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Perception of specialists about precision agricultural requirements; Bayesian confirmatory factor analysis

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Precision agriculture (PA) is an integrated agricultural pattern which implements modern farm management under the support of modern technologies to obtain integrated maximization of economic, ecological, and social benefits. Such benefits may lead to a sustainable agricultural. This article identifies requirements implementation of a PA system in Iran. A survey questionnaire was developed and mailed to a group of 40 PA experts in Qazvin province. Based upon research results, one can order the requirements based upon their impact as: Economic, Educational, Technical, Legal, Research, Farm, and Small farmer requirements.

Key words: Bayesian confirmatory factor analysis, requirements, precision agriculture (PA), sustainable agriculture, Iran

Introduction

Agricultural Ministry of Iran reported that the mean application rate of herbicides for wheat and corn were 0.99 and 4.44 kg/ha, respectively (Iran Statistical Yearbook, 2006). However, the values for Qazvin province were 2.06 and 5.10 kg/ha, respectively, indicating relatively high application rate of herbicides in Qazvin province. This fact indicates necessity of optimizing such rates using a PA system in the province (Abbaspour-Gilandeh *et al.*, 2006; Jafari *et al.*, 2006). PA is a term that refers to utilizing Global Positioning Systems (GPS), Geographic Information Systems (GIS), and Remote Sensing (RS) technologies to improve agricultural productivity and decrease the environmental impact of agricultural inputs. These technologies provide means for collecting data, such as nitrogen, phosphorus, insect counts, and disease presence at precise locations in fields. The “site-specific” information is entered into a computer to become a “spatial map”. Using this map; farmers and researchers can draw direct links between soil characteristics, fertilizer application, plant health, and yield. In addition, accurate spatial maps provide guidance for precise ‘variable rate’ application of pesticides and other agricultural chemicals. This decreases the amount of chemical inputs used, providing benefits to both the grower and the environment. (Lee and Hughes, n.d.)

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So, it seems there is need an agricultural system to achieve optimize the input or maximizing the crop yield, more income, environmental benefits and proceeds to sustainable development. Certainly, before implementing a PA system, one has to identify requirement of such system. This article explores such requirements to implement a PA system in Iran.

Prior studies

Several authors studied requirements of application a PA system. For instance, Reichardt *et al.* (2009) showed that the most important prerequisites for further adoption of PA in Germany are *reduction of costs for the technology*, *precise statements regarding the profitability of PA*, and *development of uniform standards to establish compatibility between machines from different manufacturers*. Wiebold *et al.* (1998) pointed out standardized software and equipment systems are the most PA's requirement. Many market-leading manufacturers produce equipments that do not adapt with other productions. This incompatibility creates several barriers in application of several equipments in a PA system. Fountas *et al.* (n.d.) suggested a general ISO-standard for manufactures to produce adaptive equipments which can work properly in a PA system. Lavergne (2004) pointed out that widespread PA adoption depend on economical incentives whose enrich infrastructure in rural areas. Daberkow *et al.* (2000) stated that credit reserves, the ability to access money on a loan basis, revenue insurance (a hedge against risk), and farm size positively impact on PA adoption. Kutter *et al.* (2009) suggested (1) Joint investment for PA machines (2) Joint PA technology practice, and (3) Using joint outsourcing services such as data processing and PA interpretation as three different forms of co-operation to PA farmers to reduce their PA costs. Mcbratney *et al.* (2005) found out that a strong linkage among researchers, farmers, PA machinery manufacturers, and PA consultants will: (1) enhance adoption of existing PA technologies by facilitating information exchange among these sectors; (2) promote adoption of new technologies developed by researchers as well as consultants and other firms within the small and medium enterprise sector; (3) encourage data exchange between sensor technologies and farm-machinery delivery platforms. It is important to inform advisors about PA prospects and to offer suitable advisory concepts for PA and special training courses for advisors to inform them about PA (Reichardt *et al.*, 2009).

Most of advisors did not recognize the advantages of PA technology because most of them have only little knowledge about it. Special training courses for such local advisors in the PA field could improve this situation (Reichardt and Jurgens, 2009). The preferred model for developed countries would be consultants highly trained in PA who can interpret PA data, make agronomic recommendations, and design and analyze on-going experiments in conjunction with soil and weather monitoring networks to optimize production (Mcbratney *et al*., 2005). To achieve a comprehensive use of PA technologies, it is necessary to offer an advisory service which provides technical support and agronomic knowledge (Reichardt *et al*., 2009).

Many authors attempted to explain requirements which are necessary for precision agriculture. One can categorize the above authors' findings into 5 factors: Technical, Economic, Legal, Educational, and Research factors. See section 3, for more details.

Variables and research model

According to a literature review, the following theoretical framework has been developed. Figure 1 represents the theoretical framework. Variables R1 to R50, respectively, indicate: Satellite equipments (R1) (Nikbakht and Dizaji, 2006), Develop farms mechanization level (R2) (Zarei, 2008), Develop communication systems (R3) (Zarei, 2008), Standardization of PA equipments (R4) (Cowan, 2000), Reduction incompatibility between hardware and software (R5) (Reichardt *et al*., 2009; Pedersen *et al*., 2001), Providing PA's software and hardware (R6) (Ahmadi, 1998), Establish centers for data analyses (R7) (Kutter *et al*., 2009), Use information technologies related to PA (R8) (Fountas *et al*., 2005), PA technologies (R9) (Reichardt and Jurgens, 2009), large farms to implement PA system (R10) (Adrian, 2006), Reduce internet tariffs (R11) (Zarei, 2008), Reduce cost of PA technologies (R12) (Reichardt and Jurgens, 2009), Information about PA investment return (R13) (Reichardt and Jurgens, 2009), Financial support in PA initial stage (R14) Reichardt and Jurgens, 2009), Pay subsidizes (R15) (Bordbar, 2010), Allocation credits to research (R16) (Bordbar, 2010), Credits easy to obtain (R17) (Daberkow *et al*., 2000), Economic incentives (R18) (Lavergne, 2004), Allocation credits to establish rural IT centers (R19) (Zarei, 2008), Stringent environmental regulations (R20) (Hudson and Hite, 2001), Coordination between research and execution sectors (R21) (Mcbratney *et al*., 2005), Insert PA policies in the national development program (R22) (Bid goli zade, 2009), Decrease price of related PA inputs (R23) (Bordbar, 2010), Closer collaboration of industry and agriculture (R24). Services such as farm insurance, equipment, and machineries related with PA (R25) (Lavergne, 2004), Farm cooperative for providing equipments for small farmers (R26) (Nikbakht and Dizaji, 2006), Establish companies that provide PA equipments for farmers specially small farmers (R27) (Nikbakht and Dizaji, 2006), Strategies like machinery sharing and collective farming which makes expensive technology affordable for small farmers (R28) (Kutter *et al*., 2009), Provide fundamental principles for private sector (R29) (NRC, 1997), Consultant infrastructure (R30) (Daberkow and McBride, 2003), Training seminars with practical work (R31) (Wiebold *et al*., 1998), Increased agronomic information (R32) (Reichardt *et al*., 2009), Development of simple instructions for data quality control (R33) (Reichardt *et al*., 2009), Distribution written documents about PA (R34) (Reichardt *et al*., 2009), Face-to-face training (R35) (Reichardt *et al*., 2009), Training exercises with ICT tools (R36) (Wiebold *et al*., 1998), Training experts to educate and extension PA technologies at wide level (R37)(Bordbar, 2010), Presence of agricultural advisors on farms to offer PA advices (R38) (Bordbar, 2010), Educating of teachers, agribusinesses, producers and another occupations related to PA (R39) (Bordbar, 2010), Integration PA into curricula in vocational schools, technical schools, universities and technical universities (R40) (Mcbratney *et al*., 2005), Familiarize authorities and managers with latest development in IT and PA technologies (R41), Good advisory services which provides technical support and agronomic knowledge (R42) (Reichardt and Jurgens, 2009), Existence of qualified, diverse, and available information sources (R43) (Mcbratney *et al*., 2005), Make awareness farmers, experts, and agents about PA through local media and outlets (R44) (Mcbratney *et al*., 2005), Identification of capacities and potential in order to overcome the barriers (R45) (Nikbakht and Dizaji, 2006), Research about new PA technologies (R46) (Wiebold *et al*., 1998), Establish data collecting centers (R47) (Daberkow and McBride, 2003), Establish large demonstration plots for research (R48) (Reichardt *et al*., 2009), Research about appropriate criteria for PA economic assessment (R49) (Mcbratney *et al*., 2005), Experiment PA plans on large farms and generalize it (R50) (Young Engineers club, 2009; Mcbratney *et al*., 2005).

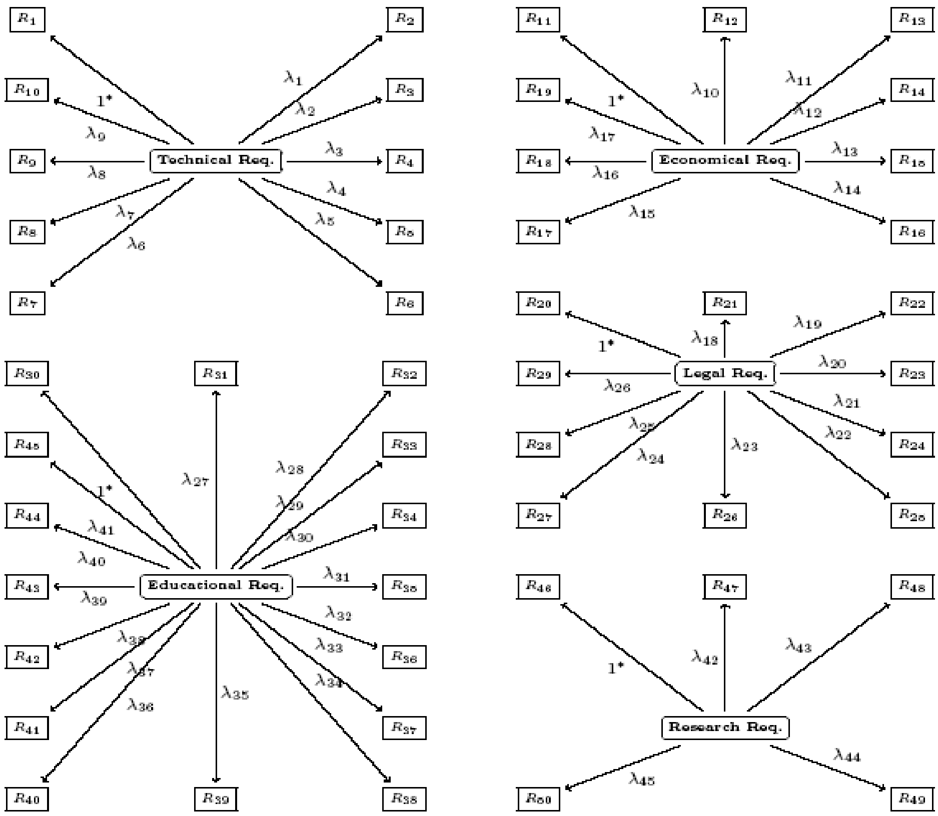

Fig. 1. Theoretical Framework of PA Requirements.

Meterials and methods

Questionnaire items were developed based on the previous literature. The questionnaire was revised with the help of experts with significant experience in precision agriculture 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. The Computed Cronbach's alpha is 87.4%, which indicated the high reliability of the questionnaire.

The research population included all the experts in Qazvin province. 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%.

Fig. 2. Qazvin Province of Iran.

This research used an open source statistical package, Win BUGS 14, which has ability to provide the Bayesian statistical models for data.

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, as seen in 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) to 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, 2007).

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 (Fig. 1). In Bayesian CFA, one of factor loadings fixed to be 1 and others estimated using sufficiently large iterations of a MCMC code.

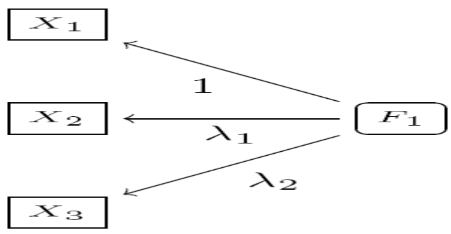

Fig.3. An example of CFA.

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. $\mathrm{H}_1 : \lambda_i \neq 0$. 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

Descriptive statistics

Table 1 represents descriptive statistics for some variables in the target population.

Table 1. Demographic Profile and Descriptive Statistics of experts.

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

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 Table 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 compare to other classical CFA approaches. More precisely, one can estimate mean, variance, and credible interval for mean of factor loadings.

As explained the above, all ordinal and observed variables in this research 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.

The final conceptual framework of requirements arrived after:, (i) removing "Establish centers for data analyses", "provide fundamental principles for private sector", “consultant infrastructure” respectively, from Technical, legal and Educational requirements; (ii) adding a new factor, named "farm requirements", which obtained two variables “Develop farms mechanization level”, “large farms to implement PA system” from *technical requirements*; (iii) adding a new factor, named “small-farmers requirements” which obtained three variables “Farm cooperative for providing equipments for small farmers”, “Establish companies that provide PA equipments for farmers specially small farmers”, “Strategies like machinery sharing which makes expensive technology affordable for small farmers”, “Strategies like collective farming which makes expensive technology affordable for small farmers” from legal requirements; (iv) move two variables “Insert PA policies in the national development program” and “Closer collaboration of industry and agriculture” to research requirements.

The following figure represents conceptual framework of requirements.

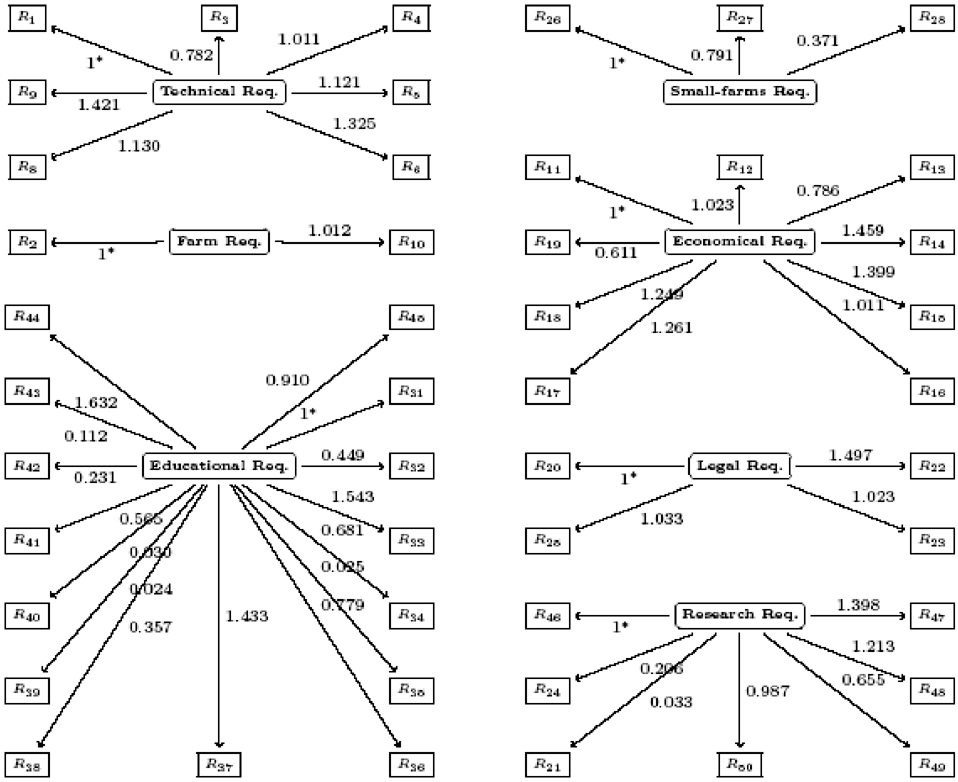

Fig. 4. A conceptual framework of requirements.

From factor loadings of the conceptual framework, in Figure 4, one may observe that:

(i) *Financial support in PA initial stage* and *Pay subsidizes* provide more impact on the economic requirements; (ii) *Development of simple instructions for data quality control*, *Training experts to educate and extension PA technologies at wide level* and *Make awareness farmers, experts, and agents about PA through local media and outlets* provide more impact on the educational requirements; (iii) *Providing PA software and hardware* and *PA technologies* provide more impact on the Technical requirements (iv) *Insert PA policies in the national development program* provides more impact on the legal requirements (v) *Establish centers for data analyses* and *Establish large demonstration plots for research* provides more impact on the research requirements. Table 2 represents the common variance which explained by each P.A. application requirements.

Table 2. The common variance which explained by each requirements.

Factor	Explained common Variance by factor
Technical requirements	15.20%
Farm requirements	3.44%
Economic requirements	19.2%
Legal requirements	11.61%
Small farmer requirements	3%
Educational requirements	18.15%
Research requirements	9.98%
Total	80.58%

From the above table, one can order the requirements based upon their impact as: economic, educational, Technical, legal, research, farm and Small farmer requirements. These factors, in total, explain about 81% of total variance.

Discussion

The Bayesian CFA suggested *economic requirements* (included: Reduce internet tariffs, Reduce cost of PA technologies, Information about PA investment return, Financial support in PA initial stage, Pay subsidizes, Allocation credits to research, Credits easy to obtain, Economic incentives, Allocation credits to establish rural IT centers), and *educational requirements* (included: Training seminars with practical work, Increased agronomic information, Development of simple instructions for data quality control, Distribution written documents about PA, Face-to-face training, Training exercises with ICT tools, Training experts to educate and extension PA technologies at wide level, Presence of agricultural advisors on farms to offer PA advices, Educating of teachers, agribusinesses, producers and another occupations related to PA, Integration PA into curricula in vocational schools, technical schools, universities and technical universities, Familiarize authorities and managers with latest development in IT and PA technologies, Good advisory services which provides technical support and agronomic knowledge, Existence of qualified, diverse, and available information sources, Make awareness farmers, experts, and agents about PA through local media and outlets, Identification of capacities and potential in order to overcome the barriers) as the two most important requirements of PA application.

Among variables which build the economic requirements, *financial support in the initial stage of PA* and *Pay subsidizes* provides more impact compares to others, while *Make awareness farmers, experts, and agents about*

PA through local media and outlets provide more impact in the educational requirements, among other variables.

The observation about *economic requirements* can be interpreted by the facts that: PA is a new technology which requires some new advanced and expensive equipments such as yield monitoring sensors, GPS receiver, etc. Such facilities are very costly for PA framers. Therefore, many of them try to avoid PA system, especially in situations where their productions have low commodity prices (Robert, 2002). Moreover, Swinton *et al.* (1997) and Lavergne (2004) identified initial costs of PA technologies are the most important financial requirements for PA farmers, which make them overwhelmed, since such technologies change rapidly. So, the main pre-requisite for PA application is reducing PA technologies costs and providing some financial supports for framers in PA initial stages (Reichardt and Jurgens, 2009).

The above finding also verified by several authors, such as, Zarei (2008); Wiebold *et al.* (1998); Reichardt and Jurgens (2009); Reichardt *et al.* (2009); Fountas (1998) among others.

The observation about *Educational requirements* can be interpreted by the facts that most of advisors did not recognize the advantages of PA technology because most of them have only little knowledge about it. Special training courses for such local advisors in the PA field could improve this situation (Reichardt and Jurgens, 2009). The preferred model for developed countries would be consultants highly trained in PA who can interpret PA data, make agronomic recommendations, and design and analyze on-going experiments in conjunction with soil and weather monitoring networks to optimize production (Mcbratney *et al.*, 2005). To achieve a comprehensive use of PA technologies, it is necessary to offer an advisory service which provides technical support and agronomic knowledge (Reichardt *et al.*, 2009). Awareness is the first critical stage in diffusing an agricultural technology (Daberkow and McBride, 2003). Existence of PA information sources and their quality directly affect the adoption of a PA system (Daberkow and McBride, 2003). Awareness of PA technologies can raise through schools, community groups, field days, local media, outlets (Mcbratney *et al.*, 2005), trade publications, and extension services (Hudson and Hite, 2001). Instructors and advisors play a critical role in such raising process. Awareness is the first critical stage in diffusing an agricultural technology (Daberkow and McBride, 2003). Existence of PA information sources and their quality directly affect the adoption of a PA system (Daberkow & McBride, 2003). Awareness of PA technologies can raise through schools, community groups, field days, local media, outlets (Mcbratney et al., 2005), trade publications, and extension services (Hudson and Hite, 2001). Instructors and advisors play a critical role in such raising process.

The finding about educational requirements verified by Wiebold *et al*. (1998); Daberkow and McBride (2003); Reichardt *et al*. (2009); NRC (1997) among others.

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