Determining Research, Education, and Extension Requirements for Application of the Precision Agricultural System in Iran

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ABSTRACT

Reluctance towards implementation of precision agriculture (PA) seems to be based on lack of consideration to education, extension, and research sectors. The objective of this study is to identify educational, extensional, and research requirements in application of the PA system. The research population included all the experts in Qazvin province who are familiar with PA concepts and PA's equipments, such as GPS and GIS. The results showed that offering a practical PA education and preparation of extension programs to introduce PA's benefits provide more impact in the extensional requirement, among other variables. Findings of this article emphasize, again, on key role of the agricultural extension in efficient implementation of PA.

Keywords: Bayesian Confirmatory Factor Analysis; Education; Extension; Iran; Precision Agriculture (PA); Requirements; Research.

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INTRODUCTION

Agriculture Ministry in Iran reported that the mean application rate of herbicides for wheat and corn during 2005 were 0.99 and 4.44 kg/ha, respectively. However, these values for Qazvin province were 2.06 and 5.10 kg/ha, respectively (Iranian Ministry of Agriculture, 2006). This report indicates relatively high application rate of herbicides in Qazvin province compared with the rest cities of Iran.

Precision agriculture (PA) is a holistic system approach to manage the spatial and temporal variability within a field in order to reduce costs, optimize yield, quality and reduce environmental impacts. This can be achieved by using appropriate technologies within a coherent management structure) Reichardt & Jurgens, 2009).

In agriculture, like in most industries, new tools and information are growing at an ever-increasing rate. To remain competitive; farmers, consultants, and agribusiness must constantly re-train. Some of the most useful new information tools have not been traditionally included in agricultural learning programs. These include GIS (Geographical Information System), GPS (Geographical Positioning System), RS (Remote Sensing), and information discovery, processing, and management tools used in PA system (Pocknee *et al*., 2002). The extension services could be a good multiplier to increase PA awareness, because they are in contact with many farmers and often informed about the insights of individual farm management (Reichardt & Jurgens, 2009). Different countries' process which is accessible by researches, experiments and performance practical projects.

In sum, lack of consideration about education, extension, and research are the most important barriers in implementing the PA system in Iran.

So the objectives of this study are as follows: identifying (1) educational, (2) extensional, (3) research requirements and (4) developing a conceptual framework.

This paper is organized as follows. In section 2, the related literature for requirements is presented. Sections 3 and 4 represents research variables, target population, and a brief explanation of research statistical methods. Data are analyzed in section 5 by employing sophisticated statistical technique, Bayesian Confirmatory Factor Analysis; which can be handled in WinBUGS Soft ware.

Requirements of the system

The requirements of this research categorized into three (1) extension, (2) education and (3) research factors.

Extension requirements

In 1998, a nationwide study was conducted in the USA. The research came to the conclusion that the unawareness of PA technologies among farmers is the main reason for low rate adoption of PA (Reichardt & Jurgens, 2009). Since PA awareness mainly depends on the available sources of information and quality of information provided for the farmers; Therefore, PA awareness will directly effect on PA adoption (McBride & Daberkow, 2003).

PA requires clarification of intellectual property, data ownership, and data privacy rights. The extension services should play a leadership role in providing training on existing law pertaining to these issues by promoting models and templates for data sharing, providing examples (to clarify benefits of sharing and aggregating data), providing protection for data privacy rights, developing legal instruments (to clarify rights and responsibilities of data use and dissemination to producers, crop consultants, and others involved in the data stream) (NRC, 1997). Larson *et al*., (2008) implied that extension might have a role in training farmers and crop consultants to use computers for obtaining and analyzing site-specific information, and for making prescription maps. While, Reichardt & Jurgens (2009) pointed

out that education of farmers plays an important role in awareness and adoption of new technologies, because it provides the necessary skills for farmers.

Extension agents (Ahlrichs, 1993; Adrian, 2006; Daberkow & McBride, 2003; Lavergne, 2004), advisory services (Kutter *et al*., 2009; Fountas *et al*., n.d.), extension bulletin (Ferguson, 2002), extension publications (Adrian, 2006), agricultural events (Kutter *et al*., 2009) are some components of extension services that affect on adoption and using PA equipments. Agricultural events such as field days, trade fairs, seminars or workshops were considered important spread of information on PA as farmers use these opportunities to exchange their knowledge (Kutter *et al*., 2009).

Education requirements

Certainly, education plays an important role in awareness and adoption of new technologies because it provides the necessary skills for farmers. PA requires certain technological skills as well as a certain agronomic understanding (Reichardt & Jurgens, 2009).

Kitchen *et al*., (2002) pointed out that (1) agronomic knowledge and skills, (2) computer and information management skills, and (3) recognition and development of PA as a management system are three broad areas which their improvement leads to PA expansion. Within each of such three dimensions, educational efforts should emphasize on specific needs of significant players interested and potentially involved in PA, such as producers, agribusiness, and educators (Kitchen *et al*., 2002).

Co-operation with universities and PA industry in educational programs might give a guarantee for PA implementation. Besides this, it could enable different stakeholders to make a dialogue with each other; the advisors could transfer new knowledge directly to the farmers and feedback to industry and research (Reichardt & Jurgens 2009). So, it is imperative that educational institutions (NRC, 1997), vocational schools, universities and technical colleges (Reichardt *et al*., 2009) modify their curricula and teaching methods to educate students and professionals in interdisciplinary approaches underlying PA (NRC, 1997).

Research requirements

A research needs to develop PA's protocols to use data collected through some PA's technologies. To obtain such protocols, one has to gather a group of lawyers and institutional experts in a research team (Mcbratney *et al*., 2005).

Farmers engaged in PA will likely be transformed from research clients into research partners. PA requires new approaches to research that are designed explicitly to improve understanding of the complex interactions between multiple factors affecting crop growth and farm decision making (NRC, 1997).

An initiate step to develop a PA's system in Iran, one has to identify abilities and potential capabilities which can overcome several barriers and consequently cause to localize the PA's technologies in Iran. On the other hand, a survey has to be done to identify spatial and temporal factors which may affect soil and plant characteristics, such as nutrients, soil texture, moisture, crop yield, etc. Result of such surveys can be employed to cultivate some Iranian strategic products (i.e., rice, wheat, etc.) by a PA technologies to reduce cost, optimize quality, and reduce environmental impacts of such products (Nikbakht & Dizaji, 2006).

Surprisingly, a few researches have been done for farmers' perceptions to adopt PA technologies. Evaluating the farmers' perceptions can lead to understand why farmers adopt technologies beyond the benefit (Adrian, 2006).

MATERIAL AND METHODS

Based upon the prior studies, the following research variables are developed and their sources are given.

Extension requirements

Play a leadership role by extension to clarify intellectual properties, data ownership, and data privacy rights for producers, crop consultants, and others who may a play critical role in data analysis (NRC, 1997); Providing a face-to-face educational system (Wiebold *et al*., 1998); Offering a practical PA education (Hudson & Hite, 2001); Holding field days (Heiniger *et al*., 2002); Preparation of extension programs to introduce PA's benefits, such as fertilizer, poison, and seed reducing, increasing income and reducing environmental impacts (Ahmadi, 2008); Offering extension programs in order to train farmers who may have ability to run a PA's field trial (Robert, 2002); Educating farmers and crop consultants to use computers for obtaining and analyzing site-specific information and making prescription maps (Larson *et al*., 2008); Raising farmers PA's awareness through: community groups, field days, outlets, etc (Lavergne, 2004; Mcbratney *et al*., 2005; Reichardt *et al*., 2009; Hudson & Hite, 2001); Diffusion and promotion of PA's information by the private extension service (kutter *et al*., 2009); Developing the PA's consultant infrastructure (Wiebold *et al*., 1998; McBride & Daberkow, 2003); Preparing some concepts for the ones who may want to provide PA's advices for farmers (Reichardt *et al*., 2009); Increased agronomical information for producers to select varieties and managing yield (Wiebold *et al*., 1998; Reichardt *et al*., 2009; NRC, 1997); Holding training seminars, trade fairs, agricultural exhibitions to promote farmers' awareness and knowledge about PA's equipments (Wiebold *et al*., 1998; kutter *et al*., 2009; Reichardt *et al*., 2009; Heiniger *et al*., 2002).

Research requirements

Establishing large demonstration plots for research (Mcbratney *et al*., 2005; Wiebold *et al*., 1998; Reichardt *et al*., 2009); Research into appropriate economical criteria to assess PA (Mcbratney *et al*., 2005); Collaboration between public research institutions and different agribusinesses to develop PA's products (Kitchen *et al*., 2002; Mcbratney *et al*., 2005; Bordbar, 2010); Research into factors which affect PA's adoption (Adrian, 2006) Study about countries' experiences in PA and identify their PA's barriers (Zarei, 2008; Nikbakht & Dizaji, 2006); Research into capacities in Ghazvin province to execute PA (Nikbakht & Dizaji, 2006); Research into using more suitable and simple PA tools with respect to developing countries environment (Cook *et al*., 2003); Study about spatial and temporal variability of soil and plant characteristics (Nikbakht & Dizaji, 2006); Measuring PA's implementation in Iran (Nikbakht & Dizaji, 2006).

Education requirements

Integration PA into universities' curricula (Reichardt & Jurgens, 2009; Mcbratney *et al*., 2005); Integration PA into vocational schools' curricula (Reichardt & Jurgens, 2009); Integration PA into educational institutions ' curricula (Reichardt & Jurgens, 2009); Pay attention to needs of PA users, such as student, producers, consultants, and other agribusinesses (Kitchen *et al*., 2002); Establishing educational PA plots (Wiebold *et al*., 1998); Holding field days that are accompanied by conferences and fairs in order to introduce PA technologies, more practically (Heiniger *et al*., 2002); Presence of experts, researchers and farmers in international seminars and congresses in order to familiarize them with PA's applications (Bordbar, 2010); Offering qualified, well written, and simple

educational PA's material (Wiebold *et al*., 1998; Mcbratney *et al*., 2005; McBride & Daberkow, 2003; Ferguson, 2002); Improve producers' computer skills and develop their GIS and GPS's knowledge (Reichardt & Jurgens, 2009; Kitchen *et al*., 2002); Offering an e-educational system for PA (Pocknee *et al*., 2002; Ferguson, 2002; Wiebold *et al*., 1998); Organizing trainers and enriching research and educational programs using a cooperative system (Kitchen *et al*., 2002); Holding training classes by industrial sectors to make producers, agriculture consultants, and agriculture service dealers skillful in application of PA equipments and PA softwares (Kitchen *et al*., 2002; Reichardt & Jurgens, 2009); Increasing collaboration between industrial and educational system in order to provide a better practical education in PA (kutter *et al*., 2009); Providing workshops and classes in order to promote farmers' abilities to use PA equipments (Kitchen *et al*., 2002); Developing self-study consumer guide for PA technologies (Wiebold *et al*., 1998); Increasing framers' PA awareness through local medias, outlets, etc (Lavergne, 2004; Mcbratney *et al*., 2005; Reichardt *et al*., 2009); Holding a especial PA educational course for teachers, agribusinesses, producers, researchers, input suppliers, etc (Kitchen *et al*., 2002; Mcbratney *et al*., 2005; Wiebold *et al*., 1998; Reichardt & Jurgens, 2009; Heiniger *et al*., 2002); Encouraging educated and young farmers to use e-tools (i.e., internet, e-mail, chat, etc) to communicate and exchange their PA information (Fountas *et al*., n.d; Fountas *et al*., 2005); Training qualified and experienced operators in the field of PA(Reichardt *et al*., 2009; Bordbar, 2010).

Questionnaire items were developed based on the previous literature. The questionnaire was revised with the help of experts with significant experience in PA to examine the validity of the research model. A 5–point likert scale ranging from 1 as strongly disagrees to 5 as strongly agree was used for the measurement. A pretest for the reliability of the instrument was conducted with 15 experts randomly chosen from the target population. It summarized requirements into three single variables, R1, R2 and R3. The computed Cronbach's alphas for R1, R2 and R3 are 86.98 percent, 80.9 percent, and 81.4 percent, respectively, which indicated the high reliability of the questionnaire.

The Province of Qazvin is one of the 30 provinces of Iran. It is located in the north-west of the country, and its center is the city of Qazvin. 13,000 km² are under cultivation in the province, covering 12 percent of the cultivable lands of the country, Iran. The agricultural products are grape, hazelnut, pistachio, almond, walnut, olive, apple, wheat, barely, sugar beet, pomegranate, fig, and cereals. The research population included all the experts in Qazvin province (N=40). They include some experts who work in either an agricultural research center or an agricultural educational center. Moreover, they are familiar with PA concepts and PA's equipments, such as GPS and GIS. The initial and follow-up mailing generated 40 useable responses from experts resulting in a response rate of 100 percent.

This research applied WinBUGS Soft ware to analyze the data. Data was analyzed using the following technique.

Bayesian confirmatory factor analysis

The usual Confirmatory factor analysis (CFA) employs the maximum likelihood (ML) method to estimate unknown parameters. It is well known that the statistical properties of the ML approach are asymptotic (Lehmann & Casella, 1998). Therefore, many of properties of the ML estimators have been oscillated for small sample size. In the context of some basic CFAs, many studies have been devoted to study the behaviors of the ML asymptotic properties with small sample sizes, see Lee 2007 for an excellent review. It was concluded by such researches that the properties of the statistics are not robust for small sample sizes, even for the multivariate normal distribution. The Bayesian approach to the CFA has ability

to: (i) work properly for small sample size. Even small sample size, the posterior distributions of parameters and latent variables can be estimated by using a sufficiently large number of observations that are simulated from the posterior distribution of the unknown parameters through efficient tools in statistical computing such as the various Markov chain Monte Carlo (MCMC) methods (Lee, 2007); (ii) utilize useful and prior information about the problem (which translated to a prior distribution) to achieve better results. For situations without accurate prior information, some type of non-informative prior distributions can be used. In these cases, the accuracy of the Bayesian estimates is close to that obtained from the classical CFA (Robert, 2001); (iii) treat the discrete variables (such as the Likert and rating scales) as the hidden continuous normal distribution with a specified threshold (or cut point). Clearly, such approach provide a powerful tool to analyze the discrete variables rather than using special, but less powerful, statistical technique to do so (Lee, 2009).

To illustrate the Bayesian CFA suppose three observed variables $X_1, X_2,$ and X_3 are going to summarize into a factor F_1 (Figure 1). In Bayesian CFA, one of factor loadings fixed to be 1 and others estimated using sufficiently large iterations of a MCMC code.

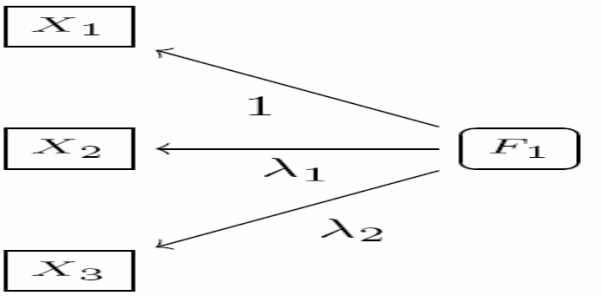

Fig 1: An example of CFA.

Now using the MCMC code, one can estimate mean, variance, and $100(1-\alpha)\%$ credible interval for mean of each factor loadings. The above structure can be readily test with hypothesis $H_0 : \lambda_i = 0$ vs. $H_1 : \lambda_i \neq 0$. Hypothesis H_0 reject in favor of hypothesis H_1 at significant level α, whenever zero does not fall in the $100(1-\alpha)\%$ credible interval of λ_i.

RESULTS AND DISCUSSION

Descriptive statistics

Table 1 summarizes the demographic profile and descriptive statistics of experts.

Table 1: Demographic Profile and Descriptive Statistics of experts

Work experience	**Mean= 12.6**	**S.D=4.2**
Gender	Female (5 percent)	Male (95 percent)
Age/year	Mean= 36.5	S.D=4.2
Major	Agricultural Mechanics (43 percent), agronomy (27 percent)	Other Majors (30 percent)
level of education	Master (45 percent), Bachelor (40 percent)	Ph.D. (15 percent)

Bayesian confirmatory factor analysis

Since sample size of the study is relatively small (n=40, for usual CFA, we need about 200 observation) and all variables follow the Likert scale. Therefore, the Bayesian CFA is an appropriate statistical technique to analysis data. To implement the Bayesian CFA to test the above theoretical framework, given in section 1, against collected data, a statistical package, named WinBUGS, has been used. WinBUGS is an open source and freely available software package, which can be used to implement Bayesian CFA. WinBUGS combines the prior information (which summarizes in a prior distribution) with observation and derives a distribution for factor loadings. This approach to factor loading provides more information about factor loading compared to other classical CFA approaches. More precisely, one can estimate mean, variance, and credible interval for mean of factor loadings.

As explained above, all ordinal and observed variables in this research are considered as normally distributed latent variables. Using such approach to ordinal and observed variables along with the Invert Gamma and the Invert Wishart priors, which commonly use with normal distribution (whenever no prior information is available), one can employ the WinBUGS software to test the theoretical framework given by Section 3.

Analysis described below was run in WinBUGS for total of 100,000 iterations, which mostly, burn-in about 10,000 iterations. All model validation criteria, such as MC-error (it should be considerably lower than variance for each estimated parameters), Autocorrelation functions (it should be approached to zero exponentially for each estimated parameters), and kernel density (all estimated parameters have to be normally distributed) have been met by the final models. To consist on briefness such validity criteria removed from the article.

Variables R1…R41 in the following, respectively, represent:

Play leadership role by extension to clarify intellectual properties, data ownership, and data privacy rights for producers, crop consultants, and others who may play a critical role in data analysis (R1); Providing a face-to-face educational system (R2); Offering a practical PA education (R3); Holding field days (R4); Preparation of extension programs to introduce PA's benefits, such as fertilizer, poison, and seed reducing, increasing income and reducing environmental impacts (R5); Offering extension programs in order to train farmers who may have ability to run a PA's field trial (R6); Educating farmers and crop consultants to use computers for obtaining and analyzing site-specific information and making prescription maps (R7); Raising farmers PA's awareness through: community groups, field days, outlets, etc (R8); Diffusion and promotion PA's information by the private extension service (R9); Development the PA's consultant infrastructure (R10); Preparing some concepts for the ones who may want to provide PA's advices to farmers (R11); Increased agronomical information for producers to select varieties and managing yield (R12); Holding training seminars, trade fairs, agricultural exhibitions to promote farmers' awareness and knowledge about PA's equipments (R13), Establishing large demonstration plots for research (R14); Research into appropriate economical criteria to assess PA (R15); Collaboration between public research institutions and different agribusinesses to develop PA's products (R16); Research into factors which affect PA's adoption (R17); Study about countries' experiences in PA and identify their PA's barriers (R18); Research into capacities in Qazvin province to execute PA (R19); Research about using more suitable and simple PA tools with respect to developing countries environment (R20); Study about spatial and temporal variability of soil and plant characteristics (R21); Measuring PA's implementation in Iran (R22);

Integration PA into universities' curricula (R23); Integration PA into vocational schools' curricula (R24); Integration PA into educational institutions' curricula (R25); Pay attention to needs of PA users, such as student, producers, consultants, and other agribusinesses (R26); Establishing educational PA plots (R27); Holding field days accompanied by conferences

and fairs in order to introduce PA technologies, more practically (R28); Presence of experts, researchers and farmers in international seminars and congresses in order to familiarize them with PA's applications (R29); Offering qualified, well written, and simple educational PA's material (R30); Improve producers' computer skills and develop their GIS and GPS's knowledge (R31); Offering an e-educational system for PA (R32); Organizing trainers and enriching research and educational programs using a cooperative system (R33); Holding training classes by industrial sectors to make producers, agriculture consultants, and agriculture service dealers skillful in application of PA equipments and PA software's (R34); Increasing collaboration between industrial and educational system in order to provide a better practical education in PA (R35); Providing workshops and classes in order to promote farmers' abilities to use PA equipments (R36); Developing self-study consumer guide for PA technologies (R37); Increasing framers' PA awareness through local medias, outlets, etc (R38); Holding a special PA educational course for teachers, agribusinesses, producers, researchers, input suppliers, etc (R39); Encouraging educated and young farmers to use e-tools (i.e., internet, e-mail, chat, etc) to communicate and exchange their PA information (R40); Training qualified and experienced operators in field of PA (R41).

From factor loadings of the above, one may observe that:

(i) Offering a practical PA education and Preparation of extension programs to introduce PA's benefits, such as fertilizer, poison, and seed reducing, increasing income and reducing environmental impacts provide more impact on the extensional requirements; (ii) Research about using more suitable and simple PA tools with respect to developing countries environment and Study about countries' experiences in PA and identify their PA's barriers provide more impact on the research requirements; (iii) Presence of experts, researchers and farmers in international seminars and congresses in order to familiarize them with PA's applications and Holding training classes by industrial sectors to make producers, agriculture consultants, and agriculture service dealers skillful in application of PA equipments and PA software's provide more impact on the educational requirements.

Table 2 represents the common variance explained by each requirements of the P.A. application.

Table 2: The common variance explained by each requirements.

Factor	Explained common Variance by factor
Educational requirements	22%
Research requirements	25.1%
Extensional requirements	39.1%
Total	86.2%

From Table 2, one can order the requirements based upon their impact on the system as: Extensional requirements, Research requirements and Educational requirements.

CONCLUSION

The Bayesian CFA suggested extensional requirements as the most important requirement of PA application. Extension plays an important role in effective information communication between researchers, extension agents, and agricultural producers, and also it considers producers' needs (Lavergne, 2004). The research findings verified by several authors such as Hudson & Hite, 2001; Reichardt & jurgens, 2009.

Among variables which build the extensional requirement, Offering a practical PA education and Preparation of extension programs to introduce PA's benefits, such as fertilizer, poison, and seed reducing, increasing income and reducing environmental impacts

provide more impact in the extensional requirement, among other variables. Our findings corroborate those of Hudson & Hite (2001) and Ahmadi (2008).

The first observation can be interpreted by the facts that the PA system is a complex one. Therefore, its users should be trained, practically. This training approach: (1) provides ability for framers to learn how they may use PA's equipments in practice. Holding field days on PA is a kind of practical training that provide opportunities to connect producers with professionals and experts to solve farmers' problems and answer their questions; (2) increases framers' confidence through developing their PA's skills. Many authors pointed out the advantages of the PA system, such as reducing input costs and increasing farm's productivity (see Lavergne, 2004, among others). These advantages interpret the second observation that the experts pointed out necessity existence of a compiling extension program as a requirement of a PA system in Iran.

Results of the survey suggest that extensional requirements are the most important from experts' point of view while this seems educational and research requirements are less important. These factors are important, of course, but this research suggests that extensional requirements are the most important consideration. Findings of this article emphasize, again, on key role of the agricultural extension in efficient implementation of PA.

Although this research represents a systemic effort to incorporate elements of educational, extensional and research requirements, it is not without limitations. The research proposes a model covering a variety of requirements; it might not be comprehensive due to the limitations of time and resources. Future researches might explore the challenges and barriers of PA's research, extension, and education.

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