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Perceptions of Agricultural Experts towards Barriers to the Adoption of Precision Agriculture

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Abstract

Precision agriculture holds significant potential for increasing crop yield, reducing costs, and ensuring environmental protection. However, the adoption of these technologies is impeded by certain barriers that need to be acknowledged. This survey aimed to investigate the perceptions of agricultural experts (n=142) regarding the barriers to adopting precision agriculture in Ardabil province, Iran. Data were collected through a questionnaire administered to the participants. The research tool was validated by a group of university staff, and its reliability was confirmed through a pilot study involving 30 experts, which yielded a high alpha value. Due to the prevailing COVID-19 situation, data collection was conducted virtually. The findings indicated that the surveyed experts possessed a relatively good understanding of precision agriculture. Five factors, namely lack of knowledge, economic constraints, inadequate extension-farmer interactions, data security concerns, and limited accessibility, collectively accounted for 73.34 percent of the total variance in barriers to adopting precision agricultural technologies. Due to the lack of knowledge and poor farmer-extension interaction, extension courses are needed to improve farmers' knowledge and awareness of precision agriculture. Regarding the economic barriers, allocating the facilities and credits for developing and applying these technologies is necessary. Concerning the barriers to data security and lack of access, the government and related organizations should support farmers in solving internet access problems. Also, training and necessary facilities to maintain data security should be provided. Considering the effect of perception of usefulness on attitude, it is necessary to provide in-service training to improve experts' knowledge and perceptions about these technologies' usefulness. Precision agriculture demonstration farms in research stations or farmers' farms with the interaction of experts can be effective.

Keywords:
Agricultural experts; Ardabil; barriers; precision agriculture; perception

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INTRODUCTION

The FAO predicts that the global population will reach 9.2 billion by 2050 (Ullah et al., 2017). To meet the increasing needs of this growing population, agricultural production must rise by 70 percent worldwide and 100 percent in developing countries (Demestichas et al., 2020). Consequently, ensuring food security and promoting the sustainability of agricultural development has become critical global challenges, particularly in developing nations (Sabouri and Farshidnia, 2018). The attainment of sustainable food security hinges on effective agricultural and rural development strategies. However, current agricultural models still require refinement to achieve this objective (Karimi-Takanlou et al., 2018). The excessive exploitation of natural resources has resulted in the degradation of pastures, deforestation, soil erosion, salinity, drainage complications, and the depletion of water resources in agriculture due to inefficient irrigation practices (Shirkhani et al., 2016). Furthermore, unsustainable agricultural systems, driven by the indiscriminate use of chemical inputs, pose threats to natural resources, leading to irrevocable harm to human health (Pierpaoli et al., 2013). Consequently, global concerns have arisen regarding the environmental and societal impacts of various agricultural activities (Eidi et al., 2020). These concerns have motivated researchers to address pollution and explore environmentally friendly alternatives to conventional agricultural practices (Sumiahadi et al., 2019).

One of the strategies proposed to address this issue is precision agriculture, a crucial aspect of innovation in agricultural production (Bosompem, 2020). It aims to tackle the shortcomings of the current agricultural development paradigm by introducing novel approaches for optimizing the utilization of agricultural inputs (Szolnoki and Nábrádi, 2017). In precision agriculture, crop production inputs such as chemical fertilizers, herbicides, and seeds are applied based on the spatial characteristics of farms to minimize waste, enhance revenue, and preserve environmental integrity (Aubert et al., 2012; Paustian and Theuvsen, 2016; Barnes et al., 2019), thereby reducing input costs and boosting crop earnings (Koutsos and Menexes, 2019). Precision agriculture is rooted in the concept that to achieve economic efficiency and minimize environmental pollution, agricultural inputs, and agrochemicals, including fertilizers, pesticides, and herbicides, should be employed in precisely calibrated amounts for each specific section of the farm (Adrian et al., 2005). Broadly speaking, precision agriculture employs cutting-edge technologies in agriculture, guided by three core principles: optimizing yields through the strategic redistribution of inputs, heightening economic productivity, and mitigating environmental impact (Arayesh & Sabouri, 2016; Homayoun and Yazdanpanah, 2019).

Given the significance of precision agriculture, numerous studies have been conducted to explore its adoption and the obstacles it faces. Several studies (Griffin et al., 2018; Sean et al., 2020; Bolfe et al., 2020) have revealed that while farmers possess a positive inclination towards precision agriculture, they often hesitate to adopt it due to the intricacies of the technologies, limited income, and lack of initial capital. Farmers are increasingly leaning towards cost-effective technologies. The substantial expense associated with implementing precision agricultural technologies and the financial constraints faced by farmers in affording them constitute fundamental barriers to the adoption of these technologies, a phenomenon documented in prior research. For instance, Robert (2002), Gandorfer et al. (2018), Barnes et al. (2019), and Ofori et al. (2020) have linked this to the low adoption rate. Pierpaoli et al. (2013) identified competitive factors, financial resources, and socio-demographics as pivotal elements affecting the adoption of precision agricultural technologies. Moreover, Daberkow and McBride (2003) demonstrated that farm size and full-time farming status influence the adoption of these technologies. Notably, farm size exhibits a positive correlation with the adoption of precision farming. Larger farms are more likely to embrace precision farming (Reichardt and Jürgens, 2009; Lambert et al., 2014).

Hence, large commercial farms are more likely to reap economic benefits from incorporating precision farming into their operations (Jensen et al., 2012). Research conducted by Bogdanski (2012), Eidt et al. (2012), and Busse et al. (2014) have indicated that a lack of trust in precision agriculture is a significant impediment to its adoption. Uncertainty regarding the return on investment associated with these technologies is also cited as a barrier in prior studies (Robertson et al., 2007; Montalvo, 2008; Lawson et al., 2011; Cullen et al., 2013; Faber & Hoppe, 2013; Schimmelpfennig and Ebel, 2016).

Technical knowledge emerges as a vital variable emphasized in adoption studies. Farmers with a sound understanding of the applications of these technologies are more inclined to employ them. Reichardt and Jürgens (2009) discovered that a solid grasp of precision farming concepts is a prime driver of technology adoption. Nevertheless, Aubert et al. (2012) posited that young farmers with less agricultural experience, coupled with a longer-term planning horizon and enhanced education, tend to be more receptive to precision farming. Daberkow and McBride (2003) also established that factors such as education, technical proficiency, familiarity with computers, and age of farmers play pivotal roles in the acceptance of these technologies. Correspondingly, the findings of Reichardt and Jürgens (2009), Long et al. (2016), and Pivoto et al. (2019) have demonstrated that a lack of technical knowledge and computer literacy poses a significant hurdle to adopting these technologies. Villa-Henriksen et al. (2020) also revealed that villagers' limited awareness about the advantages of precision agricultural technologies stands as a primary barrier to their adoption.

Despite the relatively recent introduction of precision agriculture in Iran, the advantages of its technological applications have garnered considerable acceptance. This acceptance may be attributed to the recognition of equipment and the enhanced reliability of these emerging technologies. Although the cost-effectiveness, adaptability, and reliability of precision agriculture technologies are acknowledged, it becomes imperative, considering the challenges inherent in the country's context, to recognize and address obstacles hindering the development and adoption of these technologies. As a result, the current study endeavors to pinpoint and rank the barriers perceived by agricultural experts in Ardabil province that impede the adoption of precision agricultural technologies.

METHODOLOGY

Study area. A descriptive survey research method was employed in this study. The research was conducted over a period of four months in 2020-2021 within Ardabil province, Iran (situated at 37°04′ - 39°42′N and 47°02′ - 48°55′E). The province is positioned in the North-Western region of Iran. Encompassing an area of 17,953 square kilometers, this province accounts for approximately 1.09 percent of the total land area of the country. Roughly two-thirds of the province consists of mountainous terrain with elevated altitudes, while the remaining portion features flat and low-lying areas. The northern part of the province, known as Moghan, experiences a relatively warm climate, while the central and southern regions possess a cold mountainous climate. Within the province, 208,621 hectares of the total 547,108 hectares of agricultural land are irrigated, while the remaining areas rely on rainfall for cultivation. The primary agricultural products of the province include wheat, barley, soybean, rapeseed, sugar beet, potato, alfalfa, sorghum, and tomato. Additionally, apples, pears, peaches, apricots, cherries, and grapes constitute the main horticultural products cultivated in the province.

Population and sample: All the field experts within the new agricultural extension system of the province (N=175) comprised the statistical population of this study. Utilizing the Morgan sampling table, a statistical sample of 125 experts was determined. To enhance reliability, all experts, except the 30 participants from the pilot study, amounting to 145 experts, were included in the final sample. Out of this, a total of 142 experts willingly participated in the study (n=142) (as shown in Table 1).

Instrument and data collection: A researcher-developed questionnaire served as the primary research tool for this study. Alongside capturing the socio-economic characteristics of the participants, the questionnaire encompassed two main sections: the experts' knowledge of precision agricultural technologies (consisting of 13 items) and their perceptions of barriers to utilizing these technologies (comprising 25 items). All items were formulated as 5-point Likert-type statements, ranging from one (indicating very low or complete disagreement) to five (representing very high or complete agreement). A group of university staff members validated the questionnaire for its face validity. Subsequently, a pilot study involving a sample of 30 experts was carried out, and the scale's reliability was assessed using Cronbach's alpha. The calculated alpha value for the barrier scale was 0.876, demonstrating a high level of instrument reliability.

Given the widespread prevalence of Covid-19, data collection was conducted virtually. Initially, all experts were contacted via telephone and WhatsApp to explain the study's purpose and provide instructions for completing and returning the questionnaires. Subsequently, electronic versions of the questionnaires were distributed to the experts through WhatsApp. Following the necessary follow-up messages and upon receiving 142 completed questionnaires, the data were coded in preparation for the required analyses.

Data analysis. The collected data were subjected to analysis using the SPSS software. The experts' knowledge and perceptions were assessed individually, and initial analyses encompassed frequencies, percentages, mean scores, and standard deviations (SD). The standard deviation interval from the mean (ISDM) approach was utilized to categorize participants according to their levels of knowledge and perceptions regarding barriers to adopting precision agriculture. Employing this methodology, the participants were categorized into four groups based on the ISDM.

A: Low = A< Mean– Sd

B: Relatively low: Mean – Sd <B <Mean

C: Relatively high: Mean < C < Mean + Sd

D: High= Mean + Sd < D

Linear regression analysis was utilized to investigate the factors influencing experts' perceptions. Principal component factor analysis was employed to condense the items related to experts' perceptions into a limited number of easily interpretable factors. The criterion of latent root (eigenvalue greater than one) was applied to determine the optimal number of factors to extract. Various factor solutions were assessed before finalizing the structures (Hair et al., 1998). The Varimax rotation method was employed to en-

Table 1
The Population and Sample of the Study

Region	Number of experts	Sample size
Moghan Plain	98	86
Ardabil Plain	46	34
Khalkhal and Kosar	31	22
Total	175	142

hance the interpretability of the factors.

RESULTS

Demographic characteristics: The results indicate that the mean age of the respondents was 41.02 (SD = 6.09). They possessed 13.20 (SD = 5.21) years of farming experience. Of the respondents, 28.9 percent were women, while 71.1 percent were men. In terms of education, 50.7 percent held a BSc degree, 48.6 percent had an MSc degree, and the remaining respondents held a Ph.D. in agricultural sciences. Among the participants, 74 percent specialized in plant breeding and horticultural sciences, with the rest graduating in various other fields of agricultural sciences (Table 2).

Experts' knowledge of precision agricultural technologies: Experts' familiarity with 13 technologies was assessed. The findings revealed a comprehensive understanding of global positioning systems (GPS) (mean = 5), followed by remote sensing (mean = 4.04). Conversely, their understanding of guidance systems was the least pronounced (mean=3.04). In relation to the remaining technologies, their comprehension ranged from moderate to substantial (Table 3).

Barriers to the adoption of precision agriculture: Experts' perceptions on barriers to adopting precision agriculture were assessed using 25 Likert-type items. The findings indicated that the most significant barrier was the lack of adequate and accessible credits for procuring supplies and equipment among farmers (mean = 4.58). This was followed by the absence of subsidies for production inputs, incongruence among components of precision agricultural technologies, and insufficiency in appropriate hardware and software. Conversely, the least inhibiting barriers to adoption were the absence of structured academic courses pertaining to precision agriculture and challenges in transferring technology necessary for farmers (columns 1-2, Table 5).

The outcomes of categorizing respondents according to ISDM revealed that 51.4 percent possessed a relatively high level of knowledge, while the remaining individuals had knowledge ranging from low to relatively low. In contrast, more than half of the respondents rated the barriers as ranging from low to relatively low (Table 4).

Factor analysis of barriers to the adoption of precision agriculture.

Factor analysis was employed to condense the barriers to adopting precision agriculture into a concise set of interpretable factors. The results indicated that 24 items were deemed

Table 2

Demographic Characteristics of the Respondents

Variables	Categories	Frequency	Percentage
Gender	Male	101	71.1
	Female	41	28.9
Education	BSc	72	50.7
	MSc	69	48.6
	PhD	1	0.7
Field of study	Agronomy and plant breeding	60	42.3
	Horticulture	45	31.7
	Mechanization	12	8.5
	Animal physiology	8	5.6
	Biotechnology	7	4.9
	Plant protection	5	3.5
	Weed science	5	3.5
Variables	Mean	SD	
Age (years)	41.02	6.09	
Working experience (years)	13.20	5.21	

Table 3
Experts' Knowledge of Precision Agricultural Technologies

Technologies	Mean	SD
Global positioning system (GPS)	5	0.00
Remote sensing	4.04	0.77
Yield mapping	3.95	0.86
Section management	3.87	1.05
Yield monitoring	3.86	0.83
Yield zoning	3.85	0.85
Soil type sampling	3.80	0.99
Aerial photography	3.73	0.95
Drawing and demarcation	3.52	1.19
Temporal - spatial variability	3.51	1.17
Variable rate technology	3.47	0.98
Weed mapping	3.16	1.29
Guidance system	3.04	1.21

Table 4
Classification of Experts Based on Knowledge and Perceptions

Levels	Knowledge		Perceived barriers	
	f	%	*f*	%
High	-	-	31	21.8
Relatively high	73	51.4	28	19.7
Relatively low	45	31.7	64	45.1
Low	24	16.9	19	13.4

suitable for this analysis. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity (KMO = 0.735 and Chi-square = 3771.752, $p<0.01$) affirmed the appropriateness of the data for factor analysis (Hair et al., 1998; Tabachnick and Fidell, 2007). The Varimax rotation method was utilized for factor rotation, with factor loadings greater than 0.5 being considered significant. According to the Kaiser criterion, five factors with eigenvalues exceeding one were extracted. An eigenvalue denotes the contribution of each extracted factor to the overall variance. A higher eigenvalue signifies a more substantial impact of the factor.

The foremost factor, which accounted for the largest share of explained variance (23.23%), was designated as "lack of knowledge." This factor encompassed elements such as inadequate technical and software knowledge, limited computer literacy, farmers' familiarity with computers, absence of extension training programs for mastering these technologies, unfamiliarity with the functioning of these technologies, lack of suitable hardware and software, deficiency in skilled experts and professional consultants for precision agriculture, and insufficiently knowledgeable experts. The second factor, labeled "economic barriers," elucidated 21.98 percent of the total variance. It encompassed aspects like the need for substantial initial technology investment, elevated maintenance costs, lack of government subsidies for technology utilization, limited economic efficiency of the technology, challenges in acquiring funds for farmers' equipment and supply procurement, absence of production input subsidies, issues related to user-friendliness, and inadequate financial incentives for farmers to adopt precision agriculture. The third factor, termed "weak extension-farmer interaction," accounted for 15.72 percent of the total variance. It included dimensions like restricted access to satellite facilities and data, incongruence among precision agricultural technology components, unfavorable attitudes toward precision agriculture, insufficient farmer, researcher, and extension expert participation, hurdles in technology dissemination to farmers, and dearth of training opportunities for agricultural experts. The fourth and fifth factors, at 6.28 and 6.1 percent of the total variance respectively, pertained to "data security problems and inaccessibility." The fourth factor centered on data security issues, while the fifth factor revolved around the challenges and complexities associated with these technologies, compounded by difficulties in accessing the internet, particularly in remote villages. Collectively, these five factors accounted for 73.34 percent of the total variance (Table 5).

DISCUSSION AND CONCLUSION

Precision agricultural technologies possess significant potential for augmenting crop yields, diminishing production costs, and mit-

Table 5
Factor Analysis for Barriers to the Adoption of Precision Agricultural Technologies

Items	Mean	SD	Factors				
			1	2	3	4	5
Lack of appropriate hardware and software	4.35	0.85	0.841				
Weak technical and software knowledge and computer literacy among farmers	4.24	0.98	0.745				
Lack of trained experts and professional consultants for precision agriculture	4.17	0.92	0.925				
Lack of familiarity with computers among farmers	3.45	1.14	0.780				
lack of familiarity with how these technologies work	3.39	1.25	0.771				
Lack of extension training courses to work with these technologies	3.16	1.21	0.828				
Lack of experts with sufficient knowledge	3.05	1.17	0.925				
Insufficient and difficult access to funds for purchasing supplies and equipment	4.58	0.66		0.749			
Lack of subsidy for production inputs	4.54	0.74		0.708			
Lack of appropriate financial incentives for farmers	4.09	0.75		0.774			
The problem of user-friendliness	3.80	0.74		0.867			
Low economic efficiency of the technologies	3.55	1.34		0.696			
Lack of government subsidies for the use of precision agricultural technologies	3.41	1.04		0.727			
High maintenance costs	3.36	1.03		0.602			
High initial investment	3.33	1.03		0.744			
Incompatibility of technology components	4.52	0.64			0.863		
Lack of participation of farmers, researchers, and extension experts	4.21	1.26			0.520		
Lack of access to satellite facilities and data	3.39	1.25			0.777		
Lack of favorable attitude toward precision agriculture	3.28	1.31			0.840		
Lack of training courses for agricultural experts	3.26	1.25			0.704		
Problems in transferring the technology needed by farmers	2.58	1.28			0.809		
Data security problem	3.24	1.09				0.720	
hardness and troubled work with these technologies	3.59	1.21					0.711
Problem with internet access, especially in remote villages	3.28	1.11					0.735
Variance accounted for (Total: 73.34%)	-	-	23.23	21.98	15.72	6.28	6.10
Eigenvalues	-	-	5.81	5.49	3.93	1.57	1.52

igating environmental impacts. As a result, they offer unprecedented prospects for farmers and their farms. These technologies are pivotal for advancing agriculture and streamlining optimal resource management. Numerous countries have incorporated these technologies into their medium- and long-term plans, with some even recognizing them as developmental benchmarks. However, despite their promise, the implementation of these technologies is beset by challenges and barriers that must be recognized and overcome to formulate effective policies. Irrespective of the scope and complexity of technology usage, successful development and adoption of new technologies hinge on the consideration of users' skills, knowledge, and attitudes toward their practical application. Identifying barriers to the adoption of such technologies constitutes the initial stride in their evolution. Consequently, it is imperative to accord special attention to the cultural milieu and establish requisite infrastructures to foster the adoption and utilization of these technologies.

The current study explored the perceptions of agricultural experts regarding the obstacles to adopting precision agricultural technologies. To this end, 142 online questionnaires were completed by experts from the new agricultural extension system in Ardabil province, Iran. The outcomes of the regression analysis indicated limited explanatory power of the socioeconomic variables. Notably, among the socioeconomic factors, education level emerged as the sole significant variable influencing their perceptions. This observation aligns with a similar finding by Allahyari et al. (2016) in Iran. The findings from the factor analysis demonstrated that five key factors—lack of knowledge, economic barriers, weak extension-farmer interactions, data security problems, and inaccessibility—accounted for 73.34 percent of the variance in barriers associated with the adoption of precision agricultural technologies.

The findings reveal that insufficient knowledge and information serve as the primary obstacles to the adoption of precision agricultural technologies. This outcome aligns with prior studies (Robert, 2002; Long et al., 2016; Pivoto et al., 2019; Villa-Henriksen et al., 2020) which underscored the lack of farmers' awareness and knowledge as a chief challenge in implementing precision agricultural technology. Bolfe et al. (2020) and Gandorfer et al. (2018) similarly identified the requirement for greater technical expertise among experts in utilizing the software linked to this technology as the principal rationale for its non-adoption. Additionally, Barnes et al. (2019) demonstrated that farmers' unfamiliarity with these technologies' practical usage hindered their acceptance. This observation underscores the significance and urgency of educational initiatives, a key component in the advancement of precision agricultural technology that leading countries' policymakers have consistently emphasized. The second factor constraining the use of precision agricultural technologies was economic barriers. A multitude of previous studies echoed analogous conclusions (Robert, 2002; Gandorfer et al., 2018; Griffin et al., 2018; Barnes et al., 2019; Ofori et al., 2020; Bolfe et al., 2020; Mitchell et al., 2020). Despite the considerable profitability of precision agricultural technologies, their high costs pose a substantial hurdle for smallholder farmers, who constitute the majority in the study area. Given that small-scale farmers tend to be risk-averse, incentivizing the adoption and utilization of these technologies necessitates the provision of financial support, governmental backing, and extension-based educational endeavors. Consistent with the findings of Pivoto et al. (2019), deficient extension-farmer interaction emerged as another impediment to the adoption of precision farming technology.

Given that the efficacy of extension activities heavily relies on the proficiency, competence, and engagement of extension experts, employing scientifically and operationally adept professionals, and involving them in precision agriculture-related training programs, can significantly contribute to the success of precision farming-related extension initiatives and the adoption of these technologies by farmers. Data security emerged as the fourth obstacle to adopting these technologies according to experts. While concerns about the costs associated with these technologies trouble farmers, the potential for technology theft is also a source of worry. This finding is congruent with prior research.

Ofori et al. (2020) emphasized the importance of safeguarding farm-based technologies in the adoption of precision farming technologies. Similarly, other studies (Gondorfer et al., 2018; Demestichas et al., 2020) affirmed that the potential theft of farm-installed systems acts as a barrier to adopting precision farming technologies. The fifth and final barrier was the limited accessibility of these technologies, which supports earlier research (Pickthall & Trivett, 2017; Bolfe et al., 2020). In this context, Pivoto et al. (2019) highlighted the shortage of specialized personnel in precision agriculture as a limitation in accessing precision agricultural technologies. Steele (2018) further indicated that the absence of necessary economic and technical infrastructure for implementing precision agriculture stands as a primary reason for the non-adoption of precision farming technology. According to Bolfe et al. (2020), the subpar quality of technology poses another barrier to adopting these technologies.

Based on the outcomes of the current study, the following recommendations are proposed: Given farmers' lack of familiarity with precision agriculture, the inadequate interaction between farmers and extension services, and the consequential high utilization of chemical inputs, soil erosion, and elevated production costs, it becomes imperative for farmers to embrace and utilize these technologies. Consequently, launching an extension campaign to enhance awareness and understanding of precision agriculture is crucial. Radio and television programs dedicated to precision agriculture, extension training courses designed to familiarize farmers with these technologies, and the presentation of educational films showcasing successful implementation of these technologies by other farmers can effectively persuade farmers of the importance of adopting these technologies to reduce production costs, ensure the production of wholesome goods, and conserve resources. To surmount economic barriers, agricultural policymakers and planners should allocate necessary resources and funding for farmers to acquire precision agricultural technologies. Offering financial incentives, support, and guidance to progressive farmers in the realm of precision agricultural technology is essential, along with a heightened focus on technology utilization. Additionally, formulating strategic research plans to enhance and promote these technologies is imperative. In addressing issues of data security and internet access hindrances, relevant institutions must take the requisite measures to establish infrastructure and security protocols, thereby resolving internet accessibility and data security concerns, fostering farmer trust, and alleviating apprehensions.

In conclusion, this study delved into the perceptions of agricultural experts concerning the barriers to adopting precision agriculture. Future investigations should pivot to examine farmers' attitudes and perceptions of barriers to adopting precision agriculture, while simultaneously devising strategies to encourage technology adoption among farmers.

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AUTHORS' CONTRIBUTIONS

AB: Conceptualization, Methodology, Supervision, Validation, Writing- Original draft preparation in the English language. NE: Field data collection, Statistical data analysis, Writing the first draft in Persian.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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