57
Information	3.38	3.67*	3.82	3.74**
Quality support	3.23	3.44	3.64	3.53**
Visibility	2.46	3.08***	3.31	3.18***
Image	2.20	2.30	2.56*	2.41*
Trialability	3.57	3.45	3.55	3.50
Employee knowledge	2.11	2.44*	2.96**	2.67***

If the difference is significant, the level is indicated in the initial column of comparison. Ex: When column D is compared to column A; column D contains the level of significance of the comparison.
1- Column B is compared to column A
2- Column C is compared to column B
3- Column D is compared to column A
p <0.05*
p <0.01**
p <0.001***

Table 11: Means of control variables (single item variables)

Factors	Non-adopters (n=119, 29.8%)	Diagnostic (n=159, 38.3% of sample, 56.8% of adopters)	Applicative (n=121, 29.2% of the sample, 43.2% of adopters)	Adopters (App or Dia) (n=280, 70.2%)
	A	**B**[1]	**C**[2]	**D**[3]
Operator knowledge 1 (General knowledge of precision agriculture)	2.83	3.29***	3.78***	3.50***
Operator knowledge 2 (Capacity to use computer software)	2.92	3.17	3.50**	3.31**
Historical data	3.67	3.68	4.22***	3.91
Language skills	1.79	2.01*	2.43*	2.19**
Age of the operator (years)	3.45 (44.5)	3.28 (42.8)	3.25 (42.5)	3.27 (42.7)
Education of the operator	2.47	2.52	2.62	2.56
Age of the Machinery (years)	10.37	9.63	7.94**	8.91**
Computer time (per day)	41.44	39.32	50.48*	44.13
Farm size	4.66 (199 000$)	5.06** (265000$)	5.34 ** (335 500$)	5.18*** (295 000$)

If the difference is significant, the level is indicated in the initial column of comparison. Ex: When column D is compared to column A; column D contains the level of significance of the comparison.
1- Column B is compared to column A
2- Column C is compared to column B
3- Column D is compared to column A
p <0.05*
p <0.01**
p <0.001***

Comparison of adopters and non-adopters

The results identified that the means of 11 out of 14 adoption factors were significantly different between non-adopters and adopters: the most important of these is *visibility*, followed by *non-voluntariness* (since its difference is negative this adoption factor can be interpreted as non-voluntariness instead of voluntariness), *compatibility*, *employee knowledge*, *perceived resources*, *perceived usefulness*, *perceived ease of use* and *operator innovativeness*. All these adoptions factors have a significance level of p<0.001. Adoption factors with a significance level of p<0.01 are: *information* and *quality of support*. Finally, *image* was found to be significantly different between both groups at the p <0.05 level (see Appendix 8). All adoption factors except for voluntariness were significantly different in the hypothesized direction.

The results also identified that the mean of 5 out of 9 control variables were significantly different: *operator knowledge 1 (General knowledge of precision agriculture)* and *farm size* have a significance level of p<0.001. Control variables with a significance level of p<0.01 are: *language skills* followed by *age of the machinery* and *Operator knowledge 2 (Capacity to use computer software)* (see Appendix 9). All control variables were significantly different in the expected direction.

Comparison of adopters of diagnostic technologies and non-adopters

The results identified that the means of 8 out of 14 adoption factors were significantly different between non-adopters and adopters of diagnostic technologies: the most important of these are *visibility* and *non-voluntariness*, these adoptions factors have a significance level of p<0.001. Adoption factors with a significance level of $p<0.01$ are: *perceived resources* followed by *compatibility* and *perceived usefulness*. Finally, *information*, *operator innovativeness* and *ease of use* are found to be significantly different between both groups at the $p<0.05$ level (see Appendix 13). All adoption factors except voluntariness were significantly different in the hypothesized direction.

The results also identified that the mean of 3 out of 9 control variables were significantly different: *operator knowledge 1 (General knowledge of precision agriculture)* with a significance level of $p<0.001$, *farm size* with a significance level of $p<0.01$ and *language skills* with a significance level $p<0.05$ (see Appendix 12). All control variables were significantly different in the expected direction.

Comparison of adopters of applicative technologies and adopters of diagnostic technologies

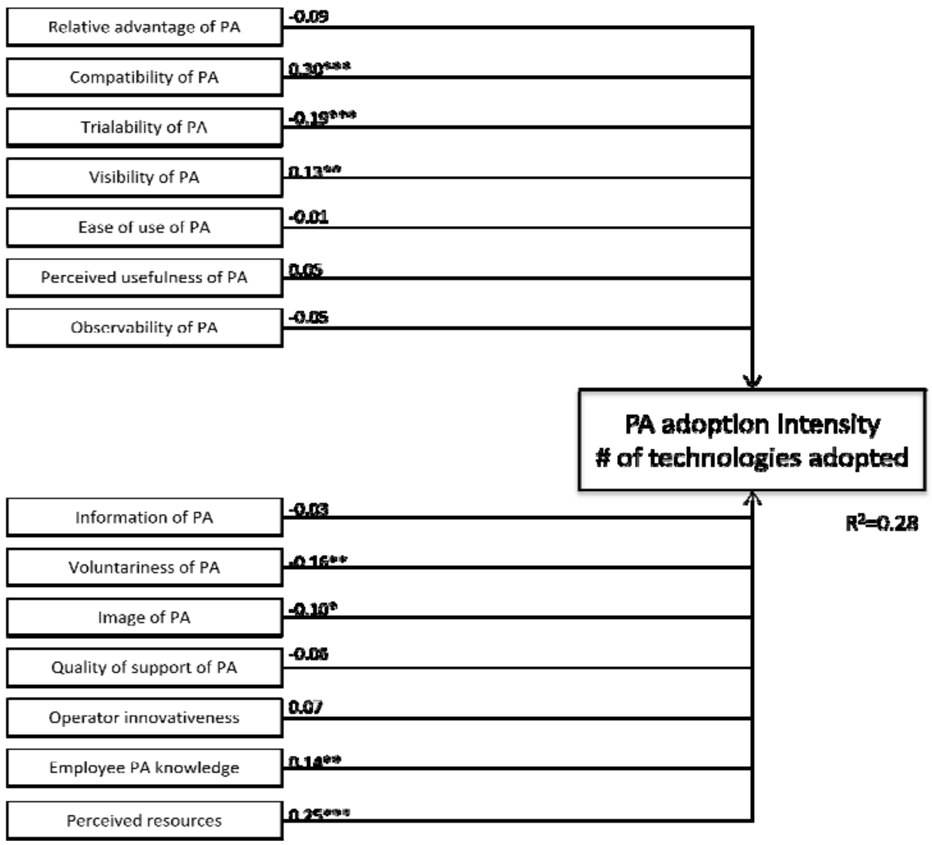
The results identified that the mean of 9 out of 14 adoption factors were significantly different between adopters of diagnostic technologies and applicative technologies: the most important of these is *compatibility*, followed by *ease of use*, *perceived resources*, *relative advantage*, *perceived usefulness* and *operator innovativeness*, these adoptions factors have a significance level of $p<0.001$. Adoption factors with a significance level of $p<0.01$ are: *employee knowledge* and *observability*. Finally, *image* is found to be significantly different between both groups at the $p<0.05$ level (see Appendix 10). All adoption factors were significantly different in the hypothesized direction.

This test also identified that the mean of 7 out of 9 control variables were significantly different: *operator knowledge 1 (General knowledge of precision agriculture)* and *historical data* with a significance level of $p<0.001$. *Farm size, operator knowledge 2 (Capacity to use computer software)* and *age of the machinery* have a significance level of $p<0.01$. *Language skills* and *computer time* have a significance level $p<0.05$ (see Appendix 11). All control variables were significantly different in the expected direction.

Adoption intensity (Global adoption model)

A global adoption model using AMOS was created since adoption factors have varying weights of influence on adoption. Some adoption factors are overpowered by others and thus have no consequential impact on the adoption intensity. Equation modeling takes this into account and identifies the significant adoption factors.

The precision agriculture adoption model is based on the dependent variable modeled on the number of technologies adopted, from zero to seven. From this analysis, seven adoption factors are identified as significantly affecting the adoption of precision agriculture technologies. Of these seven adoption factors, *compatibility, trialability* and *perceived resource* are significant at the $p<0.001$. *Employee knowledge, visibility* and *voluntariness* are significant at the $p<0.01$ and *image* is significant at the $p<0.05$ level (see Figure 3). *Trialability, image* and *voluntariness* are negatively related to PA adoption intensity, this contrary to the hypothesized results. *Compatibility*, *perceived resources*, *employee knowledge* and *visibility* are positively related to adoption intensity as expected.



Goodness of fit (Chi-square) = 4150.901
Root Mean Square Error of Approximation (RMSEA) = 0.079
Comparative Fit Index (CFI) = 0.716
p <0.05*
p <0.01**
p <0.001***
Built using AMOS results in Appendix 18
Figure 3: Precision agriculture technology adoption model

The control variables were tested to see it they would have a significant impact on the model. For every control variable the sample was separated into two subsamples: the lower half values and the upper half values. The adoption model was generated using the subsamples. The results were compared with the Global adoption model (see Figure 3) and between each subsample. The only control variable that had a significant impact on the model was *farm size* (see Appendix 19 and 20).

Hypotheses

With the comparison of the adoption groups and the AMOS results, hypotheses can now be examined. All information related to the hypotheses can be found in Table 12. Information related to control variables can be found in Table 13.

Table 12: Hypotheses results for adoption factors

	Result of model	Hypotheses results grouped by adoption categories		
Adoption factor	**PA Adoption intensity model (# of techn. adopted)**	Adoption of applicative technologies	Adoption of diagnostic technologies	Adoption of PA technologies (yes/no)
	d	**c**	**b**	**a**
Relative advantage of PA		H1c		
Compatibility of PA	**H2d**	H2c	H2b	H2a
Visibility of PA	**H4d**		H4b	H4a
Ease of use of PA		H5c	H5b	H5a
Perceived usefulness of PA		H6c	H6b	H6a
Observability of PA		H7c		
Information of PA			H8b	H8a
Non-Voluntariness of PA	**H9d**	H9c		H9a
Quality of support of PA				H11a
Operator's innovativeness		H12c	H12b	H12a
Perceived resources	**H14d**	H14c	H14b	H14a
Employee PA knowledge	**H15d**	H15c	H15b	H15a
Trialability of PA	**N-H3d**			
Image	**N-H10d**	H10c		H10a

The code of the hypothesis in the Table indicates that the relationship is significant and positively related to the dependant variable, thus confirming the hypothesis.
If the code of the hypothesis preceded by N-, the relationship is significant but negatively related to the dependent variable, thus not confirming the hypothesis.
An empty cell indicates that the hypothesis is not confirmed.
Operator knowledge was broken down into three separate control variables and is not in this table (general knowledge of PA technologies, capacity to use computer software and computer time).
Voluntariness is better interpreted as non-voluntariness since it is negatively related to the independent variable.

Table 13: Relationship results for control variables

Control variable	Adoption of applicative technologies	Adoption of diagnostic technologies	Adoption of PA technologies (yes/no)
	c	**b**	**a**
Use of historical data	E16c		
Age			
Education			
Size of farm	E19c	E19b	E19a
Age of the machinery	E20c		E20a
Language skills	E21c	E21b	E21a
General knowledge of precision agriculture technologies	E22c	E22b	E22a
Capacity to use computer software	E23c		E23a
Computer time	E24c		

The code of the relationship in the Table indicates that the difference is significant and confirms the relationship.
If the code of the relationship is preceded by N-, the relationship is reversed and significant but does not confirm the relationship.
An empty cell indicates that the relationship is not confirmed.
General knowledge of precision agriculture technologies, capacity to use computer software and computer time was created by the separation of the "operator knowledge" adoption factor.

Open question results

As mentioned before, respondents were invited to answer an open question to explain in greater detail what reasons impacted their adoption or non-adoption decision of precision agriculture technologies. For the most part, the answers in the open question were a repetition of the factors that were already present in the questionnaire. However, "facilité de travail"/ease of work is the only qualitative factor that was identified by respondents a significant number of times and was not integrated in the questionnaire. Ease of work is a combination of the following concepts: “facilité de travail”/ease of work, “travail de nuit”/night time work, “reduction de stress”/stress reduction and “réduction de fatigue”/reduction of fatigue. 10.1% of all 415 respondents (42 respondents) indicated, by writing in the open question, that one of these factors encouraged their adoption of PA technologies. Ease of work is the way precision agriculture technologies facilitates the day to day work that must be accomplished in the fields compared to prior technologies.

Many other reasons were indicated by the respondents such as: better “productivity”, a dimension of relative advantage. “Productivity” was stated 18.6 percent of the time as a factor in adoption PA technologies. “Reduction of inputs” is another factor that is a dimension of relative advantage that was identified by 32 respondents (7.7%). “Obtaining better data on the fields” was another dimension part of relative advantage that was cited by 34 respondents (8.2%). “Precision of work” was mentioned by 38 respondents (9.2%). This is a dimension of compatibility, since the use of “precision of work” was used not as a means to reduced inputs but as a style of work that pleased the operator. “High costs” were cited by 52 respondents (12.3%), as a factor that would impact negatively the adoption of PA technologies. “High costs” is conceptually included in the factor perceived resources in the questionnaire. Other reasons were indicated by the respondents but are not presented since they did not come up with enough frequency, less than 20 times (4.8%) to make them of interest in this study.

Section 5 – Discussion

This section will first discuss the global adoption model and the factors that significantly affect precision agriculture technologies. This will be followed by a discussion on the comparison of the means by adopter categories. It must be noted that the results of the means, though interesting and a potential source of information, must be interpreted with caution since the results are not always significant in the global model. To lighten the text in the discussion, diagnostics technologies are abbreviated to DT and applicative technologies to AT.

Adoption intensity (Global adoption model)

Adoption factors

The study identified *perceived resources*, *compatibility* and *visibility* as having a significant and positive impact on the number of PA technologies adopted. *Trialability*, *voluntariness* and *image* have a significant but negative impact on the number of PA technologies adopted.

In the PA literature, *perceived resources* has been identified by Feder, Just et al (1985) and Daberkow and McBride (2003). Those studies used "borrowing capacity" as the resource in question. The construct in this study includes any dimension that the operator perceives as a required resource: knowledge, opportunities, financial resources (borrowing capacity) etc. The PA literature found that the higher the borrowing capacity of the operator, the more likely the operator was to adopt. The same is true in the small business literature where the organization with greater financial resources were more likely to adopt. Small businesses suffer from what the literature calls resource poverty and thus, businesses with more resources are more likely to adopt (Utterback, 1974; Moch et Morse, 1977; Dewar et Dutton, 1986; Thong, 1999). The results are in accordance with prior IS and innovation literature since *perceived resources* is positively related to the number of PA technologies adopted by the respondent. Respondents who rate *perceived resources* higher adopt a greater quantity of PA technologies. The results indicate that more resources will increase the number of PA technologies adopted.

Compatibility is one of Roger's (2003) five main characteristics of innovation and significantly affects adoption in many studies (Aubert et Hamel, 2001; Craig Van, France et al., 2004; Compeau, Meister et al., 2007). In these articles, an increase in *compatibility* leads to a greater likelihood of adoption. *Compatibility* was examined through the lenses of preferred work styles (Compeau, Meister et al., 2007) and existing technologies. The results indicate that the same is true with PA technologies. Respondents who consider PA technologies compatible with their style of work and machinery adopt a greater number of PA technologies.

Employee knowledge (Kitchen, Snyder et al., 2002) was identified as a potential adoption barrier in the PA literature but was not measured in the same way as this study. *Employee knowledge* in Kitchen, Snyder et al. (2002) was a qualitative observation of adoption barriers. In the IS literature *employee knowledge* was also identified as a significant adoption factor (Thong, 1999). In this model, the number of technologies adopted increases with the operator's perception of his employees' knowledge of PA technologies. This can be explained by the fact that the farm employees are often the ones who are using the machinery and must know how the technology works. This is consistent with Attewell's (1992) conceptualization of innovation as a process of lowering knowledge barriers. Because these organizations like small business do not have internal IT departments they rely on consultants. These consultants may and should structure their offer in order to reduce the knowledge barriers (Attewell, 1992). It is also possible that the reversal of the causality is at play here. If an operator uses more PA technologies his employees will consequently know more about them since they use them.

Visibility has been identified in the innovation and IS literature (Sangjo, Joongho et al., 2003; Ilie, Slyke et al., 2005) as positively affecting the likelihood of adoption. It has not been identified in the PA literature. The results indicate that *visibility* affects positively the adoption intensity. The more the producers perceive the technology as visible the more technologies the producer adopts. However, PA technologies are often invisible since they are often integrated into existing technologies and are therefore very difficult to see unless an operator is within close proximity of the technology. Increasing the *visibility* of these technologies could therefore lead to more adoption.

The previous adoption factors fitted the hypotheses, the following factors did not. *Image* was identified in the model as having a negative impact on adoption intensity. *Image* has been identified in prior IS literature and was found to have a positive impact on adoption (Craig Van, France et al., 2004). The results indicate that the more an operator feels that these technologies differentiate him from others the less of these technologies he will adopt. It is possible that the context of the agricultural industry is the cause here. It is possible that since operators do not associate the agricultural field with high technology that they choose not to identify themselves with the differentiation that adopters of high technology usually incur.

Non-voluntariness is an adoption factor that the IS and the innovation literature have observed as positively affecting adoption (Compeau, Meister et al., 2007). The results of this adoption factor are in line with Compeau, Meister et al. (2007) that hypothesized and demonstrated that voluntariness negatively affects use intensity. It is likely that the industry's representatives are giving the operators the impression through sale tactics that they will have to adopt these technologies, thus applying what appears to be successful pressure on the operators.

Trialability is an adoption factor that was identified in many adoption studies (Aubert et Hamel, 2001; Rogers, 2003; Sangjo, Joongho et al., 2003; Wee, 2003; Craig Van, France et al., 2004; Syed Shah, Ali et al., 2007). In these studies, the hypothesized effect on the adoption variable is that the more the innovation is available for testing, the likelier the adoption will take place. However, in this study the opposite effect is identified. Results indicate that operators who perceive PA technologies as more testable will adopt less technologies. It is possible that the learning curve associated with testing these technologies is high enough that vendors (Wee, 2003) have trouble convincing operators via demonstrations. This could be because the industry has not found a way to make these technologies easily testable. However, it may not be appropriate to use *trialability* on a set of technologies such as PA technologies since every technology within the groups could have a different level of *trialability*. Furthermore, *trialability* may be more appropriately used when comparing between different technologies.

Control Variables

As stated in the results sections, the control variables were not included in the adoption model, however every control variable was used to separate the sample into two subsamples: respondents with the lower half values and the upper half values of the control variable. Adoption models were generated using each subsample. *Farm size* was the one leading to significant differences between the two models. It is sometimes used as an adoption factor (Thong, 1999) in the IS and small business literature. Two significantly different models were generated (see Appendix 19 and 20). These models only shared one factor, *compatibility*, all others were different.

The larger farms adoption intensity was significantly affected by *employee knowledge*, *perceived resources* and *compatibility*. These adoption factors were also present in the global adoption factors model. However, *quality of support* negatively affects adoption intensity for the large farms model. *Quality of support* is found in other IS adoption literature (Aubert et Hamel, 2001; Bang Nam, Kyeong Seok et al., 2006). This contrary effect could be because operators of large farms are completely dependent on the technologies and despite having what they consider good support; do not trust it in the hands of the vendors or the manufacturers. Answers to the open questions suggest that they want to be able to do the maintenance themselves and have more independence. These large farms are thus less likely to adopt more PA technologies if they do not know how to do the maintenance and support tasks themselves. It could also be caused by a reversal in causality. It's possible that the operators who use fewer technologies tend to perceive better *quality of support* since the PA technologies that operators must begin by adopting have been around since the early 90's. The operators who use more PA technologies, thus using more modern and complex ones seem to find that the *quality of support* suffers.

The smaller farms adoption intensity was significantly affected by *visibility* and *compatibility*. These adoption factors were also present on the global adoption model. However, other adoption factors that are not present in the global adoption model were significant in the small farm model: *perceived usefulness*, *relative advantage* and *operator innovativeness*. *Operator innovativeness* has been identified by Bhatti's (2007) study on adoption of mobile commerce. That study identified *operator innovativeness* as positively affecting adoption. Results indicate that innovative operators will adopt more PA technologies. *Perceived usefulness* in the IS literature is found to have a positive effect on adoption (Sangjo, Joongho et al., 2003; Bhatti, 2007), the same is observed in this study. If small farms consider that PA technologies are useful for them they will adopt more PA technologies. *Relative advantage* negatively affects adoption intensity. In other IS research *relative advantage* almost always impacts adoption positively (Aubert et Hamel, 2001; Craig Van, France et al., 2004; Compeau, Meister et al., 2007). In this study, the *relative advantage* construct measured the overall benefits of the technology. It did not ask if the benefits were consequential to the operator. It is possible that the more an operator knows about PA technology and its benefits; the better he understands that a smaller farm may not profit from all these technologies, thus negatively affecting adoption intensity. Smaller farms do have some use for PA technologies since *perceived usefulness* has a positive impact on adoption intensity. Further research into smaller farms is necessary to understand exactly why they are using these technologies. It is clear, based on these results, that the agricultural industry cannot be treated as a single entity. *Business size* significantly affects which adoption factors will be relevant within the same industry and with the same technologies.

Adopters of diagnostic technologies

This section compares the means by adopter categories. It must be noted that the comparison of the means, though interesting and a potential source of information, must be interpreted with caution since comparisons are done one variable at a time. This does not take into account interactions or covariance, like a global model, as discussed before, would.

Adoption factors

Results indicate that the value attributed to the following factors is significantly different between non-adopters and adopters of DT: *visibility*, *non-voluntariness*, *compatibility*, *perceived usefulness*, *perceived resources*, *operator innovativeness*, *information* and *employee knowledge*. Of the eight adoption factors observed, three of these had been identified in previous adoption of PA literature: *employee knowledge* (Kitchen, Snyder et al., 2002), *operators innovativeness* (Feder, Just et al., 1985; Baerenklau et Knapp, 2007) and *perceived resources* (Feder, Just et al., 1985; Daberkow et McBride, 2003). The other five adoption factors that were identified from the IS literature and the adoption literature are not present in the PA literature. Some of the adoption factors that were identified in the PA literature are not measured the same way as in this study; *employee knowledge* and *operator innovativeness* are two of these factors.

The value attributed to *employee knowledge* by adopters of DT was significantly superior to those of non-adopters. This is in line with other studies where *employee knowledge* positively affects adoption (Thong, 1999). In this study, the operator's perception of his *employees' knowledge* increased with every adoption group. This may be because employers will not adopt unless their employees have sufficient knowledge to use PA technologies.

Operator innovativeness has been identified by Feder, Just et al. (1985) and Baerenklau and Knapp (2007) in the PA literature. This concept was measured using *risk attitudes* and *risk management tendencies* and was found to positively affect adoption in those studies. The results indicate that the operators rating of *operator innovativeness* increases with every adoption group. Bhatti's (2007) study on adoption of mobile commerce also identified *operator innovativeness* as positively affecting adoption. Adoption of an innovation represents inherent risks. O*perator innovativeness* increases between non-adopters and adopters of DT. Operators who are more innovative will tend to adopt DT. This could indicate that PA technologies are not yet mainstream. *Operator innovativeness* also increases between adopters of DT and adopters of AT. This may indicate that operators need to be more innovative than operators who adopted DT to adopt AT technologies.

Perceived resources has been identified by Feder, Just et al. (1985) and Daberkow and McBride (2003) in the PA literature. As explained in the discussion of the global model, the PA literature found that the higher the borrowing capacity of the operator, the more likely the operator was to adopt. Adopters of DT had higher *perceived resources* than non-adopters. The same was true between adopters of AT and DT. Thus hinting that the more resources the operator has at his disposal, the more likely the operator will adopt.

Visibility has been identified in the innovation and IS literature (Sangjo, Joongho et al., 2003; Ilie, Slyke et al., 2005) as positively affecting adoption. This factor has not been identified in the PA literature. The results indicate that adopters of DT perceive PA technologies as more visible than non-adopters. Diagnostic technologies are particularly invisible since yield maps, GPS systems and yield monitors are often integrated into existing technologies. It is possible that respondents will only adopt when they can see PA technologies and thus, consider them sufficiently visible.

Non-voluntariness is another adoption factor that the IS and the innovation literature have identified as positively affecting adoption (Compeau, Meister et al., 2007). The results of this study indicate that non-voluntariness is higher for adopters of DT than non-adopters. This may be because sales representatives have sufficient pressure on the respondents for them to adopt.

Compatibility is one of Roger's (2003) five main characteristics of innovation and positively affects adoption (Aubert et Hamel, 2001; Sangjo, Joongho et al., 2003; Craig Van, France et al., 2004; Compeau, Meister et al., 2007). There is also a significant difference in the perception of *compatibility* between the DT and the AT groups. It is possible that operators must consider the technologies and work styles sufficiently compatible in order to adopt DT and AT.

Perceived usefulness is an adoption factor that is found in TAM (Davis, Bagozzi et al., 1989; Davis, 1989) and in DOI (Rogers, 1962). Perceived usefulness positively affects adoption (Sangjo, Joongho et al., 2003; Bhatti, 2007) but is not present in the PA literature. *Perceived usefulness* measures whether or not respondents considered PA technologies useful. Adopters of DT indicate that PA technologies are more useful than non-adopters. This trend continues for adopters of AT. Results indicate that a higher *perceived usefulness* value may be necessary to adopt DT and AT.

Information is another adoption factor in the IS literature (Aubert et Hamel, 2001) that is significantly lower with non-adopters than with adopters of DT. This adoption factor is particularly appropriate for this adoption category since this category specializes in the gathering of field data. The adopters of AT are not significantly different to the adopters of DT. This is logical since the AT specialize in bringing modifications to the field. It is possible that the need for the type of information that DT provides encourages the adoption of DT.

Adopters of applicative technologies

Adoption factors

Once the adoption of at least one diagnostic technology has taken place the adoption of applicative technologies can occur. Results indicate that the following factors are significantly different between adopters of DT and adopters of AT: *operator innovativeness*, *perceived resources*, *relative advantage*, *perceived usefulness*, *compatibility*, *ease of use*, *observability*, *image* and *employee knowledge*. Of these nine factors two were identified in the precision agriculture literature: *operator innovativeness* and *perceived resources* (Feder, Just et al., 1985). These are discussed in the adopters of DT section. The other seven adoption factors are described below.

Perceived usefulness, *compatibility* and *ease of use* are all significantly different between adopter of DT and non-adopters and they are again significantly different between adopters of AT and DT. These adoption factors were not identified in previous PA literature. The same logic that explains the differences between non-adopters and adopters of DT applies to the DT and AT groups.

Relative advantage is one of Roger's (2003) five main characteristics of innovation, is present in many adoption studies (Thong, 1999; Aubert et Hamel, 2001; Rogers, 2003; Compeau, Meister et al., 2007) and was found to positively affect adoption (Craig Van, France et al., 2004). *Relative advantage* is measured by the attainment of their desired benefits: reduction of inputs, increase productivity, reduction of environmental impact and better information on which to base decision. Results indicate that PA technologies achieve their goals. Both non-adopters and adopter of DT appear to have similar perceptions on the benefits of the technology. However, adopters of AT rated the benefits of PA significantly higher. This would indicate that the operators must believe in the benefits significantly more to adopt AT.

Observability in the literature positively affects adoption (Ilie, Slyke et al., 2005; Compeau, Meister et al., 2007). Results indicate that adopters of AT rate *observability* higher than adopters of DT. This may be because of the types of results that can be communicated. The results of applicative technologies could be a direct reduction of gas consumption or a reduction of fertilizer use. These results have a direct and real impact on the exploitation and are more tangible compared to results of DT. DT leads to better decisions. AT leads to actions. These are more observable.

Finally, *image* is higher in the AT group then the DT group. *Image* (Aubert et Hamel, 2001; Wee, 2003; Craig Van, France et al., 2004) is the perception of differentiation that the producers feel. It was found to have a positive impact on adoption (Craig Van, France et al., 2004). A willingness to differentiate themselves from others will lead to AT adoption.

Control variables

In prior studies, *computer familiarity*, *farm size*, *computer records*, *operator's age*, *age of capital stock* and *education* had an impact on PA adoption (Ferguson, 2002; Kitchen, Snyder et al., 2002; Daberkow et McBride, 2003; McBride et Daberkow, 2003; Fountas, Blackmore et al., 2005; Baerenklau et Knapp, 2007). In this study, five of the factors previously identified had significantly different means between the DT and AT groups: *farms size, use of historical data, capacity to use computer software* and *age of capital stock*.

Adopters of DT had significantly bigger farms than non-adopters and adopters of AT also had significantly bigger farm than adopters of DT. This may be because large farms have the financial resources and the ROI necessary to adopt AT technologies.

Use of historical data was significantly greater with adopters of AT compared to adopters of DT. This seems contradictory since the single purpose of DT is to collect and analyze data. However, it seems that even though respondents have a richer source of data they do not make use of it more often. However, the results suggest that once they begin using their data, they'll adopt AT.

Capacity to use computer software and time spent per day on a computer did come across as significantly different between adopters of DT and adopters of AT. Adopters of AT spent more time per day on a computer and rated their computer software capacity higher than adopters of DT. This may be a consequence of AT adoption since the use of computers begins to be part of many processes that the operator performs in his day to day operations.

Age of capital stock is also significantly different between the DT and AT groups. Adopters of AT had newer machinery than adopters of DT. This may be because new machinery has PA technologies integrated. It could be hypothesized therefore that respondents with older machinery are more likely to adopt since they must replace their machinery. And when operators renew their equipment they adopt at the same time. However, this equipment can be maintained cost effectively over a very long period of time, therefore this cannot be assumed. There was no difference in the age of capital stock between adopters of DT and non-adopters, this may be because the adoption of DT is not as invasive and can be more easily integrated with older machinery compared to AT.

Two other control variables did come across as significantly different between adopters of DT and non-adopters and are not identified in the PA literature, these are: *general knowledge of precision agriculture* and *language skills*. Adopters of DT rate their knowledge higher than do non-adopters. It is possible that once operators have sufficient knowledge of PA they adopt DT and AT. *Language skills* is also a control variable that is different between the groups. Adopters of DT rate their English *language skills* higher than non-adopters. These results could indicate that language is a barrier to PA adoption and that if operators improve their English *language skills* they are more likely to adopt DT and AP.

Summary of results and alternative explanations

The findings indicate that *non-voluntariness, perceived resources, employee knowledge, compatibility* and *visibility* positively affects the number of PA technologies adopted. *Image* and *trialability* negatively affect the number of PA technologies adopted. The number of PA technologies adopted by larger farms is more specifically and positively affected by *employee knowledge*, *perceived resources* and *compatibility*. It is also negatively affected by *quality of support*. The number of PA technologies adopted by smaller farms is more specifically and positively affected by *compatibility*, *operator innovativeness*, *perceived usefulness* and *visibility*. It is also negatively affected by *relative advantage*.

It must be noted that there is the possibility that causality is not solely a one way process from adoption factors to the dependent variable. There could be a two way process in which adoption may influence the adoption factors over time. For example, employee knowledge was found to positively affect the number of PA technologies adopted. However, it is possible that the more PA technologies the operator adopts, the more the employees acquire knowledge about them since these technologies become part of the work processes. This “reversal” of causality is another potential explanation for the relationship between adoption intensity and the adoption factors.

Practical implications

The practical implications of this study can be classified in four groups: the farm operators, the associations, the government and the PA industry. They will be presented in that order.

Farm operators

Farm operators must know where their farms fit in relation to the largest farms of the province because the adoption of PA technologies is affected by different factors depending on the size of the farm. As a general indicator farms below 375 000$ in revenue fall under the “smaller” farm model and farms above 375 000$ fall under the “larger” farm model.

Certain factors affect both small and large farms operators. Using some of these factors, *compatibility*, *trialability* and *image*, recommendations can be made to help operators adopt PA technologies. Operators who consider that their style of work is compatible with the use of PA technologies are more likely to adopt.

Operators should therefore adopt work styles that are in line with precision agriculture such as field management instead of crop management, trying to reduce inputs, basing decisions on solid data etc. They should also purchase machinery that is compatible with PA technology add-ons. Operators who perceive that PA technology differentiates them from others are less likely to adopt PA technologies. Operators should not consider that PA technologies are any different than the tractor they drive. By considering that PA technologies are common and not a differentiating factor; operators increase their likelihood of adopting PA technologies. Operators should look into what their operating processes would be if they used PA technologies. Operators may notice that the changes are not as significant as they believe, thus reducing the perception of differentiation. They should also discuss with other operators who have adopted many PA technologies, because if you reverse the causality it appears that the more PA technologies an operator adopts the less he feels that it differentiates operator. Operators who perceived PA technologies as available on a trial basis were less likely to adopt them. Operators should not solely base their adoption decision on a single demonstration or a single vendor. They should explore the market, read publications and learn what they can from multiple sources.

Small farms operators are more specifically affected by *visibility*, *operator innovativeness*, *usefulness* and *relative advantage*. Small farm operators should learn to spot the use of PA technologies. Operators who can spot the use of PA technologies are more likely to adopt them. Operators who can spot the use of PA technologies could more easily identify whether or not the technologies could be used in their organizations. If peers with similar organizations use PA technologies but do not advertise their use, visibility would help operators identify, by comparing the exploitations, if the technology might be profitable to them. Therefore, operators should put emphasis on how to spot technologies by going to demonstrations, conferences and listening to sales representatives. Operators who would like to adopt PA technologies should also try to be as innovative as possible. Innovative operators are more likely to adopt. Operators should be curious about new techniques, technologies and try to understand how they work. They should also surround themselves with others who like to try new things. Operators should also try to understand if PA technologies will be useful to them. Operators who find that PA technologies are useful are more likely to adopt. Operators should invest time and do some research via conferences, sales representatives etc. to determine whether or not PA technologies can be useful to them and their organization. They should also find ways to implement what PA technologies they can. When small farms are more aware of the potential benefits of PA technologies (relative advantage) the less PA technologies they will adopt. This could be because small farms do not respect the structural requirements to obtain all the advantages of PA technologies. Operators should look into whether or not their exploitation respects the right conditions to achieve these advantages, look into whether it would be possible for them to achieve these conditions and whether or not it is worth investing to achieve these conditions.

Large farm operators are more specifically affected by *quality of support*, *employee knowledge* and *perceived resources*. Operators who perceive that the *quality of support* is good are less likely to adopt. This could be caused by a reversal in causality. It is possible that the operators who use fewer technologies tend to perceive better *quality of support* since the PA technologies that operators must begin by adopting have been around since the early 90's. The operators who use more PA technologies, thus using more modern and complex ones seem to find that the *quality of support* suffers. Operators should be aware that *quality of support* may suffer as they adopt more and more recent PA technologies. Therefore, operators should surround themselves with a network of operators who use similar technologies and not only rely on the vendor and manufacturer. They should also identify all channels of support that are available to them such as associations and user groups. These actions could help the operator to improve his quality of support by being more independent or relaying on more than one backup and would facilitate an increase in the amount of technologies adopted. Operators who have a high opinion of their employees' knowledge of PA are more likely to adopt PA technologies. Operators should maximize their employees' knowledge of PA. They should encourage current employees to undergo training. They should show support for their employees efforts such as giving them the time off required to do the training. They could make PA knowledge a criterion for employment. They could also hire part time employees who have knowledge of PA technologies that could transfer their knowledge to the full time employees. They could use student internships from agriculture programs or agriculturist programs in order to transfer new practices and knowledge to their employees. They could also send their employees to conferences on technologies and participate in information sessions. These actions could help employee knowledge and encourage PA adoption. Finally, operators who feel they have the necessary resources are more likely to adopt. The respondents made it clear in the open questions that the term "resources" corresponds to financial resources. Operators have access to credit via different organizations however; other solutions such as partnership with vendors and manufacturers are also a solution to the capital availability problem. Operators could enter into partnerships with the vendor or manufacturers. Operators could offer their farms as testing grounds for new technologies and the vendor could offer free or low cost access to the technologies and support.

Governments

Governments can also play a role in the adoption of PA technologies. Operators who feel external pressure to adopt PA technologies are more likely to adopt PA technologies. *Non-voluntariness* is a factor that affects all operators. Governments could therefore increase the likelihood of PA adoption by imposing the submission of input reports (quantity and type of fertilizers used etc.) These reports are similar to tax reports and like accounting software facilitates tax reporting, PA software facilitates input reporting. *Operator innovativeness* is another factor that influences smaller farms and positively affects adoption. Governments should give reasons for operators to innovate. Governments should make the agricultural industry an industry where risk and innovation is rewarded. This will encourage the behavior and increase the likelihood of adoption. *Perceived usefulness* is another factor that governments can use to increase adoption. By funding PA research and organizations that transfers PA knowledge to operators, operators can have an objective insight on the usefulness of these technologies. *Employee knowledge* is another factor governments could use to encourage adoption. They could put in place financial incentives to help operators cover the expenses of obtaining training for their employees such as matching any amount that the employer spends. They could also force operators to spend a certain percentage of their revenue or profit on employee training. Governments could also use *perceived resources* to increase the adoption of PA technologies. By facilitating credit for capital investment, training or maintenance costs governments could increase the likelihood of adoption. Finally, governments could encourage adoption by increasing the *quality of support* available. They could encourage vendors to have regional offices by reducing their regional taxation. They could also encourage partnerships between consulting organizations and educational institutions to teach and train future experts.

Associations

Associations could also play a role in the adoption of PA technologies. They could do this by having staff on hand that can assist with providing basic support. This staff could also obtain answers to questions that their members may have. This would increase the likelihood that operators will adopt. Associations should also encourage innovation. Using their newsletter or other communiqués, they could publish articles that encourage innovation. Communiqués could also be used to normalize the use of PA technologies so that operators do not feel they are differentiating themselves if they adopt. They could also be useful to communicate that PA technologies are the new norm, thus putting external pressure on the operators. There could also be prizes and competitions on the most innovative way operators have found to solve problems. Associations could also organize employee training sessions to lower costs and reduce the managerial work of the operators. Associations could also play a role in the acquisition of equipment. *Compatibility* affects positively the likelihood of adoption. Associations could compile a list of equipment that can be easily upgradable. By doing so, they would be creating a type of “protégez-vous” (consumer review magazine) of the agricultural industry.

Precision agriculture industry

The industry could also benefit from certain factors identified in this study to encourage adoption. The industry could act on support and training by creating different packages and turning them into separate business products. Packages could be designed to meet the specific needs of the operator, thus improving *employee knowledge* and *quality of support*. For employee training, on farm training could be part of the package. For *quality of support* the industry could also insure that every region has an office with quality staff that can handle support for local operators. Also a mentor program could be put in place. This mentor program would be a network of operators where operators support each other. This program could be operated by the vendor and could sell memberships to the operators who wish to join. The industry could also play on visibility. *Visibility* positively affects adoption. The industry would profit from making this almost "invisible" technology more visible. The seed industries have managed to make their technology more visible by using identification signs along the fields. A similar approach could be used by the PA industry to increase visibility. The industry could also act on *perceived usefulness* by publishing implementation success stories to demonstrate the usefulness of their technologies. The industry could also promote innovativeness via their sales representatives. Encouraging operators to be innovative with their technologies could lead to new techniques and would lead to a greater likelihood of adoption. The industry could also act on *image*. Operators who feel that PA technologies differentiate them from other operators are less likely to adopt. The industry must not give the impression that these technologies differentiate the operator. Trialability results indicate that operators who perceive PA technologies as testable are less likely to adopt. This may be a sign that demonstrations are not convincing the operators. Vendors should put effort in designing demonstrations that will convince the operator. *Relative advantage* is another factor that the industry can act on. Small farm operators who believe in the benefits of PA technologies will adopt fewer of them. This may be because these operators are in a better position to know that these technologies are not as profitable as they could be. The industry should therefore try to adopt a sale strategy that will focus on technologies that small farms can profit from. The industry can also use *non-voluntariness* to encourage adoption. Non-voluntariness affects adoption positively. By making operators feel that PA technology is a new norm, they are applying external pressure that will increase the likelihood of adoption. *Compatibility* also affects adoption positively. The industry should build machinery that is compatible with PA add-ons and emphasize this aspect in their sales strategy. They should also focus on indicating to the operator how PA technologies will fit with their work styles. This will increase the likelihood of adoption.

Theoretical implications and future research

The theoretical implications can be grouped in three categories: methodological, theory of diffusion of innovation and PA adoption literature. They are presented in that order.

Methodological

The innovation in question, precision agriculture, is a single innovation but is a group of technologies separated in two categories: adopters of diagnostic and adopters of applicative technologies. This is very specific to the agricultural industry but can serve as an example for other innovations that could exhibit the same characteristics.

Theory of diffusion of innovation

This study contributes a *relative advantage* construct for precision agriculture technologies. This construct presents the four main advantages in using precision agriculture technologies: reduction of inputs, increase productivity, reduction of environmental impact and better information on which to base decision. With a Cronbach's alpha of 0.819 this construct can be used for further research.

This study validates the use of the IS adoption factors and the adoption factors of the DOI literature to explore the adoption of precision agriculture technologies.

The global adoption model varies the intensity of adoption as the dependent variable. It must be noted that other causal relationships were tested where the adoption factors come into play as intermediary variables such as in Aubert and Hamel (2001) and Compeau, Meister et Al (2007). Such relationships did not hold true. The definition of *relative advantage* used in this study could be the possible reason why *relative advantage* cannot be used as an intermediary variable. The definition used for *relative advantage* in this study was based on the benefits of PA technologies as identified in the literature: reduction of inputs, reduction of environmental impact, increased productivity and better information on which to base decisions. This is different from the definition used for studies where relative advantage is an intermediary variable. That definition focused on whether or not the technologies were advantageous to the user and not whether they met their hypothesized objectives (benefits). It appears that causal relationships between adoption factors and *relative advantage* when the definition is based on benefits may not be compatible. Perceived usefulness replaced *relative advantage* as an intermediary variable. Conceptually *perceived usefulness* resembles *relative advantage* in studies where it was successfully used as an intermediary variable (Aubert et Hamel, 2001; Compeau, Meister et al., 2007). This did not yield any results. A possible explanation why such relationships did not hold true may be because of the type of technology (Swanson, 1994). According to Swanson's (1994) IS innovation classification, PA technologies are type 3b innovations, product and business product innovation. Smart card technology in Aubert and Hamel (2001) is a type 2 innovation, product and business administrative process innovation. And ergonomic keyboards in Compeau, Meister et al. (2007) cannot be categorized within Swanson's technology types since ergonomic keyboards are not product, process or integration innovations. The level of personal investment is also very different; an ergonomic keyboard cost very little, has a small learning curve and does not affect the core business. Smart card technology in the medical sector requires more money to adopt compared to a keyboard, has a greater learning curve since the user must learn a new administrative process and does not affect the core business. PA technology requires an important capital investment to purchase the machinery, up to hundreds of thousands of dollars, has an important learning curve and impacts the core business. Of all these technologies, it is the only one that has a two step adoption process. These differences may be reasons why the relationships between the adoption factors in Compeau, Meister et al. (2007) did not hold true.

Another theoretical implication is the impact of *business size* on the adoption model. Depending on the size of the farms, the adoption factors that affect adoption are very different. This results in two models for the same industry and technology. This is considerably different from previous small business literature where business size could be considered an adoption factor (Thong, 1999). In this context, it appears that the farms should be studied in groups where the sample is composed of similar size organizations. Technology type and how these technologies earn their return on investment may be a reason for the impact of business size: ergonomic keyboards help write faster with a better posture, thus the ROI is based on time saved by writing faster and lowering medical costs. Smart card technology bases its ROI on time saved with patients. The variability is limited since doctors can only see so many patients in a day. PA technologies ROI is based on the number of hectares an operator exploits, this is very variable from farm to farm. Taking into account the high capital investment and the nature of the ROI this may be a reason for the impact of *business size*.

PA adoption literature

This study also validates the use of the IS adoption factors and the adoption factors of the innovation literature to explore the adoption of precision agriculture. This study identified five adoption factors that were not previously identified in the PA adoption literature: *compatibility*, *non-voluntariness*, *image*, *visibility* and *trialability*.

Another contributing aspect of this study is the identification of *ease of work* via the open question as a potential consequence of precision agriculture technologies. This is not a dimension that has been clearly identified in the current literature. This dimension appears to be conceptually part of *relative advantage*. Further study is needed in order to validate this.

This study, unlike previous studies, (Feder et Umali, 1993; Ferguson, 2002; Daberkow et McBride, 2003; Fountas, Blackmore et al., 2005) did not find age and education to be significant. This may be because of the contextual factors of Quebec such as the aging population of operators. Operators have about the same age on all farms. This lack of variance may explain why age has little impact on adoption. Education may not have an important impact because of the continuing education programs that the associations and government support in order to transfer relevant information to operators.

Limits

The limits of this study can be grouped into three categories: methodology, theory of diffusion of innovation, PA adoption literature. They are presented in that order.

Methodology

An important proportion of respondents were from the largest farms in Quebec. These results are therefore not applicable to the entire province of Quebec and should not be transposed on all the provinces' farms especially since dividing the sample in two groups by *farm size* generated two distinct models. A validation of the "small" farm model with an appropriate sample could extend the use of the model the smaller farms of the province.

The measurement was taken at one moment in time with respondents in different stages of adoption. There could be a two way impact where adoption itself may impact the perception respondents have of independent variables. Therefore, a longitudinal study should be done in order to identify clearly which factors effect adoption and which are consequences of adoption. There is the possibility that causality is not solely a one way process from adoption factors to the dependent variable. There could be a two way process in which adoption may influence the adoption factors over time. This type of survey could not address this issue.

There is also the mono-method bias that could be problematic in this study. It is unlikely that respondents who have adopted will make themselves look incompetent by answering in a way that contradicts their adoption of PA technologies. For example, if an operator that has adopted multiple kinds of PA technologies indicates in the questionnaire that the technologies are not compatible, then why did he do it in the first place? He may change his answers in order to look coherent despite the reality of his situation.

Theory of diffusion of innovation

The global adoption model is a causal model that is measuring intensity of adoption. Past research confirms this is an acceptable method of measuring adoption but other measures such as adoption intention, scope of use and satisfaction should be examined to better understand the relationship between the adoption factors and the adoption of precision agriculture technologies (Jasperson, Carter et Zmud, 2005; Burton-Jones et Straub, 2006; Compeau, Meister et al., 2007). Comparing this study with others that use an *advantageous* definition of relative advantage compared to the *objectives* definition requires caution since the impact of relative advantage in the model could be very different.

The use of the adoption factor *trialability* may not be appropriate in this context for two reasons. The first reason is because the respondents are asked to evaluate the *trialability* of a group of technologies simultaneously. It is possible that the technologies in question all have a different level of *trialability*; therefore there is no way to know which technologies the respondent is rating. And the second reason is that *trialability* may be better suited to comparing two similar technologies instead of evaluating its direct effect on adoption. Further research is required.

PA adoption literature

It seems likely that *ease of work* is a contributing factor in the adoption of precision technology that was not included in this study since it was mentioned in the open question by the respondents. Ease of work is not a factor that has been explored in the literature and should be looked at more closely in future research. This factor could be a dimension within *relative advantage*.

Section 6 - Conclusion

The research question: What are the factors that influence the adoption of precision agriculture technologies with Quebec farmers? The findings indicate that *non-voluntariness, perceived resources, employee knowledge, compatibility* and *visibility* positively affects the number of PA technologies adopted. *Image* and *trialability* negatively affect the number of PA technologies adopted. The number of PA technologies adopted by larger farms is more specifically and positively affected by *employee knowledge*, *perceived resources* and *compatibility*. It is also negatively affected by *quality of support*. The number of PA technologies adopted by smaller farms is more specifically and positively affected by *compatibility*, *operator innovativeness*, *perceived usefulness* and *visibility*. It is also negatively affected by *relative advantage*.

A secondary objective was to assess the current adoption rate of these technologies. The findings indicate that there is a 70.2% adoption of at least one PA technology amongst Quebec's largest farms. This is an important finding since in 2000, 5% of Quebec farms used a GPS (Jacques, 2007) compared to 44.6% in this sample. Findings indicate that unlike many US studies age and education had no impact on adoption. It did validate that farm size does have an important impact on the factors that affect adoption intensity.

This study contributed to three bodies of literature. The IS adoption literature by creating a new relative advantage construct. The small business adoption literature by reassessing the importance of business size in the small business context and the PA adoption literature by adding adoptions factors that affect the adoption of PA technologies. This study adds to the PA literature eight factors that influence adoption: *compatibility, visibility, non-voluntariness, quality of support, operator innovativeness, perceived usefulness, relative advantage* and *trialability*.

In addition, this study makes practical recommendations for farm operators, associations, governments and the PA industry. To increase the number of PA technologies operators use they should: adopt work styles that are compatible with PA technologies such as field management, buy machinery that is compatible with PA technologies and understand that PA technologies do not differentiate them from other operators. Smaller farm operators can: learn how to identify PA technologies, surround themselves with innovative operators and identify where PA technologies could be useful for them. Larger farms operators can: surround themselves with operators who use similar technologies to help each other, increase the PA knowledge of their employees and look into forging partnerships with PA vendors and manufacturers. Associations can also help increase adoption intensity by: having staff on hand that could support members on PA questions, publishing articles in communiqués that promote innovation, making clear to operators that PA is the new norm, organizing employee training sessions and publishing lists of machinery that is recommended for PA. Governments can increase PA adoption by: putting in place input reporting for farms, encouraging legislation that will make the agricultural industry one that will reward innovation, funding organizations and research that create and transfer knowledge to operators, helping or forcing operators to train their employees in PA technologies and encouraging vendor to set up regional offices to insure regional support. Finally, the PA industry can increase PA adoption intensity by: making training a separate business product, setting up a membership program for peer support, setting up regional offices, putting up signs to make PA technologies more visible, publishing success stories in communiqués, making operators feel that these technologies are the new norm and not a differentiating factor, finding ways to demonstrate the equipment in a convincing way and encouraging the sale of PA compatible technologies by pricing them accordingly.

This research may also serve as a foundation for other research in order to help identify what are Quebec producers' needs in order to adopt these technologies. Despite the seemingly slow evolution and adoption of technologies in agriculture, understanding the factors that influence the process will help bring potential solutions to the agricultural industry to accelerate the adoption of a promising technology.

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Appendix

Appendix 1: Questionnaire

HEC MONTRÉAL

Étude sur les facteurs qui influencent l'adoption des technologies d'agriculture de précision au Québec

Ce questionnaire porte sur les technologies d'agriculture de précision et vos perceptions à propos de celles-ci.

Nous vous remercions de votre précieuse collaboration.

Si vous désirez des informations supplémentaires veuillez contacter :

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Vous trouverez, dans les prochaines pages, un questionnaire auquel nous vous invitons à répondre.

Directives

Ce questionnaire a été développé dans le cadre d'un mémoire de Maîtrise ès sciences en gestion (M. Sc.) à HEC Montréal portant sur la question suivante : **« Quels sont les facteurs qui influencent l'adoption des technologies d'agriculture de précision des agriculteurs québécois?»**. Cette étude est faite en collaboration avec le CIRANO (centre interuniversitaire de recherche et d'analyse des organisations), le CRAAQ (centre de référence en agriculture et agroalimentaire du Québec) et la FPCCQ (Fédération des producteurs de cultures commerciales du Québec).

Répondez sans hésitation aux questions incluses dans ce questionnaire, car ce sont vos premières impressions qui reflètent généralement le mieux votre pensée. Il n'y a pas de limite de temps pour répondre au questionnaire. Nous avons estimé que cela devrait vous prendre environ 15 minutes.

Les renseignements recueillis sont anonymes et resteront strictement confidentiels; ils ne seront utilisés que pour l'avancement des connaissances et la diffusion des résultats globaux dans des forums savants ou professionnels.

Vous êtes complètement libre de refuser de participer à ce projet et vous pouvez décider, en tout temps, d'arrêter de répondre aux questions. Le fait de remplir ce questionnaire sera considéré comme votre consentement à participer à notre recherche.

Si vous avez des questions concernant cette recherche, vous pouvez contacter le chercheur principal, Monsieur Jonathan Grimaudo, au numéro de téléphone ou à l'adresse de courriel indiqués ci-dessous.

Le comité d'éthique de la recherche de HEC Montréal a statué que la collecte de données liée à la présente étude satisfait aux normes éthiques en recherche auprès des êtres humains. Pour toute question en matière d'éthique, vous pouvez communiquer avec le secrétariat de ce comité au (514) 340-7182 ou au cer@hec.ca

Une fois que vous aurez terminé le questionnaire, insérez-le dans l'enveloppe prépayée et mettez-le à la poste pour l'acheminer au chercheur.

Merci de votre précieuse collaboration!

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Définition

L'agriculture de précision : est un concept de gestion de parcelles agricoles basé sur l'hétérogénéité intra parcellaire qui utilisent des technologies comme : le système GPS, la télédétection (ex : satellite, avion), la cartographie (ex : carte de rendement), le système d'information géographique (SIG), les capteurs de rendement, les technologies à taux variables (ex : semoir, épandeur), etc. pour améliorer l'exploitation.

Questions

*Pour indiquer vos réponses, veuillez **noircir** le cercle correspondant. Si jamais vous voulez changer votre réponse, barrez la réponse initiale et noircissez le cercle approprié.*	Faible				Excellent	Je ne sais pas
1. Quel est mon niveau de connaissance générale sur l'agriculture de précision?	①	②	③	④	⑤	⓪
2. Quelle est ma capacité à utiliser des applications informatiques?	①	②	③	④	⑤	⓪

*Pour indiquer vos réponses, veuillez **noircir** le cercle correspondant.*	Jamais				Toujours	Je ne sais pas
3. Utilisez-vous les données historiques de vos champs?	①	②	③	④	⑤	⓪

*Pour indiquer vos réponses, veuillez **noircir** le cercle qui correspond le mieux à votre niveau d'accord concernant les aspects figurant ci-dessous.*	Pas du tout en accord				Tout à fait en accord	Je ne sais pas
4. En général, je suis très curieux de comprendre comment les choses fonctionnent.	①	②	③	④	⑤	⓪
5. En général, j'aime bien expérimenter de nouvelles façons de faire.	①	②	③	④	⑤	⓪
6. En général, j'aime bien tenter ma chance.	①	②	③	④	⑤	⓪
7. En général, j'aime bien être entouré de gens non conventionnels qui osent essayer de nouvelles choses.	①	②	③	④	⑤	⓪
8. En général, je cherche souvent de l'information sur de nouveaux produits.	①	②	③	④	⑤	⓪
9. L'utilisation des technologies d'agriculture de précision augmente la productivité.	①	②	③	④	⑤	⓪
10. L'utilisation des technologies d'agriculture de précision diminue le coût des intrants (Ex. : fertilisant, pesticides, etc.).	①	②	③	④	⑤	⓪
11. L'utilisation des technologies d'agriculture de précision donne de meilleures informations sur lesquelles baser des décisions.	①	②	③	④	⑤	⓪
12. L'utilisation des technologies d'agriculture de précision réduit l'impact environnemental des activités agricoles.	①	②	③	④	⑤	⓪
13. L'utilisation des technologies d'agriculture de précision est compatible avec la plupart des aspects de mon travail (machinerie, etc.).	①	②	③	④	⑤	⓪

14. L'utilisation des technologies d'agriculture de précision correspond à mon style de travail.	①	②	③	④	⑤	⓪
Pour indiquer vos réponses, veuillez ***noircir*** *le cercle qui correspond le mieux à votre niveau d'accord concernant les aspects figurant ci-dessous.*	Pas du tout en accord				Tout à fait en accord	Je ne sais pas
15. Je comprends clairement comment utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
16. Apprendre à utiliser des technologies d'agriculture de précision est (serait) facile pour moi.	①	②	③	④	⑤	⓪
17. Je trouve que l'interaction avec les technologies d'agriculture de précision est inflexible.	①	②	③	④	⑤	⓪
18. L'utilisation des technologies d'agriculture de précision correspond bien à la façon dont j'aime travailler.	①	②	③	④	⑤	⓪
19. C'est (Ce serait) facile **d'exécuter** du travail en utilisant des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
20. Ce n'est (ne serait) pas facile pour moi de **devenir habile** à utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
21. Je trouve les technologies d'agriculture de précision faciles à utiliser.	①	②	③	④	⑤	⓪
22. Mes employés/main-d'œuvre familiale sont tous bien formés sur les technologies d'agriculture de précision (répondez seulement si vous avez de la main-d'œuvre).	①	②	③	④	⑤	⓪
23. Il y a au moins un employé/main-d'œuvre familiale qui est un expert en technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
24. Je classe la compréhension de mes employés/main-d'œuvre familiale sur les technologies d'agriculture de précision comme étant très bonne comparée aux autres entreprises de la même industrie.	①	②	③	④	⑤	⓪
25. Je vois ce que les agriculteurs font en utilisant des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
26. Je ne vois pas beaucoup d'autres agriculteurs utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
27. C'est facile pour moi d'observer les autres utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
28. J'ai souvent l'occasion de voir des technologies d'agriculture de précision être utilisées.	①	②	③	④	⑤	⓪
29. Je vois plusieurs personnes utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
30. L'information fournie par les technologies d'agriculture de précision est produite dans un format utile (carte de rendement, etc.)	①	②	③	④	⑤	⓪
31. Les technologies d'agriculture de précision donnent toute l'information dont j'ai besoin.	①	②	③	④	⑤	⓪

32. Les technologies d'agriculture de précision donnent de l'information pertinente.	①	②	③	④	⑤	⓪
33. Il est facile d'obtenir du support sur les technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
Pour indiquer vos réponses, veuillez ***noircir*** *le cercle qui correspond le mieux à votre niveau d'accord concernant les aspects figurant ci-dessous.*	Pas du tout en accord				Tout à fait en accord	Je ne sais pas
34. Les gens responsables du support sur les technologies d'agriculture de précision ont des connaissances suffisantes pour répondre à mes questions.	①	②	③	④	⑤	⓪
35. Je sens que les gens responsables du support des technologies d'agriculture de précision travaillent dans mon intérêt.	①	②	③	④	⑤	⓪
36. Les gens qui utilisent des technologies d'agriculture de précision se différencient.	①	②	③	④	⑤	⓪
37. Les gens qui utilisent des technologies d'agriculture de précision ont plus de prestige que ceux qui ne les utilisent pas.	①	②	③	④	⑤	⓪
38. Exploiter avec des technologies d'agriculture de précision est un symbole de statut social.	①	②	③	④	⑤	⓪
39. J'ai les ressources, les opportunités et la connaissance pour utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
40. Je suis (serais) capable d'utiliser des technologies d'agriculture de précision si je le veux (voulais).	①	②	③	④	⑤	⓪
41. J'ai accès aux ressources dont j'ai (aurais) besoin pour utiliser des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
42. Il n'a pas de barrière à mon utilisation des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
43. Les représentants agricoles (vendeur, conseillé, etc.) s'attendent à ce que j'utilise des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
44. Même si ça peut être utile, l'utilisation des technologies d'agriculture de précision est facultative pour mon travail.	①	②	③	④	⑤	⓪
45. La décision d'utiliser des technologies d'agriculture de précision me revient entièrement.	①	②	③	④	⑤	⓪
46. L'utilisation des technologies d'agriculture de précision est obligatoire.	①	②	③	④	⑤	⓪
47. Les représentants agricoles (vendeur, conseillé, etc.) demandent que j'utilise des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
48. Je peux facilement discuter avec des interlocuteurs anglophones si nécessaire.	①	②	③	④	⑤	⓪

*Pour indiquer vos réponses, veuillez **noircir** le cercle qui correspond le mieux à votre niveau d'accord concernant les aspects figurant ci-dessous.* **Avant de décider d'utiliser ou non des technologies d'agriculture de précision,...**	Pas du tout en accord				Tout à fait en accord	Je ne sais pas
49. ... je pouvais (je pourrais) les essayer à titre expérimental.	①	②	③	④	⑤	⓪
50. ... je n'avais (je n'aurais) aucune difficulté à dire aux autres les résultats de l'adoption des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪
51. ... j'étais (je serais) autorisé(e) à les utiliser assez longtemps pour voir ce qu'elles pouvaient faire.	①	②	③	④	⑤	⓪
52. ... j'étais (je serais) en mesure de les essayer de façon adéquate.	①	②	③	④	⑤	⓪
53. ...j'avais (j'aurais) du mal à expliquer pourquoi l'adoption des technologies d'agriculture de précision pouvait être bénéfique.	①	②	③	④	⑤	⓪
54. … je connaissais (je connais) un endroit où j'avais pu (je pourrais) les essayer.	①	②	③	④	⑤	⓪
55. ...je pouvais (je pourrais) informer les autres des avantages et des inconvénients liés à l'adoption de ces technologies.	①	②	③	④	⑤	⓪
56. … j'étais (je serais) en mesure d'essayer leurs diverses applications.	①	②	③	④	⑤	⓪
57. ... j'avais (j'aurais) de la difficulté à dire si c'est bon ou mauvais d'adopter des technologies d'agriculture de précision.	①	②	③	④	⑤	⓪

*Pour indiquer vos réponses, veuillez **noircir**, pour les questions 58 à 63 le cercle qui se rapproche de l'adjectif qui caractérise la phrase en gras ci-dessous. Exemple (#58) : Si vous trouvez que dans l'accomplissement de votre travail les technologies d'agriculture de précision sont plutôt fondamentales que négligeables, alors noircissez le chiffre qui se rapproche de « Fondamentales » donc le cercle 4 ou 5. Continuez de cette façon jusqu'au numéro 63.* **En général, dans l'accomplissement de mon travail, des technologies d'agriculture de précision sont (seraient): ...**								Je ne sais pas
58.	...Négligeables	①	②	③	④	⑤	Fondamentales	⓪
59.	...Peu pertinentes	①	②	③	④	⑤	Pertinentes	⓪
60.	...Peu importantes	①	②	③	④	⑤	Importantes	⓪
61.	...Ennuyantes	①	②	③	④	⑤	Intéressantes	⓪
62.	...Banales	①	②	③	④	⑤	Fascinantes	⓪
63.	...Peu attirantes	①	②	③	④	⑤	Attirantes	⓪

*Pour indiquer vos réponses, veuillez **cocher** la case correspondante.*

64. Quel est votre âge?

☐ 20 à 29	☐ 40 à 49	☐ 60 et plus
☐ 30 à 39	☐ 50 à 59	

Pour indiquer vos réponses, veuillez ***cocher*** *la case correspondante.*

65. Quel est votre sexe?

☐ Homme ☐ Femme

66. Quel est votre dernier niveau d'éducation complété?

☐ PRIMAIRE ☐ UNIVERSITAIRE 1er CYCLE
☐ SECONDAIRE ☐ UNIVERSITAIRE 2e CYCLE
☐ CÉGEP-TECHNIQUE

67. Quelles technologies d'agriculture de précision utilisez-vous, parmi les suivantes? Si vous n'utilisez pas des technologies d'agriculture de précision, ne répondez pas et passez directement à la question 69.

☐ GPS ☐ Système d'information géographique ☐ Capteurs de rendement
☐ Cartographie (ex : carte de rendement) ☐ Système de navigation (Ex : Autopilote) ☐ Technologies à taux variables (Ex : semoir, épandeur) NB : Taux variables en cours d'application
☐ Télédétection (ex : satellite, avion)

Autres : ____

68. À quelle capacité utilisez-vous les technologies d'agriculture de précision **que vous employez**? Si vous n'utilisez pas des technologies d'agriculture de précision, ne répondez pas et passez à la prochaine question.

☐ 0% à 20% ☐ 40% à 60% ☐ 80% à 100%
☐ 20% à 40% ☐ 60% à 80%

Pour indiquer vos réponses ***écrivez*** *directement sur le questionnaire*	Réponse
69. Quel est l'âge moyen de votre machinerie, en années?	______________________
70. Pendant combien de minutes par jour utilisez-vous en moyenne un ordinateur? (ex : 0, 30, 60, 90 minutes)	______________________

Pour indiquer vos réponses, veuillez ***cocher*** *la case correspondante.*

71. Quelle est la taille de votre ferme, selon le revenu, approximativement en dollars ($) par année?

☐ Moins de 9 999 $ ☐ 50 000 – 99 999 $ ☐ 250 000 – 499 999 $
☐ 10 000 – 49 999 $ ☐ 100 000 – 249 999 $ ☐ 500 000 $ et plus

72. *Question ouverte (facultative): Quelles sont vos raisons pour avoir choisi d'utiliser ou non les technologies d'agriculture de précision.*

Veuillez maintenant insérer le questionnaire complété dans l'enveloppe prépayée et mettez-le à la poste pour l'acheminer au chercheur.

Merci pour votre précieuse collaboration et pour le temps que vous avez bien voulu consacrer à cette étude!

Jonathan Grimaudo

Appendix 2: Frequency for sample comparison

Age of the operator

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20 à 29	18	4.3	4.5	4.5
	30 à 39	62	14.9	15.6	20.2
	40 à 49	136	32.8	34.3	54.4
	50 à 59	136	32.8	34.3	88.7
	60 et plus	45	10.8	11.3	100.0
	Total	397	95.7	100.0	
Missing	System	18	4.3		
Total		415	100.0		

Education of the operator

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Primaire	20	4.8	5.0	5.0
	Secondaire	195	47.0	48.6	53.6
	2.5	1	.2	.2	53.9
	Céjep - Technique	143	34.5	35.7	89.5
	Universitaire 1er cycle	35	8.4	8.7	98.3
	Universitaire 2e cycle	7	1.7	1.7	100.0
	Total	401	96.6	100.0	
Missing	System	14	3.4		
Total		415	100.0		

Farm size

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10 000$ a 49 999$	7	1.7	1.8	1.8
	50 000$ a 99 999$	18	4.3	4.6	6.3
	100 000$ a 249 999$	94	22.7	23.9	30.2
	250 000$ a 499 999$	114	27.5	28.9	59.1
	500 000$ et plus	161	38.8	40.9	100.0
	Total	394	94.9	100.0	
Missing	System	21	5.1		
Total		415	100.0		

Gender of the operator

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Homme	387	93.3	96.8	96.8
	Femme	13	3.1	3.2	100.0
	Total	400	96.4	100.0	
Missing	System	15	3.6		
Total		415	100.0		

Appendix 3: Mann-Whitney and Wilcoxon test on items

	Operator knowledge 1	Operator knowledge 2	Historical data	Operator innovativeness 1	Operator innovativeness 2	Operator innovativeness 3	Operator innovativeness 4	Operator innovativeness 5	Relative advantage 1	Relative advantage 2
Mann-Whitney U	437.500	415.500	418.500	433.500	419.500	398.000	323.500	409.000	370.000	326.500
Wilcoxon W	902.500	880.500	883.500	898.500	884.500	863.000	788.500	874.000	805.000	732.500
Z	-0.196	-0.538	-0.494	-0.279	-0.489	-0.808	-1.968	-0.642	-0.843	-1.530
Asymp. Sig. (2-tailed)	0.845	0.591	0.621	0.780	0.625	0.419	0.049	0.521	0.399	0.126
	Relative advantage 3	Relative advantage 4	Compatibility 1	Compatibility 2	Ease of use 1	Ease of use 2	Ease of use 3	Compatibility 3	Ease of use 4	Ease of use 5
Mann-Whitney U	378.500	389.500	421.000	386.000	291.000	301.000	229.500	419.500	406.000	372.500
Wilcoxon W	813.500	795.500	886.000	792.000	726.000	736.000	505.500	884.500	871.000	837.500
Z	-0.717	-0.518	-0.223	-0.557	-2.101	-1.971	-0.306	-0.248	-0.231	-0.775
Asymp. Sig. (2-tailed)	0.473	0.604	0.824	0.578	0.036	0.049	0.759	0.804	0.818	0.438
	Ease of use 6	Employee knowledge 1	Employee knowledge 2	Employee knowledge 3	Visibility 1	Visibility 2	Visibility 3	Visibility 4	Visibility 5	Information 1
Mann-Whitney U	250.000	193.500	245.500	193.000	221.500	258.000	291.000	333.500	339.000	193.000
Wilcoxon W	628.000	493.500	623.500	518.000	599.500	693.000	756.000	798.500	804.000	571.000
Z	-1.919	-1.601	-1.525	-2.228	-2.764	-2.423	-2.057	-1.573	-1.300	-2.926
Asymp. Sig. (2-tailed)	0.055	0.109	0.127	0.026	0.006	0.015	0.040	0.116	0.193	0.003

	Information 2	Information 3	Quality of support 1	Quality of support 2	Quality of support 3	Image 1	Image 2	Image 3	Perceived resources 1	Perceived resources 2
Mann-Whitney U	259.000	240.500	174.000	140.500	188.500	256.500	339.500	330.500	328.500	327.000
Wilcoxon W	637.000	675.500	580.000	440.500	566.500	662.500	717.500	708.500	793.500	792.000
Z	-1.722	-2.247	-3.240	-3.166	-2.909	-2.201	-0.445	-0.379	-1.489	-1.750
Asymp. Sig. (2-tailed)	0.085	0.025	0.001	0.002	0.004	0.028	0.656	0.705	0.136	0.080
	Perceived resources 3	Perceived resources 4	Voluntariness 1	Voluntariness 2	Voluntariness 3	Voluntariness 4	Voluntariness 5	Language skills	Trialability 1	Observability 1
Mann-Whitney U	226.500	271.000	336.500	299.000	398.000	419.000	250.000	343.500	319.500	376.000
Wilcoxon W	632.500	706.000	687.500	734.000	804.000	854.000	656.000	778.500	725.500	754.000
Z	-2.795	-2.022	-0.268	-1.754	-0.153	-0.026	-2.592	-0.658	-1.036	-0.038
Asymp. Sig. (2-tailed)	0.005	0.043	0.789	0.079	0.878	0.979	0.010	0.510	0.300	0.970
	Trialability 2	Trialability 3	Observability 2	Trialability 4	Observability 3	Trialability 5	Observability 4	Perceived usefulness 1	Perceived usefulness 2	Perceived usefulness 3
Mann-Whitney U	288.500	299.000	274.500	238.500	355.000	278.000	377.000	355.000	278.000	340.500
Wilcoxon W	666.500	705.000	652.500	616.500	761.000	684.000	755.000	790.000	684.000	746.500
Z	-1.158	-1.381	-1.809	-0.958	-0.405	-1.769	-0.017	-0.847	-1.950	-0.891
Asymp. Sig. (2-tailed)	0.247	0.167	0.070	0.338	0.685	0.077	0.986	0.397	0.051	0.373

	Perceived usefulness 4	Perceived usefulness 5	Perceived usefulness 6	Age of the operator	Gender of the operator	Education of the operator	Geographic positioning system	Geographic information system	Yield monitors	Cartogr aphy
Mann-Whitney U	353.500	318.500	382.500	376.500	391.000	378.000	399.000	379.500	384.000	383.500
Wilcoxon W	759.500	724.500	788.500	782.500	826.000	784.000	805.000	785.500	819.000	789.500
Z	-0.700	-1.306	-0.171	-0.493	-0.619	-0.497	-0.129	-0.703	-0.407	-0.420
Asymp. Sig. (2-tailed)	0.484	0.191	0.864	0.622	0.536	0.619	0.897	0.482	0.684	0.675
	Navigation system	Variable rate application technology	Teledetection	Others	Capacity utilized	Age of the Machinery	Computer time	Farm size		
Mann-Whitney U	375.000	347.000	391.000	378.000	206.000	337.500	284.500	340.000		
Wilcoxon W	810.000	782.000	826.000	784.000	396.000	772.500	690.500	718.000		
Z	-0.751	-1.565	-0.619	-1.402	-0.081	-1.113	-2.028	-0.673		
Asymp. Sig. (2-tailed)	0.453	0.118	0.536	0.161	0.936	0.266	0.043	0.501		
a	Grouping Variable:	First_Last_30								

Appendix 4: Mann-Whitney and Wilcoxon test on adoption factors

	Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information
Mann-Whitney U	409.500	402.000	436.000	317.000	262.000	307.500	246.500
Wilcoxon W	905.500	837.000	932.000	782.000	640.000	772.500	681.500
Z	-0.804	-0.708	-0.422	-1.975	-1.593	-2.118	-2.398
Asymp. Sig. (2-tailed)	0.421	0.479	0.673	0.048	0.111	0.034	0.016
	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Mann-Whitney U	152.500	404.000	289.000	334.500	359.000	389.500	316.500
Wilcoxon W	558.500	810.000	754.000	769.500	765.000	824.500	722.500
Z	-3.950	-0.032	-2.389	-1.341	-0.763	-0.484	-1.636
Asymp. Sig. (2-tailed)	0.000	0.974	0.017	0.180	0.446	0.629	0.102

Appendix 5: Individual loadings and Cronbach's alpha

Operator knowledge			
	Component	Cronbach's alpha	
	1		
Operator knowledge 1	0.769446679	0.26	0.341
COMPUTE ope_K2=LG10(ok2)	0.865553931		
COMPUTE comp_T=SQRT(comp)	0.694518983		
Extraction Method: Principal Component Analysis.			
a. 1 components extracted.			

Operator innovativeness		
	Component	Cronbach's alpha
	1	
Operator innovativeness 1	0.68317908	0.832
Operator innovativeness 2	0.857809201	
Operator innovativeness 3	0.817149163	
Operator innovativeness 4	0.767900174	
Operator innovativeness 5	0.733360793	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Relative advantage		
	Component	Cronbach's alpha
	1	
Relative advantage 1	0.797481561	0.819
Relative advantage 2	0.83328668	
Relative advantage 3	0.761588837	
Relative advantage 4	0.81786527	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Compatibility		
	Component	Cronbach's alpha
	1	
Compatibility 1	0.839983764	0.859
Compatibility 2	0.931197929	
Compatibility 3	0.879605317	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Employee knowledge		
	Component	Cronbach's alpha
	1	
Employee knowledge 1	0.858548606	0.835
Employee knowledge 2	0.880219663	
Employee knowledge 3	0.883545116	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Information		
	Component	Cronbach's alpha
	1	
Information 1	0.841259402	0.804
Information 2	0.839183753	
Information 3	0.866080327	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Quality of support		
	Component	Cronbach's alpha
	1	
Quality of support 1	0.831362923	0.788
Quality of support 2	0.896981346	
Quality of support 3	0.800323006	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Image			
	Component	Cronbach's alpha	
	1		
Image 1	0.602414061	0.724	
Image 2	0.913925962		0.843
Image3	0.868761357		
Extraction Method: Principal Component Analysis.			
a. 1 components extracted.			

Perceived resources		
	Component	Cronbach's alpha
	1	
Perceived resources 1	0.859857577	0.811
Perceived resources 2	0.820268228	
Perceived resources 3	0.819994365	
Perceived resources 4	0.707564595	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Perceived usefulness		
	Component	Cronbach's alpha
	1	
Perceived usefulness 1	0.717477906	0.894
Perceived usefulness 2	0.804098075	
Perceived usefulness 3	0.805351247	
Perceived usefulness 4	0.845703408	
Perceived usefulness 5	0.842838429	
Perceived usefulness 6	0.835970527	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Trialability		
	Component	Cronbach's alpha
	1	
Trialability 1	0.774714752	0.841
Trialability 2	0.87207404	
Trialability 3	0.895150478	
Trialability 5	0.761283875	
Trialability 4	0.599044123	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Visibility			
	Component	Cronbach's alpha	
	1		
Visibility 2 - R	0.589964265	0.838	
Visibility 1	0.719230942		0.859
Visibility 3	0.839572855		
Visibility 4	0.877185073		
Visibility 5	0.859851131		
Extraction Method: Principal Component Analysis.			
a. 1 components extracted.			

Ease of use				
	Component		Cronbach's alpha	
	1	2		
Ease of use 1	0.801311237	-0.043362427	0.773	0.838
Ease of use 2	0.882474665	0.100459882		
Ease of use 4	0.766838753	0.005793084		
Ease of use 5 - R	0.519719287	0.538163582		
Ease of use 6	0.856855224	0.08910067		
Ease of use 3 - R	-0.115901748	0.918144386		
Extraction Method: Principal Component Analysis.				
Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 3 iterations.				

Ease of use		
	Component	Cronbach's alpha
	1	
Ease of use 1	0.806371546	0.859
Ease of use 2	0.88332575	
Ease of use 4	0.780597101	
Ease of use 6	0.874605011	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Ease of use - R		
	Component	Cronbach's alpha
	1	
Ease of use 3 - R	0.770499935	0.331
Ease of use 5 - R	0.770499935	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Voluntariness			
	Component		Cronbach's alpha
	1	2	
Voluntariness 1 - R	0.795167353	-0.162846806	0.461
Voluntariness 2	0.002782329	0.763310972	
Voluntariness 3	-0.040168028	0.718684307	
Voluntariness 4 - R	0.566655396	0.430137833	
Voluntariness 5 - R	0.85523248	0.007635819	
Extraction Method: Principal Component Analysis.			
Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 3 iterations.			

Voluntariness		
	Component	Cronbach's alpha
	1	
Voluntariness 2	0.779970246	0.35
Voluntariness 3	0.779970246	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Voluntariness - R			
	Component	Cronbach's alpha	
	1		
Voluntariness 4	0.614478123	0.613	
Voluntariness 1	0.769588693		0.668
Voluntariness 5	0.851834155		
Extraction Method: Principal Component Analysis.			
a. 1 components extracted.			

Observability			
	Component		Cronbach's alpha
	1	2	
Observability 1	0.851695927	0.083428777	0.59
Observability 2 - R	0.251165141	0.791816242	
Observability 3	0.847557614	0.118341077	
Observability 4 - R	-0.021367929	0.874651336	
Extraction Method: Principal Component Analysis.			
Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 3 iterations.			

Observability		
	Component	Cronbach's alpha
	1	
Observability 1	0.860146371	0.647
Observability 3	0.860146371	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Observability - R		
	Component	Cronbach's alpha
	1	
Observability 2 - R	0.841970281	0.588
Observability 4 - R	0.841970281	
Extraction Method: Principal Component Analysis.		
a. 1 components extracted.		

Appendix 6: Exploratory factor analysis

Rotated Component Matrix(a)	1	2	3	4	5	6	7	8	9	10	11	12	13
Operator innovativeness 1			0.63										
Operator innovativeness 2			0.796										
Operator innovativeness 3			0.763										
Operator innovativeness 4			0.685										
Operator innovativeness 5			0.71										
Relative advantage 1					0.65								
Relative advantage 2					0.809								
Relative advantage 3					0.561								
Relative advantage 4					0.765								
Ease of use 1						0.481							
Ease of use 2						0.693							
Ease of use 4						0.518							
Ease of use 5						0.675							
Ease of use 6						0.612							
Employee knowledge 1							0.774						
Employee knowledge 2							0.792						
Employee knowledge 3							0.804						
Visibility 1				0.552									
Visibility 3				0.736									
Visibility 4				0.848									
Visibility 5				0.837									
Information 1									0.674				
Information 2									0.742				
Information 3									0.768				
Quality of support 1										0.771			
Quality of support 2										0.855			
Quality of support 3										0.668			
Image 2											0.814		
Image3											0.82		
Perceived resources 1								0.621					
Perceived resources 2								0.579					
Perceived resources 3								0.682					
Perceived resources 4													
Voluntariness 1												-0.783	
Voluntariness 5												-0.804	

Rotated Component Matrix(a)	1	2	3	4	5	6	7	8	9	10	11	12	13
Trialability 1		0.76											
Trialability 2		0.88											
Trialability 3		0.861											
Trialability 4		0.499											
Trialability 5		0.723											
Observability 1		0.621											
Observability 2													0.74
Observability 3		0.572											
Observability 4													0.835
Perceived usefulness 1	0.576												
Perceived usefulness 2	0.674												
Perceived usefulness 3	0.672												
Perceived usefulness 4	0.805												
Perceived usefulness 5	0.799												
Perceived usefulness 6	0.814												

Appendix 7: Exploratory factor analysis (trialability and observability)

Rotated Component Matrixa		
	Component	
	1	2
Trialability 1	0.740098058	
Trialability 2	0.853658344	
Trialability 3	0.880413853	
Trialability 4	0.575864095	
Trialability 5	0.765220098	
Observability 1	0.656134412	
Observability 2		0.827135648
Observability 3	0.662154364	
Observability 4		0.803654637

Appendix 8: Adoption factors (multiple items) comparison between adopters and non-adopters

Adoption		Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Non	Mean	3.6866	3.9080	3.2232	3.0527	2.1056	2.4580	3.3754	3.2344	2.2018	3.0114	3.5667	3.4828	3.4765	3.8609
	N	119	116	118	117	90	117	103	96	114	117	117	116	115	115
	Std. Deviation	.83483	.88693	.92018	.86142	1.11102	.97026	1.04076	1.03239	1.22424	1.01148	1.07504	1.00635	.90765	1.00120
	Minimum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Maximum	5.00	5.00	5.00	4.75	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Oui	Mean	4.0655	4.0312	3.7855	3.5159	2.6674	3.1814	3.7359	3.5265	2.4112	3.5370	3.4971	3.5735	3.9664	3.2635
	N	278	278	279	278	243	278	272	270	273	278	278	279	276	277
	Std. Deviation	.62356	.77564	.83292	.84387	1.16435	.93772	.80283	.92958	1.12362	.86139	1.01967	.95349	.72123	1.02374
	Minimum	2.00	1.25	1.00	1.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.00
	Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total	Mean	3.9519	3.9949	3.6184	3.3787	2.5155	2.9671	3.6369	3.4499	2.3495	3.3813	3.5177	3.5468	3.8223	3.4388
	N	397	394	397	395	333	395	375	366	387	395	395	395	391	392
	Std. Deviation	.71405	.81079	.89634	.87405	1.17539	1.00236	.88792	.96479	1.15653	.93841	1.03549	.96891	.81090	1.05177
	Minimum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Mann-Whitney U	12110.000	15021.500	10667.000	11306.500	7833.000	9593.000	11469.500	10756.500	13565.000	11310.500	15529.000	15471.500	10590.500	10493.500
Wilcoxon W	19250.000	21807.500	17688.000	18209.500	11928.000	16496.000	16825.500	15412.500	20120.000	18213.500	54310.000	22257.500	17260.500	48996.500
Z	-4.248	-1.077	-5.583	-4.802	-3.998	-6.455	-2.731	-2.488	-2.021	-4.797	-.710	-.697	-5.204	-5.379
Asymp. Sig. (2-tailed)	.000	.281	.000	.000	.000	.000	.006	.013	.043	.000	.478	.486	.000	.000

Appendix 9: Control variables (single items) comparison between adopters and non-adopters

Adoption		Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
Non	Mean	2.8305	2.9153	3.6695	1.7931	3.4492	1.0504	2.4706	10.3718	41.4364	4.6579
	N	118	118	118	116	118	119	119	117	118	114
	Std. Deviation	.98973	1.18809	1.30125	1.34822	1.03443	.21974	.86184	5.53288	46.26261	1.07117
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	300.00	500 000$ et plus
Oui	Mean	3.4982	3.3141	3.9134	2.1941	3.2671	1.0251	2.5589	8.9088	44.1341	5.1799
	N	277	277	277	273	277	279	280	274	276	278
	Std. Deviation	.91535	1.03503	1.14828	1.40732	1.00764	.15668	.75912	4.66956	43.40760	.92500
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	1.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	360.00	500 000$ et plus
Total	Mean	3.2987	3.1949	3.8405	2.0746	3.3215	1.0327	2.5326	9.3465	43.3261	5.0281
	N	395	395	395	389	395	398	399	391	394	392
	Std. Deviation	.98562	1.09682	1.19957	1.40033	1.01782	.17798	.79109	4.98184	44.23994	.99704
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	360.00	500 000$ et plus

	Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
Mann-Whitney U	10326.000	13364.000	14781.000	12885.000	14486.000	16180.000	15316.000	13579.000	14886.500	11420.500
Wilcoxon W	17347.000	20385.000	21802.000	19671.000	52989.000	55240.000	22456.000	51254.000	21907.500	17975.500
Z	-6.104	-2.985	-1.573	-3.172	-1.870	-1.300	-1.393	-2.413	-1.395	-4.596
Asymp. Sig. (2-tailed)	.000	.003	.116	.002	.062	.194	.164	.016	.163	.000

Appendix 10: Adoption factors (multiple items) comparison between diagnostic and applicative technologies

Type of technology		Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Diagnostic	Mean	3.9329	3.8539	3.5629	3.2964	2.4404	3.0860	3.6732	3.4360	2.2994	3.3597	3.4538	3.4371	3.8100	3.3217
	N	158	158	159	158	137	158	153	151	157	158	158	159	157	157
	Std. Deviation	.64504	.79702	.81707	.80923	1.10142	.94512	.80882	.96068	1.13913	.84629	.97981	1.00590	.70948	1.06370
	Minimum	2.00	1.25	1.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.00
	Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Applicative	Mean	4.2400	4.2646	4.0806	3.8049	2.9607	3.3069	3.8165	3.6415	2.5625	3.7705	3.5540	3.7542	4.1728	3.1875
	N	120	120	120	120	106	120	119	119	116	120	120	120	119	120
	Std. Deviation	.54962	.68238	.76177	.80342	1.18289	.91670	.79113	.87915	1.08891	.82796	1.07138	.85010	.68650	.96811
	Minimum	2.60	2.00	1.00	1.50	1.00	1.00	2.00	1.33	1.00	1.75	1.00	1.00	2.00	1.00
	Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total	Mean	4.0655	4.0312	3.7855	3.5363	2.6674	3.1814	3.7359	3.5265	2.4112	3.5370	3.4971	3.5735	3.9664	3.2635
	N	278	278	279	278	243	278	272	270	273	278	278	279	276	277
	Std. Deviation	.62356	.77564	.83292	.84387	1.16435	.93772	.80283	.92958	1.12362	.86139	1.01967	.95349	.72123	1.02374
	Minimum	2.00	1.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.00
	Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Mann-Whitney U	6761.500	6464.500	6004.500	6100.000	5407.000	8357.000	8249.000	8071.000	7795.000	6845.000	8870.000	7806.000	6484.500	8724.000
Wilcoxon W	19322.500	19025.500	18724.500	18661.000	14860.000	20918.000	20030.000	19547.000	20198.000	19406.000	21431.000	20526.000	18887.500	15984.000
Z	-4.115	-4.573	-5.344	-5.114	-3.427	-1.697	-1.339	-1.443	-2.058	-3.985	-.921	-2.632	-4.373	-1.065
Asymp. Sig. (2-tailed)	.000	.000	.000	.000	.001	.090	.180	.149	.040	.000	.357	.008	.000	.287

Appendix 11: Control variables (single items) comparison between diagnostic and applicative technologies

Type of technology		Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
Diagnostic	Mean	3.2866	3.1720	3.6815	2.0129	3.2803	1.0314	2.5157	9.6338	39.3217	5.0566
	N	157	157	157	155	157	159	159	157	157	159
	Std. Deviation	.94768	1.04500	1.24054	1.31419	.96632	.17507	.75352	4.88666	38.57843	.91572
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	1.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	270.00	500 000$ et plus
Applicative	Mean	3.7750	3.5000	4.2167	2.4322	3.2500	1.0167	2.6157	7.9359	50.4832	5.3445
	N	120	120	120	118	120	120	121	117	119	119
	Std. Deviation	.79349	.99579	.93650	1.49345	1.06313	.12856	.76583	4.18770	48.49895	.91538
	Minimum	2.00	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	2.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	20.00	360.00	500 000$ et plus
Total	Mean	3.4982	3.3141	3.9134	2.1941	3.2671	1.0251	2.5589	8.9088	44.1341	5.1799
	N	277	277	277	273	277	279	280	274	276	278
	Std. Deviation	.91535	1.03503	1.14828	1.40732	1.00764	.15668	.75912	4.66956	43.40760	.92500
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	1.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	360.00	500 000$ et plus

	Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
Mann-Whitney U	6760.000	7776.500	7159.500	7750.500	9346.000	9399.000	9130.500	7051.000	7805.500	7615.500
Wilcoxon W	19163.000	20179.500	19562.500	19840.500	21749.000	16659.000	21850.500	13954.000	20208.500	20335.500
Z	-4.293	-2.601	-3.597	-2.298	-.117	-.780	-.797	-3.315	-2.432	-2.993
Asymp. Sig. (2-tailed)	.000	.009	.000	.022	.907	.435	.425	.001	.015	.003

Appendix 12: Control variables (single items) comparison between non-adopter and adopter of diagnostic technologies

No_diagn		Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
No PAT	Mean	2.8305	2.9153	3.6695	1.7931	3.4492	1.0504	2.4706	10.3718	41.4364	4.6579
	N	118	118	118	116	118	119	119	117	118	114
	Std. Deviation	.98973	1.18809	1.30125	1.34822	1.03443	.21974	.86184	5.53288	46.26261	1.07117
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	300.00	500 000$ et plus
Diagnostic	Mean	3.2866	3.1720	3.6815	2.0129	3.2803	1.0314	2.5157	9.6338	39.3217	5.0566
	N	157	157	157	155	157	159	159	157	157	159
	Std. Deviation	.94768	1.04500	1.24054	1.31419	.96632	.17507	.75352	4.88666	38.57843	.91572
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	1.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	270.00	500 000$ et plus
Total	Mean	3.0909	3.0618	3.6764	1.9188	3.3527	1.0396	2.4964	9.9489	40.2291	4.8901
	N	275	275	275	271	275	278	278	274	275	273
	Std. Deviation	.99033	1.11386	1.26462	1.33085	.99778	.19529	.80049	5.17559	41.98027	1.00129
	Minimum	Faible	Faible	Jamais	Pas du tout en accord	20 à 29	Homme	Primaire	.00	.00	10 000$ a 49 999$
	Maximum	Excellent	Excellent	Toujours	Tout à fait en accord	60 et plus	Femme	Universitaire 2e cycle	29.00	300.00	500 000$ et plus

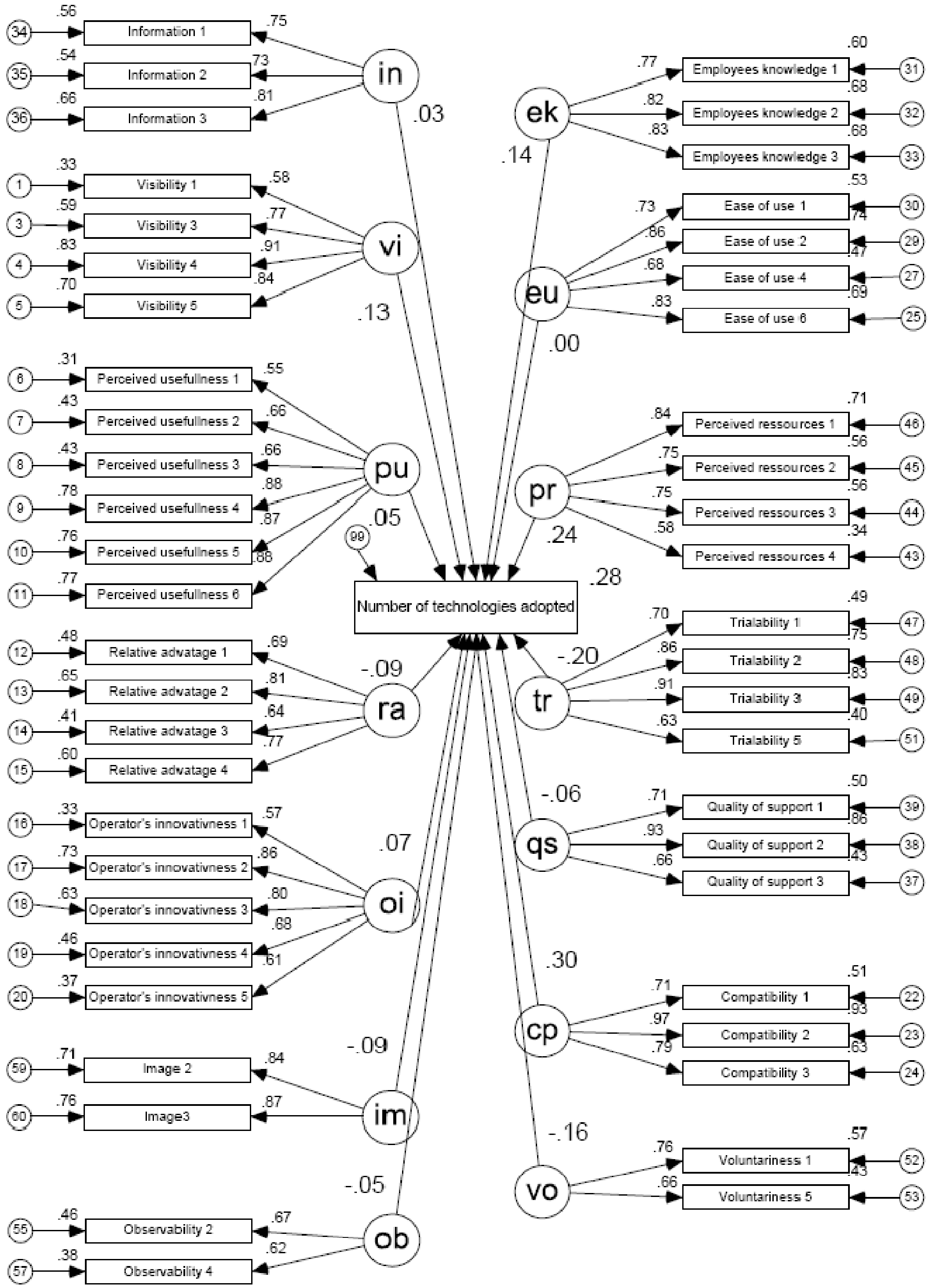
	Operator knowledge 1	Operator knowledge 2	Historical data	Language skills	Age of the operator	Gender of the operator	Education of the operator	Age of the Machinery	Computer time	Farm size
Mann-Whitney U	6873.500	8218.000	9209.000	7822.500	8166.000	9281.000	8910.500	8730.500	9030.000	7165.000
Wilcoxon W	13894.500	15239.000	21612.000	14608.500	20569.000	22001.000	16050.500	21133.500	16051.000	13720.000
Z	-3.852	-1.663	-.086	-2.055	-1.758	-.802	-.904	-.707	-.369	-3.093
Asymp. Sig. (2-tailed)	.000	.096	.932	.040	.079	.423	.366	.480	.712	.002

Appendix 13: Adoption factors (multiple items) comparison between non-adopter and adopter of diagnostic technologies

No_diagn		Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
No PAT	Mean	3.6866	3.9080	3.2232	3.1199	2.1056	2.4580	3.3754	3.2344	2.2018	3.0114	3.5667	3.4828	3.4765	3.8609
	N	119	116	118	117	90	117	103	96	114	117	117	116	115	115
	Std. Deviation	.83483	.88693	.92018	.80671	1.11102	.97026	1.04076	1.03239	1.22424	1.01148	1.07504	1.00635	.90765	1.00120
	Minimum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Maximum	5.00	5.00	5.00	4.80	5.00	4.50	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Diagnostic	Mean	3.9329	3.8539	3.5629	3.3365	2.4404	3.0860	3.6732	3.4360	2.2994	3.3597	3.4538	3.4371	3.8100	3.3217
	N	158	158	159	158	137	158	153	151	157	158	158	159	157	157
	Std. Deviation	.64504	.79702	.81707	.76977	1.10142	.94512	.80882	.96068	1.13913	.84629	.97981	1.00590	.70948	1.06370
	Minimum	2.00	1.25	1.33	1.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.00
	Maximum	5.00	5.00	5.00	4.80	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total	Mean	3.8271	3.8768	3.4182	3.2444	2.3076	2.8188	3.5534	3.3576	2.2583	3.2115	3.5018	3.4564	3.6690	3.5496
	N	277	274	277	275	227	275	256	247	271	275	275	275	272	272
	Std. Deviation	.74133	.83511	.87718	.79154	1.11493	1.00356	.91904	.99199	1.17445	.93450	1.02103	1.00451	.81459	1.06968
	Minimum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Maximum	5.00	5.00	5.00	4.80	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

	Operator knowledge	Relative advantage	Compatibility	Ease of use	Employee knowledge	Visibility	Information	Quality of support	Image	Perceived resources	Trialability	Observability	Perceived usefulness	Voluntariness
Mann-Whitney U	7893.000	8576.500	7368.000	7694.500	5013.500	5853.000	6738.500	6339.000	8341.500	7332.500	8549.000	8905.500	6981.000	6304.500
Wilcoxon W	15033.000	21137.500	14389.000	14597.500	9108.500	12756.000	12094.500	10995.000	14896.500	14235.500	21110.000	21625.500	13651.000	18707.500
Z	-2.295	-.912	-3.076	-2.384	-2.398	-5.212	-1.981	-1.670	-.975	-2.940	-1.066	-.492	-3.205	-4.297
Asymp. Sig. (2-tailed)	.022	.362	.002	.017	.016	.000	.048	.095	.330	.003	.286	.623	.001	.000

Appendix 14: CFA (Confirmatory factor analysis)



Appendix 15: Correlation matrix

Correlation Matrix	Ope_inn	rel_adv	compt	ease_use	empl_know	visibility	info	qua_supp	image	perc_res	trialab	observ	perc_use	volunt
Ope_inn	1.000													
rel_adv	0.423**	1.000												
compt	0.580**	0.583**	1.000											
ease_use	0.454**	0.352**	0.668**	1.000										
empl_know	0.289**	0.284**	0.471**	0.461**	1.000									
visibility	0.317**	0.229**	0.503**	0.497**	0.497**	1.000								
info	0.273**	0.413**	0.429**	0.441**	0.355**	0.376**	1.000							
qua_supp	0.179**	0.348**	0.370**	0.334**	0.242**	0.340**	0.484**	1.000						
image	0.108*	0.297**	0.263**	0.096	0.248**	0.273**	0.213**	0.235**	1.000					
perc_res	0.398**	0.313**	0.586**	0.662**	0.436**	0.518**	0.443**	0.391**	0.195**	1.000				
trialab	0.221**	0.234**	0.287**	0.322**	0.198**	0.200**	0.260**	0.191**	0.065	0.330**	1.000			
observ	0.358**	0.209**	0.403**	0.419**	0.247**	0.252**	0.223**	0.097	0.074	0.401**	0.402**	1.000		
perc_use	0.479**	0.467**	0.650**	0.462**	0.338**	0.391**	0.411**	0.305**	0.213**	0.411**	0.241**	0.353**	1.000	
volunt	-0.135**	-0.082	-0.273**	-0.168**	-0.234**	-0.280**	-0.151**	-0.168**	-0.325**	-0.257**	-0.120*	-0.115*	-0.200**	1.000

Ope_inn=MEAN(oi1,oi2,oi3,oi4,oi5)
rel_adv=MEAN(ra1,ra2,ra3,ra4)
compt=MEAN(cp1,cp2,cp3)
ease_use=MEAN(eu1,eu2,eu4,eu5_R,eu6)
empl_know=MEAN(ek1,ek2,ek3)
visibility=MEAN(vi1,vi3,vi4,vi5)
info=MEAN(in1,in2,in3)
qua_supp=MEAN(qs1,qs2,qs3)
image=MEAN(im2,im3)
perc_res=MEAN(pr1,pr2,pr3,pr4)
trialab=MEAN(tr1,tr2,tr3,tr4,tr5)
observ=MEAN(ob2_R,ob4_R)
perc_use=MEAN(pu1,pu2,pu3,pu4,pu5,pu6)
volunt=MEAN(vo1_R,vo5_R)

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Appendix 16: Variance and squared correlation matrix (shared variance)

Correlation Matrix	Ope_inn	rel_adv	compt	ease_use	empl_know	visibility	info	qua_supp	image	perc_res	trialab	observ	perc_use	volunt
Ope_inn	0.256													
rel_adv	0.179	0.456												
compt	0.336	0.340	0.532											
ease_use	0.206	0.124	0.446	0.336										
empl_know	0.084	0.081	0.222	0.213	0.471									
visibility	0.100	0.052	0.253	0.247	0.247	0.538								
info	0.074	0.170	0.184	0.194	0.126	0.141	0.427							
qua_supp	0.032	0.121	0.137	0.111	0.059	0.116	0.235	0.420						
image	0.012	0.088	0.069	0.009	0.061	0.074	0.045	0.055	0.672					
perc_res	0.159	0.098	0.343	0.439	0.190	0.269	0.196	0.153	0.038	0.475				
trialab	0.049	0.055	0.082	0.104	0.039	0.040	0.068	0.037	0.004	0.109	0.466			
observ	0.128	0.044	0.163	0.175	0.061	0.064	0.050	0.009	0.005	0.161	0.161	0.230		
perc_use	0.229	0.219	0.423	0.214	0.114	0.153	0.169	0.093	0.045	0.169	0.058	0.124	0.533	
volunt	0.018	0.007	0.074	0.028	0.055	0.078	0.023	0.028	0.106	0.066	0.014	0.013	0.040	0.330

Ope_inn=MEAN(oi1,oi2,oi3,oi4,oi5)
rel_adv=MEAN(ra1,ra2,ra3,ra4)
compt=MEAN(cp1,cp2,cp3)
ease_use=MEAN(eu1,eu2,eu4,eu5_R,eu6)
empl_know=MEAN(ek1,ek2,ek3)
visibility=MEAN(vi1,vi3,vi4,vi5)
info=MEAN(in1,in2,in3)
qua_supp=MEAN(qs1,qs2,qs3)
image=MEAN(im2,im3)
perc_res=MEAN(pr1,pr2,pr3,pr4)
trialab=MEAN(tr1,tr2,tr3,tr4,tr5)
observ=MEAN(ob2_R,ob4_R)
perc_use=MEAN(pu1,pu2,pu3,pu4,pu5,pu6)
volunt=MEAN(vo1_R,vo5_R)

Appendix 17: Items source, quality, adaptation and translation

Operator knowledge

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Operator knowledge of PA	CEO's IS knowledge	(Thong, 1999)	2*	0.64
	CEO's IT/e-business (eB) knowledge	(Bang Nam, Kyeong Seok et al., 2006)	3*	0.860

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Operator knowledge 1 – ok1	0.858	The level of general knowledge of IT/eB by the CEO	What is my level of general knowledge concerning precision agriculture?	Quel est mon niveau de connaissance générale sur l'agriculture de précision?
Operators's knowledge 2 - ok 2	0.843	CEO's capability to use computer software	What are my capabilities to use computer software?	Quelle est ma capacité à utiliser des applications informatiques?
Operator knowledge 3 - ok3	0.744	hours of PC usage by the CEO per day	How many hours per day do I use a computer?	Pendant combien d'heures par jour utilisez-vous un ordinateur?

Operator's innovativeness

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Operator's innovativeness	Personal innovativeness	(Bhatti, 2007)	5*	0.901
	CEO's innovativeness	(Thong, 1999)	32[1]	0.82
	CEO's attitude towards innovation	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.835

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Operator innovativeness 1 – oi1	0.597	I am very curious about how things work.	I am very curious about how things work.	En général, je suis très curieux de comprendre comment les choses fonctionnent.
Operator innovativeness 2 – oi2	0.766	I like to experiment with new ways of doing things.	I like to experiment with new ways of doing things.	En général, j'aime bien expérimenter de nouvelles façons de faire.
Operator innovativeness 3 – oi3	0.880	I like to take a chance.	I like to take a chance.	En général, j'aime bien tenter ma chance.
Operator innovativeness 4 – oi4	0.850	I like to be around unconventional people who dare to try new things.	I like to be around unconventional people who dare to try new things.	En général, j'aime bien être entouré de gens non conventionnels qui osent essayer de nouvelles choses.
Operator innovativeness 5 – oi5	0.881	I often seek out information about new products.	I often seek out information about new products.	En général, je recherche souvent de l'information sur de nouveaux produits.

[1] Kirton's Adaptation-Innovation Inventory (KAI) instrument

Relative advantage:

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Relative advantage of PA	Relative advantage	(Wee, 2003)	6*	0.87
	Relative advantage	(Syed Shah, Ali et al., 2007)	7	0.7123
	Relative advantage	(Craig Van, France et al., 2004)	3*	0.76
	Relative advantage	(Thong, 1999)	52	0.90
	Relative advantage and benefits	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.664
	Attitude[3]	(Sangjo, Joongho et al., 2003)	3*	0.7452
	Relative advantage	(Aubert et Hamel, 2001)	6*	L: 0.78 L: 0.82 L: 0.85 L: 0.72 L: 0.79 L: 0.82
	Perceived relative advantage	(Ilie, Slyke et al., 2005)	6*	0.93

Item code	Researcher's item	Question - Translated to French
Relative advantage 1 – ra1	Using precision agriculture technology increases my productivity	L'utilisation des technologies d'agriculture de précision augmente la productivité.
Relative advantage 2 – ra2	Using precision agriculture technology decreases my input costs.	L'utilisation des technologies d'agriculture de précision diminue le coût des intrants. (Ex : fertilisant, pesticides etc.)
Relative advantage 3 – ra3	Using precision agriculture technologies gives me better information on which to base decisions	L'utilisation des technologies d'agriculture de précision donne de meilleures informations sur lesquelles baser des décisions.
Relative advantage 4 – ra4	Using precision agriculture technologies reduces the environmental impact of my activities.	L'utilisation des technologies d'agriculture de précisions réduit l'impact environnemental des activités agricoles.

[2] Items taken from Moore and Benbasat's instrument (Moore and Moore, G.C.. and Benbasat, I. Development of an instrument to measure the perceptions of adopting an information tecbnology innovation. Information Systems Research, 2,3 (1991), 192-221.

[3] As per Lee, Y. and K. A. Kozar (2005). "Investigating Factors Affecting the Adoption of Anti-Spyware Systems." Communications of the ACM **48**(8): 72-77. Relative advantage can be classified within attitudes. Only one item in the list measures relative advantage.

Compatibility

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Compatibility of PA	Compatibility	(Wee, 2003)	3*	0.82
	Compatibility	(Syed Shah, Ali et al., 2007)	5	0.8539
	Compatibility	(Craig Van, France et al., 2004)	3*	0.90
	Compatibility of IS	(Thong, 1999)	2[4]	0.78
	Compatibility and complexity[5]	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.521
	Compatibility	(Sangjo, Joongho et al., 2003)	3*	0.8881
	Compatibility	(Aubert et Hamel, 2001)	3*	L: 0.76 L: 0.86 L: 0.84
	Perceived compatibility	(Ilie, Slyke et al., 2005)	4*	0.92

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Compatibility 1 – cp1	N/A	Using broadband Internet is compatible with most aspects of my work.	Using precision agriculture technologies is compatible with most aspects of my work. (Machinery etc.)	L'utilisation des technologies d'agriculture de précision est compatible avec la plupart des aspects de mon travail. (machinerie etc.)
Compatibility 2 – cp2	N/A	Using broadband Internet fits my work style.	Using precision agriculture technologies fits my work style.	L'utilisation des technologies d'agriculture de précision est en adéquation avec (correspond à) mon style de travail.
Compatibility 3 – cp3	N/A	Using broadband Internet fits well with the way I like to work.	Using precision agriculture technologies fits well with the way I like to work.	L'utilisation des technologies d'agriculture de précision est en bonne adéquation avec la façon dont j'aime travailler.

[4] Items taken from Moore and Benbasat's instrument (Moore and Moore, G.C.. and Benbasat, I. Development of an instrument to measure the perceptions of adopting an information tecbnology innovation. Information Systems Research, 2,3 (1991), 192-221.

[5] The author combined the compatibility and complexity factors, one item was used to measure each of the combined factors.

Ease of use of PA / Complexity of PA

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Complexity of PA /Ease of use of PA	Complexity	(Wee, 2003)	3*	0.78
	Complexity	(Syed Shah, Ali et al., 2007)	6	0.6702
	Perceived ease of use	(Bhatti, 2007)	4*	0.801
	Complexity	(Craig Van, France et al., 2004)	4*	0.78
	Complexity of IS	(Thong, 1999)	26	0.86
	Compatibility and complexity7	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.521
	Perceived ease of use	(Sangjo, Joongho et al., 2003)	6*	0.8760
	Ease of use	(Aubert et Hamel, 2001)	3*	L: 0.70 L: 0.80 L: 0.79
	Perceived ease of use	(Ilie, Slyke et al., 2005)	3*	0.72

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Ease of use 1 – eu1	0.730	I clearly understand how to use broadband Internet	I clearly understand how to use precision agriculture technologies.	Je comprends clairement comment utiliser les technologies d'agriculture de précision.
Ease of use 2 – eu2	0.658	Learning to operate broadband Internet is easy for me	Learning to operate precision agriculture technologies systems is easy for me.	Apprendre à utiliser des technologies d'agriculture de précision est (serait) facile pour moi.
Ease of use 3 (R)– eu3_R	0.799	I find broadband Internet inflexible to interact with	I find precision agriculture technologies inflexible to interact with.	Je trouve que l'interaction avec les technologies d'agriculture de précision est inflexible.
Ease of use 4 – eu4	0.583	It is easy to perform work using broadband Internet	It is easy to perform work using precision agriculture technologies.	C'est (Ce serait) facile d'exécuter du travail en utilisant des technologies d'agriculture de précision.
Ease of use 5(R) – eu5_R	0.810	It is not easy for me to become skilful in using broadband Internet	It is not easy for me to become skillful in using precision agriculture technologies.	Ce n'est (ne serait) pas facile pour moi de devenir habile à utiliser des technologies d'agriculture de précision.
Ease of use 6 – eu6	0.661	I find broadband Internet easy to use	I find precision agriculture technologies easy to use.	Je trouve les technologies d'agriculture de précision faciles à utiliser.

[6] Items taken from Moore and Benbasat's instrument (Moore and Moore, G.C.. and Benbasat, I. Development of an instrument to measure the perceptions of adopting an information tecbnology innovation. Information Systems Research, 2,3 (1991), 192-221.

[7] The author combined the compatibility and complexity factors; one item was used to measure each of the combined factors.

Employee PA knowledge

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Employee PA knowledge	Employee IS knowledge	(Thong, 1999)	3*	0.75
	Employee IT/e-business knowledge	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.807

Item code	Initial Loading	Initial description	My adaptation	Question - Translated to French
Employee PA knowledge 1 – ek1	0.614	My employees were all computer-literate.	My employees were all well trained in precision agriculture technologies.	Mes employés/main-d'œuvre familiale sont tous bien formés sur les technologies d'agriculture de précision.
Employee PA knowledge 2 – ek2	0.607	There was at least one employee who was a computer expert.	There was at least one employee who was a precision agriculture technologies expert.	Il y a au moins un employé/main-d'œuvre familiale qui est un expert en technologies d'agriculture de précision.
Employee PA knowledge 3 – ek3	0.825	I would rate my employees' understanding of computers as very good compared with other small companies in the same industry.	I would rate my employees' understanding of precision agriculture technologies as very good compared with other companies in the same industry.	Je classe la compréhension de mes employés/main-d'œuvre familiale sur les technologies d'agriculture de précision comme étant très bonne comparée aux autres entreprises de la même industrie.

Trialability

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Trialability	Trialability	(Wee, 2003)	2*	0.77
	Trialability	(Syed Shah, Ali et al., 2007)	5	0.7783
	Trialability	(Sangjo, Joongho et al., 2003)	5*	0.8926

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Trialability 1 – tr1	0.792	Before deciding on whether or not to use broadband Internet I would be able to use it on a trial basis	Before deciding on whether or not to use precision agriculture technologies I would be able to use it on a trial Basis.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, je pouvais (je pourrais) les essayer à titre expérimental.
Trialability 2 – tr2	0.827	Before deciding on whether or not to use broadband Internet I would be permitted to use it long enough to see what it can do	Before deciding on whether or not to use precision agriculture technologies I would be permitted to use them long enough to see what they can do.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, j'étais (je serais) autorisé(e) à les utiliser assez longtemps pour voir ce qu'elles pouvaient faire.
Trialability 3 – tr3	0.795	Before deciding on whether or not to use broadband Internet I would be able to try it out properly	Before deciding on whether or not to use precision agriculture technologies I would be able to try it out properly.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, j'étais (je serais) en mesure de les essayer de façon adéquate.
Trialability 4 – tr4	0.799	Before deciding on whether or not to use broadband Internet I know a place where I would be able to try it out	Before deciding on whether or not to use precision agriculture technologies I know a place where I would be able to try it out.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, je connaissais (je connais) un endroit où j'avais pu (je pourrais) les essayer.
Trialability 5 – tr5	0.820	Before deciding on whether or not to use broadband Internet I would be able to try its various uses	Before deciding on whether or not to use precision agriculture technologies I would be able to try its various uses.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, j'étais (je serais) en mesure d'essayer leurs diverses applications.

Observability

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Observability	Observability	(Wee, 2003)	5*	0.91
	Result demonstrability	(Sangjo, Joongho et al., 2003)	4*	0.7080
	Observability	(Syed Shah, Ali et al., 2007)	4	0.7136
	Result demonstrability	(Craig Van, France et al., 2004)	4*	0.58
	Perceived result demonstrability	(Ilie, Slyke et al., 2005)	3*	0.80

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Observability 1 – ob1	0.724	Before deciding on whether or not to use broadband Internet I have no difficulty telling others about the results of adopting broadband Internet.	Before deciding on whether or not to use precision agriculture technologies I have no difficulty telling others about the results of adopting precision agriculture technologies.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, je n'avais (je n'aurais) aucune difficulté à dire aux autres les résultats de l'adoption des technologies d'agriculture de précision.
Observability 2(R) – ob2_R	0.862	Before deciding on whether or not to use broadband Internet I have difficulty explaining why adopting broadband Internet may be beneficial.	Before deciding on whether or not to use precision agriculture technologies I have difficulty explaining why adopting precision agriculture technologies may be beneficial.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, j'avais (j'aurais) du mal à expliquer pourquoi l'adoption des technologies d'agriculture de précision pouvait être bénéfique.
Observability 3 – ob3	0.791	Before deciding on whether or not to use broadband Internet I could communicate to others the pros and cons of adopting broadband Internet.	Before deciding on whether or not to use precision agriculture technologies I could communicate to others the pros and cons of adopting precision agriculture technologies.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, je pouvais (je pourrais) informer les autres des avantages et des inconvénients liés à l'adoption de ces technologies.
Observability 4(R) – ob4_R	NA	Before deciding on whether or not to use broadband Internet I have difficulty telling whether it is good or bad to adopt broadband Internet.	Before deciding on whether or not to use precision agriculture technologies I have difficulty telling whether it is good or bad to adopt precision agriculture technologies.	Avant de décider d'utiliser ou non les technologies d'agriculture de précision, j'avais (j'aurais) de la difficulté à dire si c'est bon ou mauvais d'adopter des technologies d'agriculture de précision.

Visibility

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Visibility	Visibility	(Sangjo, Joongho et al., 2003)	4*	0.7837
	Visibility	(Craig Van, France et al., 2004)	2*	0.18
	Visibility	(Ilie, Slyke et al., 2005)	5*	0.83

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Visibility 1 – vi1	0.571	I have seen what others do using IM.	I have seen what others do using precision agriculture technologies.	Je vois ce que les agriculteurs font en utilisant des technologies d'agriculture de précision.
Visibility 2(R) – vi2_R	0.676	I have not seen many others using IM.	I have not seen many others using precision agriculture technologies.	Je ne vois pas beaucoup d'autres agriculteurs utiliser des technologies d'agriculture de précision.
Visibility 3 – vi3	0.653	It is easy for me to observe others using IM.	It is easy for me to observe others using precision agriculture technologies.	C'est facile pour moi d'observer les autres utiliser des technologies d'agriculture de précision.
Visibility 4 – vi4	0.859	I have had plenty of opportunity to see IM being used.	I have had plenty of opportunity to see precision agriculture technologies being used.	J'ai souvent l'occasion de voir des technologies d'agriculture de précision être utilisées.
Visibility 5 – vi5	0.796	I have seen many people using IM.	I have seen many people using precision agriculture technologies.	Je vois plusieurs personnes utiliser des technologies d'agriculture de précision.

Perceived usefulness

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Perceived usefulness	Perceived usefulness	(Bhatti, 2007)	5*	0.709
	Perceived usefulness	(Sangjo, Joongho et al., 2003)	6*	0.8830
	Perceived usefulness	(Aubert et Hamel, 2001)	6*	L: 0.80 L: 0.84 L: 0.77 L: 0.84 L: 0.81 L: 0.79

Item code	Initial Loading	Initial description	Question - My adaptation
Perceived usefulness 1 – pu1	0.80	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: négligeable à fondamental	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précisions sont: négligeables à fondamentales
Perceived usefulness 2 – pu2	0.84	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: peu pertinent à pertinent	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précision sont: peu pertinentes à pertinentes
Perceived usefulness 3 – pu3	0.77	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: peu important à important	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précision sont: peu importantes à importantes
Perceived usefulness 4 – pu4	0.84	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: ennuyant à intéressant	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précision sont: ennuyantes à intéressantes
Perceived usefulness 5 – pu5	0.81	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: banal à fascinant	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précision sont: banales à fascinantes
Perceived usefulness 6 – pu6	0.79	En général, dans l'accomplissement de mon travail, le système de la carte de santé est: peu attirant à attirant	En général, dans l'accomplissement de mon travail, les technologies d'agriculture de précision sont: peu attirantes à attirantes

Information

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Information	Information	(Aubert et Hamel, 2001)	3*	L: 0.82 L: 0.84 L: 0.87

Item code	Initial Loading	Initial description	Question - My adaptation
Information 1 – in1	0.82	L'information fournie par le système de la Carte de Santé est produite dans un format utile.	L'information fournie par les technologies d'agriculture de précision est produite dans un format utile.
Information 2 – in2	0.84	Le système de la Carte Santé me donne toute l'information dont j'ai besoin.	Les technologies d'agriculture de précision donnent toute l'information dont j'ai besoin.
Information 3 – in3	0.87	Le système de la Carte Santé me donne de l'information pertinente	Les technologies d'agriculture de précision donnent de l'information pertinente.

Quality of support

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Quality of support	Governmental support for e-business	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.743
	Quality	(Aubert et Hamel, 2001)	4*	L: 0.49 L: 0.85 L: 0.91 L: 0.84

Item code	Initial Loading	Initial description	Question - My adaptation
Quality of support 1 – qs1	0.85	Il est facile d'obtenir du support informatique.	Il est facile d'obtenir du support sur les technologies agriculture de précision.
Quality of support 2 – qs2	0.91	Les gens responsables du support informatique ont des connaissances suffisantes pour répondre à mes questions.	Les gens responsables du support sur les technologies d'agriculture de précision ont des connaissances suffisantes pour répondre à mes questions.
Quality of support 3 – qs3	0.84	Je sens que les gens responsables du support informatique travaillent dans mon intérêt.	Je sens que les gens responsables du support des technologies d'agriculture de précision travaillent dans mon intérêt.

Image

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Image	Image	(Wee, 2003)	4*	0.86
	Image	(Craig Van, France et al., 2004)	3*	0.71
	Image	(Aubert et Hamel, 2001)	2*	L: 0.94 L: 0.95

Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Image 1 – im1	N/A	People who use the Web to purchase products or services have a high profile.	People who use precision agriculture technologies to produce products have a high profile.	Les gens qui utilisent des technologies d'agriculture de précision se différencient.
Image 2 – im2	N/A	People who use the Web to purchase products or services have more prestige than those who do not.	People who use precision agriculture technologies to produce products have more prestige than those who do not.	Les gens qui utilisent des technologies d'agriculture de précision ont plus de prestige que ceux qui ne les utilisent pas.
Image 3 – im3	N/A	Purchasing products or services over the web is a status symbol.	Farming with precision agriculture technologies is a status symbol.	Exploiter avec des technologies d'agriculture de précision est un symbole de statut social.

Perceived resources

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Perceived resources	Cost of e-business adoption	(Bang Nam, Kyeong Seok et al., 2006)	2*	0.832
	Perceived resources	(Sangjo, Joongho et al., 2003)	4*	0.8394

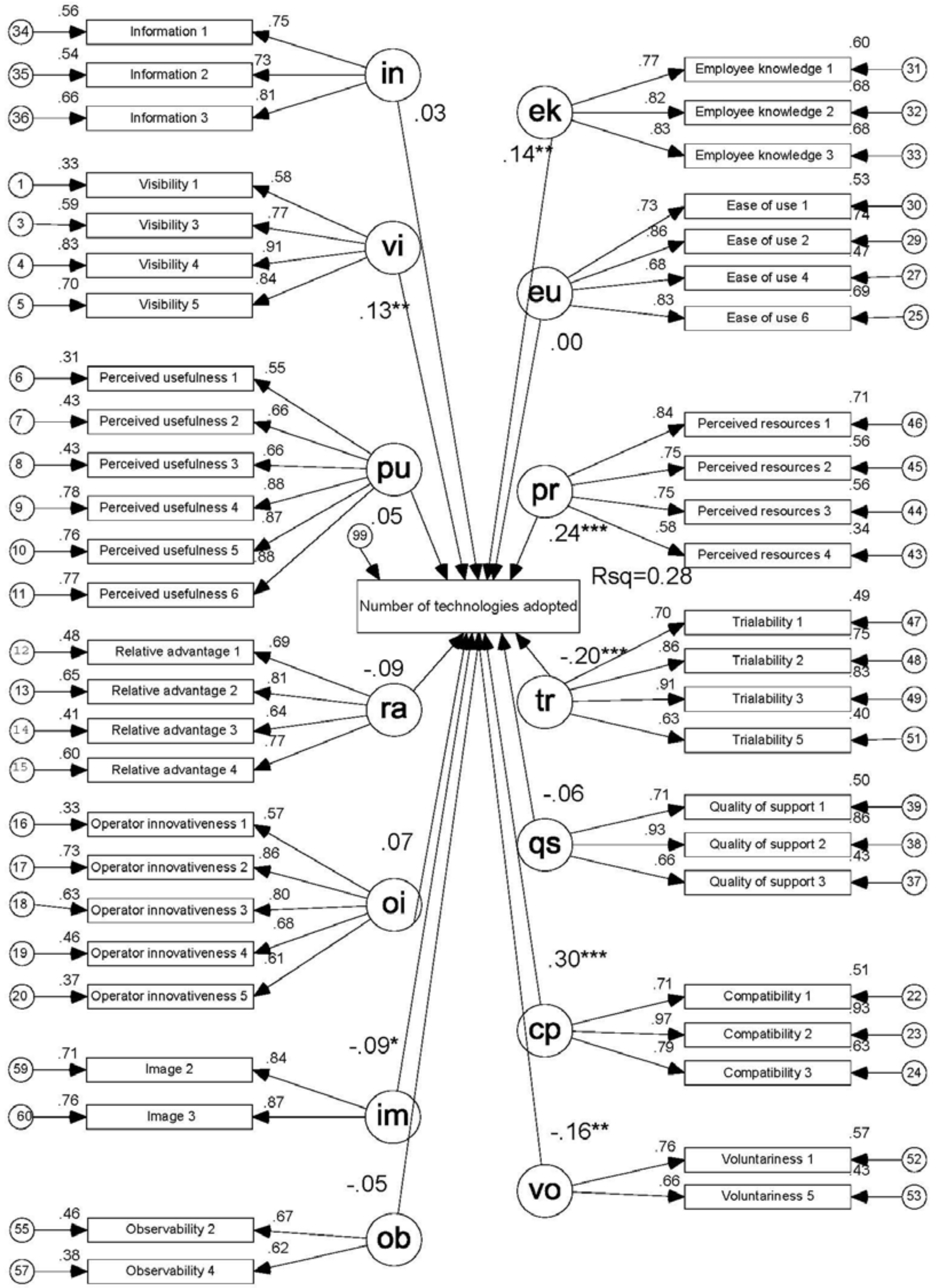
Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Perceived resources 1 – pr1	0.746	I have the resources, opportunities and knowledge for using broadband internet.	I have the resources, opportunities and knowledge for using precision agriculture technologies.	J'ai les ressources, les opportunités et la connaissance pour utiliser les technologies d'agriculture de précision.
Perceived resources 2 – pr2	0.763	I would be able to use broadband internet if I wanted to.	I would be able to use precision agriculture technologies if I wanted to.	Je suis (serais) capable d'utiliser des technologies d'agriculture de précision si je le veux (voulais).
Perceived resources 3 – pr3	0.846	I have access to the resources I would need for using broadband internet.	I have access to the resources I would need for using precision agriculture technologies.	J'ai accès aux ressources dont j'ai (aurais) besoin pour utiliser des technologies d'agriculture de précision.
Perceived resources 4 – pr4	0.742	There are no barriers to my using broadband internet.	There are no barriers to my using precision agriculture technologies.	Il n'a pas de barrières à mon utilisation des technologies d'agriculture de précision.

Voluntariness

Factor applied to PA	Literatures factors	Author	# of Items	Cronbach's alpha
Voluntariness	Subjective Norms	(Bhatti, 2007)	3*	0.783
	Voluntariness	(Compeau, Meister et al., 2007)	6*	Greater than 0.7

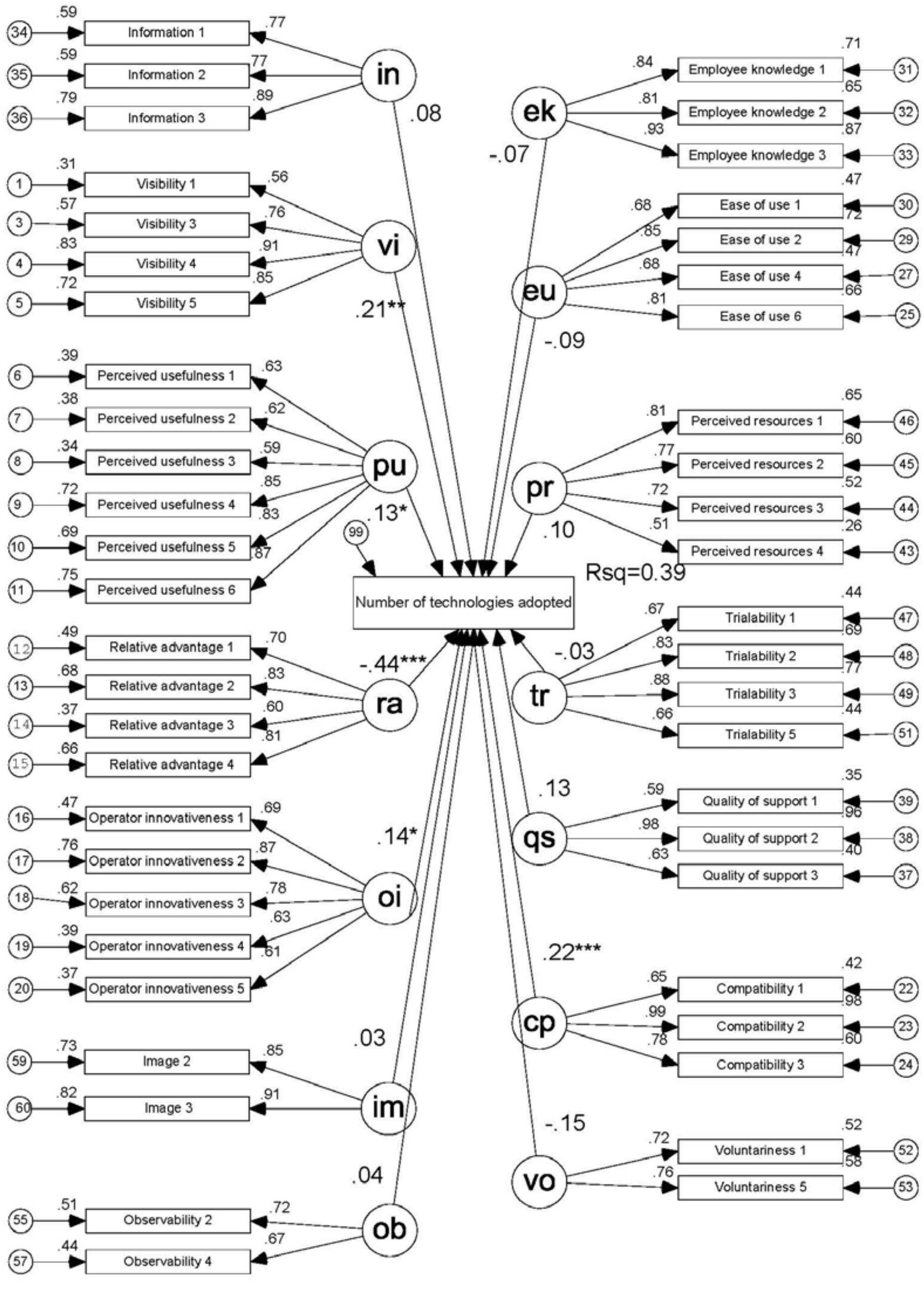
Item code	Initial Loading	Initial description	Context adaptation	Question - Translated to French
Voluntariness 1 (R) – vo1_R	Greater than 0.7	Managers in my organization expect me to use the hospital computer system.	Representatives of my cooperative expect me to use precision agriculture technologies.	Les représentants agricoles (vendeur, conseillé, etc.) s'attendent à ce que j'utilise des technologies d'agriculture de précision.
Voluntariness 2 - vo2	Greater than 0.7	Although it might be helpful, using the hospital computer system is optional in my job.	Although it might be helpful, using precision agriculture technologies is optional in my work.	Même si ca peut être utile, l'utilisation des technologies d'agriculture de précision est facultative pour mon travail.
Voluntariness 3 – vo3	Greater than 0.7	My decision to use the hospital computer system is entirely up to me.	My decision to use precision agriculture technologies computer system is entirely up to me.	La décision d'utiliser des technologies d'agriculture de précision me revient entièrement.
Voluntariness 4(R) – vo4_R	Greater than 0.7	The use of the hospital computer system is mandatory in my organization.	The use of precision agriculture technologies is mandatory in my cooperative.	L'utilisation des technologies d'agriculture de précision est obligatoire.
Voluntariness 5(R) – vo5_R	Greater than 0.7	My organization requires me to use the hospital computer system in performing my job.	My cooperative requires me to use precision agriculture technologies in performing my work.	Les représentants agricoles (vendeur, conseillé, etc.) demandent que j'utilise des technologies d'agriculture de précision.

Appendix 18: Global adoption model (adoption factors)



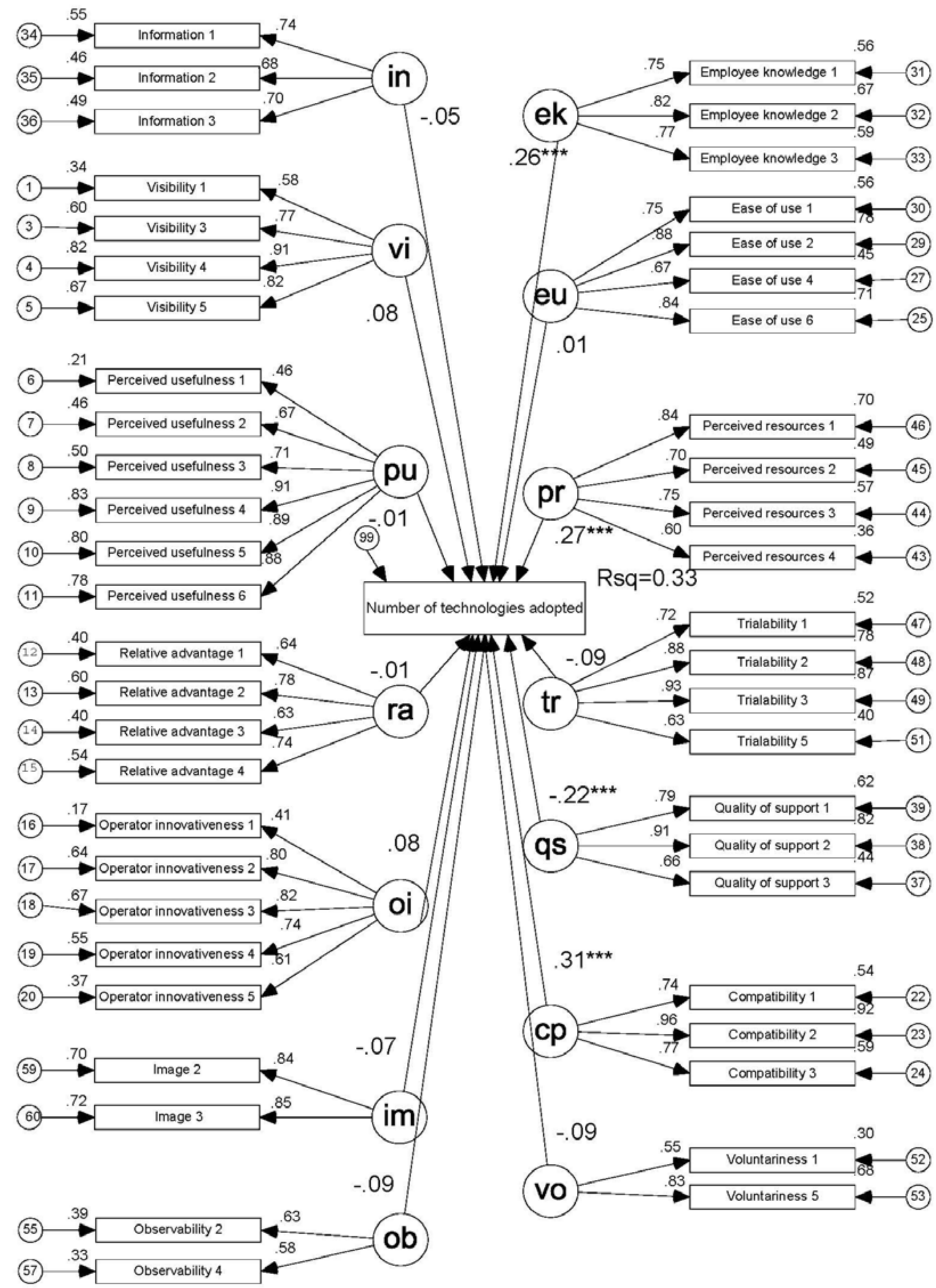
Goodness of fit (Chi-square) = 4150.901
Root Mean Square Error of Approximation (RMSEA) = 0.079
Comparative Fit Index (CFI) = 0.716

Appendix 19: Global adoption model for the smaller farms in sample (adoption factors)



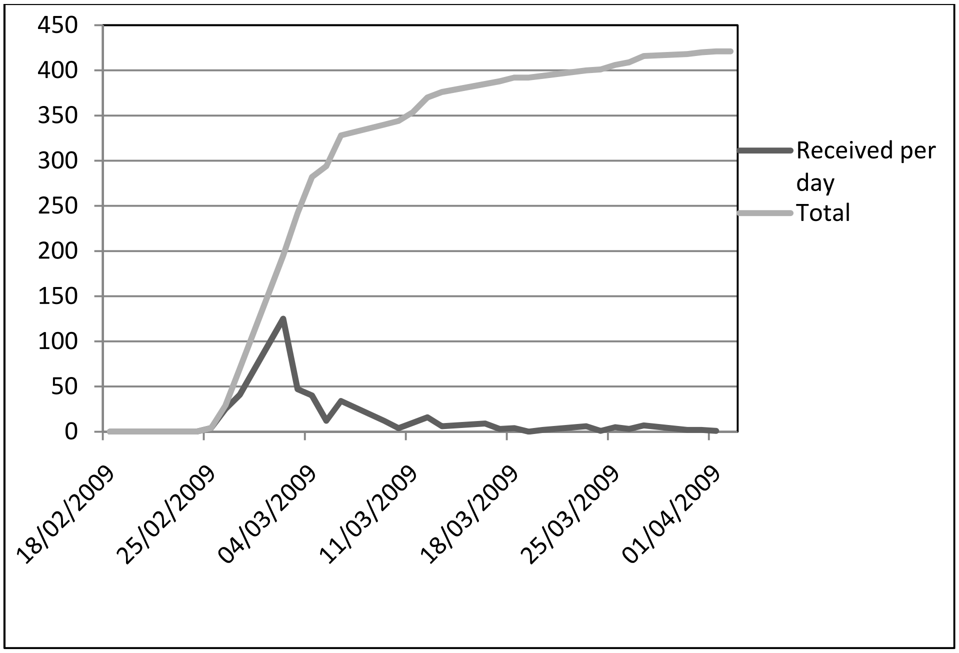
Goodness of fit (Chi-square) = 2765.723
Root Mean Square Error of Approximation (RMSEA) = 0.084
Comparative Fit Index (CFI) = 0.672

Appendix 20: Global adoption model for the larger farms in sample (adoption factors)



Goodness of fit (Chi-square) = 2837.386
Root Mean Square Error of Approximation (RMSEA) = 0.081
Comparative Fit Index (CFI) = 0.705

Appendix 21: Return chart



Appendix 22: Exploratory factor analysis with cross-loadings

Rotated Component Matrix(a)	1	2	3	4	5	6	7	8	9	10	11	12	13
Operator's innovativeness 1	0.05	0.63	0.08	0.16	0.15	-0.01	0.15	0.17	-0.08	-0.07	-0.06	-0.02	0.07
Operator's innovativeness 2	0.22	0.80	0.07	0.02	0.08	0.13	0.08	0.10	0.04	0.08	-0.05	0.11	0.01
Operator's innovativeness 3	0.15	0.76	0.00	0.04	0.13	0.08	-0.01	0.17	0.09	0.15	0.05	0.06	0.06
Operator's innovativeness 4	0.26	0.69	0.01	0.12	0.13	0.05	0.07	0.06	0.09	-0.03	0.13	0.03	0.07
Operator's innovativeness 5	0.11	0.71	0.08	0.07	0.09	0.05	0.13	0.03	0.12	-0.02	-0.04	-0.01	-0.07
Relative advantage 1	0.21	0.26	0.06	0.03	0.68	0.10	0.11	0.07	0.01	0.15	0.16	-0.04	0.06
Relative advantage 2	0.10	0.08	0.09	-0.01	0.79	0.11	0.00	0.04	0.14	0.04	0.12	-0.07	0.02
Relative advantage 3	0.27	0.23	0.10	0.03	0.57	-0.08	0.20	0.02	0.30	0.06	0.05	0.01	-0.01
Relative advantage 4	0.07	0.14	0.08	0.04	0.75	0.10	-0.03	0.14	0.11	0.16	0.12	0.02	0.06
Ease of use 1	0.09	0.17	-0.02	0.33	0.13	0.25	0.37	0.52	0.11	0.06	-0.04	0.11	-0.04
Ease of use 2	0.15	0.17	0.19	0.18	0.12	0.15	0.28	0.73	0.17	0.02	0.02	-0.03	0.03
Ease of use 4	0.26	0.17	0.13	0.12	0.12	0.23	0.11	0.52	0.28	0.26	0.12	0.05	0.08
Ease of use 5	0.04	0.13	0.05	0.00	0.02	-0.03	0.13	0.70	-0.07	0.00	-0.16	0.05	0.22
Ease of use 6	0.23	0.17	0.17	0.24	0.14	0.20	0.17	0.63	0.21	0.14	0.04	-0.04	0.04
Employees knowledge 1	0.01	0.05	0.12	0.25	0.11	0.77	0.03	0.12	0.04	0.10	0.07	0.14	0.04
Employees knowledge 2	0.11	0.11	0.05	0.19	0.11	0.79	0.15	0.12	0.12	0.03	0.04	0.04	0.03
Employees knowledge 3	0.12	0.09	0.01	0.15	0.06	0.81	0.11	0.07	0.14	0.04	0.11	0.04	0.06
Visibility 1	0.11	0.12	0.00	0.55	0.12	0.24	0.28	-0.01	0.15	0.12	0.14	0.04	0.16
Visibility 3	0.14	0.14	0.03	0.73	-0.06	0.18	0.18	0.20	0.15	0.10	0.12	-0.02	-0.01
Visibility 4	0.15	0.03	0.02	0.85	0.03	0.17	0.08	0.13	0.10	0.09	0.06	0.11	0.00
Visibility 5	0.08	0.13	0.06	0.84	0.03	0.14	0.09	0.09	0.03	0.09	0.05	0.09	-0.03
Information 1	0.05	0.04	0.08	0.25	0.16	0.16	0.07	0.20	0.69	0.18	0.01	0.03	0.10
Information 2	0.14	0.13	0.09	0.05	0.15	0.17	0.17	0.03	0.74	0.18	0.07	0.06	-0.09
Information 3	0.26	0.07	0.03	0.10	0.16	0.06	0.11	0.11	0.77	0.17	0.01	0.02	0.01

Quality of support 1	-0.02	0.04	0.10	0.20	0.05	0.02	0.18	0.09	0.21	0.77	-0.02	0.05	-0.06
Quality of support 2	0.11	-0.02	0.06	0.11	0.13	0.02	0.13	0.05	0.12	0.85	0.00	0.04	-0.05
Quality of support 3	0.26	0.09	0.01	0.03	0.22	0.18	0.09	0.04	0.16	0.66	0.15	0.00	-0.02
Image 2	0.13	0.00	-0.03	0.10	0.25	0.10	0.08	-0.03	0.08	0.06	0.81	0.16	-0.10
Image3	0.01	0.00	0.03	0.16	0.13	0.13	0.05	-0.07	-0.01	0.04	0.84	0.22	-0.07
Perceived resources 1	0.17	0.19	0.11	0.25	0.08	0.22	0.66	0.28	0.07	0.05	0.02	0.13	0.11
Perceived resources 2	0.13	0.16	0.13	0.10	0.09	0.01	0.67	0.34	0.12	0.10	0.08	-0.02	0.16
Perceived resources 3	0.07	0.05	0.06	0.27	0.04	0.03	0.74	0.09	0.14	0.24	0.00	0.14	0.02
Perceived resources 4	0.09	0.19	0.11	0.04	0.04	0.29	0.53	0.21	0.11	0.17	0.11	-0.02	-0.07
Voluntariness 1	-0.09	-0.02	-0.04	-0.09	0.00	-0.09	-0.21	-0.10	-0.09	-0.15	-0.14	-0.77	0.00
Voluntariness 5	0.00	-0.09	-0.04	-0.08	0.06	-0.08	0.05	0.04	0.00	0.05	-0.21	-0.80	0.06
Trialability 1	0.05	0.06	0.78	0.01	0.11	0.09	-0.11	0.12	-0.06	0.03	0.00	0.04	0.01
Trialability 2	0.05	-0.02	0.89	-0.03	0.07	-0.02	0.00	0.05	0.02	0.05	0.00	0.01	-0.04
Trialability 3	0.11	0.02	0.87	0.00	0.10	0.02	0.13	0.18	0.02	0.05	0.01	0.02	-0.02
Trialability 4	0.00	0.15	0.51	0.27	0.04	0.07	0.13	-0.07	0.29	0.10	-0.07	0.19	0.17
Trialability 5	0.05	0.14	0.71	0.06	-0.04	0.08	0.29	-0.02	0.16	-0.01	0.04	-0.07	0.03
Observability 2	0.10	0.12	0.05	0.03	0.05	0.03	0.17	0.15	0.06	-0.15	-0.03	0.08	0.73
Observability 4	0.06	-0.03	-0.01	0.02	0.05	0.08	-0.04	0.09	-0.04	0.02	-0.11	-0.14	0.84
Perceived usefulness 1	0.55	0.09	0.04	0.17	0.34	0.23	0.13	0.05	0.06	0.04	-0.08	0.30	-0.04
Perceived usefulness 2	0.65	0.13	0.08	0.14	0.33	0.14	0.13	0.13	0.06	0.03	-0.15	0.26	0.02
Perceived usefulness 3	0.65	0.10	0.06	0.19	0.41	0.08	0.15	0.06	0.04	0.07	-0.16	0.19	-0.07
Perceived usefulness 4	0.82	0.20	0.07	0.11	0.05	0.02	0.05	0.12	0.11	0.06	0.12	-0.07	0.11
Perceived usefulness 5	0.81	0.23	0.04	0.07	0.05	0.02	0.04	0.09	0.16	0.12	0.12	-0.05	0.08
Perceived usefulness 6	0.83	0.22	0.08	0.03	0.03	0.04	0.06	0.10	0.10	0.08	0.13	-0.09	0.08