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Challenges of Applying Conservation Agriculture in Iran: An Overview on Experts and Farmers' Perspectives

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ABSTRACT: Different countries face diverse challenges for Conservation Agriculture (CA) development. The main purpose of this study was to examine the challenges of applying CA in Iran from the perspective of experts and farmers. A focus group method was used to investigate the challenges. The research sample consisting of farmers and experts of CA in different provinces includes those 19 experts and 15 farmers. Inductive content analysis and coding (open, axial, and selective coding) were employed to analyze the farmers' and experts' discussions. The findings showed that the challenges of applying CA in the studied provinces could be divided into 6 general categories: institutional-infrastructure (7 concepts), economic (5 concepts), training-research (2 concepts), environmental (4 concepts), mechanization (2 concepts), and cognitive (2 concepts) challenges. The economic and institutional-infrastructure challenges were the most frequent related to applying CA. It can be concluded that to solve the challenges of applying CA, it is necessary to link various sectors of government (the Ministry of Agriculture), education and research (Agricultural Research, Education and Extension Organization), and industry together. But farmers themselves are also a major contributor to meet the challenges of CA development through participation in planning CA project and training-extension programs. Therefore, farmers' communities should also pave the way for a transition from conventional agriculture to CA with their participation.

KEYWORDS: No-tillage, maintaining crop residue, crop rotation, sustainable agriculture, agricultural ecosystems

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Introduction

Agricultural intensification, based on tillage-based agriculture, has, at all levels of economic development, negative effects on the quality of the essential natural services and the associated ecosystem services provided by nature.[1] The degradation of the land resource base has caused crop yields and factor productivities to decline and has promoted the practice of an alternative production paradigm that is ecologically sustainable as well as profitable.[2-4] Conservation Agriculture (CA) is an approach for managing agricultural ecosystems that leads to achieving sustainable agriculture by minimizing soil degradation and soil erosion and maintaining crop residue and crop diversity[1,5] in the world, especially in developing countries. According to global estimates in 2017, about 180 million hectares of land in the world has been brought under this type of agriculture.[6]

Conservation Agriculture enhances biodiversity and natural biological processes above and below the ground surface and contributes to increasing water and nutrient use efficiency, improving and sustaining crop production.[1] The main approach of CA is that chemical fertilizers, herbicides, and insecticides are used only if necessary, and an emphasis is put on the use of mechanical and natural methods.[6] Conservation Agriculture requires significantly less water use due to increased infiltration and enhanced water holding capacity from crop residues left on the soil surface.[4] It also protects the soil surface from extreme temperatures and greatly reduces surface evaporation.[7] Furthermore, long-term integrated CA systems can reduce annual weed pressure, allowing for reduced herbicide use.[1] Combined with a higher system biodiversity and increased organic matter and nutrient cycling, CA can promote reduced requirements for chemical inputs.[8] The benefits of CA include, but not limited to, soil erosion alleviation, efficient use of inputs, labor supply, and fossil fuels,[9-11] flexibility in dry farming systems under climate change,[12] reduction of production costs,[13] alleviation of greenhouse gases emission,[14-19] improvement of crop diversity,[16] improvement of resource efficiency and environmental conditions,[20] reduction of plowing costs,[18] the use of fossil fuels, and soil water evaporation.[21]

Moreover, although CA has been promoted in many different countries, governments and farmers are faced with challenges for its development. Some of these challenges may be related to CA technical, social, and environmental issues and each have various aspects depending of countries where CA is implemented.

In Iran, CA started in 4 provinces: Khouzestan, Fars, Golestan, and Khorasan in an area of 150 hectares in 2007,[1] and then, it was applied in the other provinces.

Based on the land degradation processes and climate situations, Iran's land has not attained a good status for sustainable crop production.[7-9] Most of Iran's lands (such as Yazd, Semnan, South Khorasan, and Sistan and Balochestan provinces) are in poor condition and unsuitable for sustainable crop production.[22]

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In addition to common limitations caused by low precipitation, low soil organic carbon, severe soil erosion, and high soil sodium were the predominant soil and land conditions limiting the agricultural land suitability in Iran. Most of Iran's farms are located in low-productive areas.[22]

There are little areas for cropland extension to expand production, but the development of CA could improve sustainability and decrease pressure on natural resources and the environment in Iran. Three major economic and social expected benefits could result from CA application in Iran. The positive impact of CA on the distribution of labor during the production cycle and, even more importantly, the reduction in labor requirement are the main reasons for farmers in Iran to apply CA, especially for farmers who rely fully on family labor. Moreover, with CA, farming communities could become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides, and other pollutants, and conservation of environmental integrity and services. Conservation Agriculture may lead to equal opportunities to use new farming systems, quality of life improvement, reduction of rural poverty, social solidarity, and social participation among farmers, and social welfare.

To achieve this, more flexible and transitional promotion of CA by its components facilitated through greater farmers' participation in research and extension systems will be required.[23] Participation in extension is the process of communication among farmers and extension workers, during which the farmers take the leading role to analyze their situation to plan, implement, and evaluate development activities.[24] Farmers' participation is considered a key component to the long-term sustainability of agricultural projects.[25] Stakeholders' participation in decision-making is more likely to lead to sustainable development in rural areas.[26] In addition, Ataei et al[5] concluded that social power should be identified and project management should be organized through them and their participation in attempts to implement CA.

Thus, the review of the literature shows most research studies have focused on the advantages of CA from a technical or economic aspect, while little has been done on farmers and experts' views on the challenges and barriers to CA development and their role. There is the need of (1) an all-inclusive model of key challenges and barriers of CA development from the farmers and experts' perspective and (2) the comprehension of farmers and experts' engagement to deal with CA implementation in Iran.

Therefore, the objective of this study was to investigate the challenges of applying CA from experts and farmers' perspectives in Iran. The specific objectives included (1) determining the barriers and challenges of CA application by farmers, (2) categorizing the barriers and challenges of CA application in some provinces in Iran, and (3) prioritizing the barriers and challenges of CA application in this country.

The results of the study could identify the barriers and challenges of applying and developing CA particularly in Iran. Moreover, sectors involved in CA projects recognized challenges and barriers based on which a systematic contextualized plan can be provided to solve and mitigate challenges of CA adoption.

CA challenges and barriers in Iran and other countries

In 2014, a comprehensive organization was established with the formation of the Supreme Headquarters of CA in the Ministry of Agriculture and Technical Committee at ministerial level, provincial agricultural organization (Agriculture Jahad Organization), and township agricultural management in Iran. National Headquarters Department of CA is under the authority of the Ministry of Agriculture. The Supreme Headquarters of CA is responsible for macroeconomic policies in support of CA's technology development in interaction with intra- and inter-organizational sectors. The National Headquarters of CA is responsible for issues related to the design, development, approval, and notification of programs, projects, guidelines, and other activities related to the development and promotion of CA. CA Technical Committee is responsible for the operating procedures of the programs and projects, development or revision of operating instructions, identification of equipment list, and allocation of funds for each project. At the provincial level, Agriculture Jahad Organization and the executive committee tracks issues related to the implementation of programs with provincial and national guidelines; identifies provincial priorities, and is responsible for the implementation, extension, and education; compares the results of research projects with field conditions within the CA-based applied research and delivery model farms framework (HUB); aggregates the results; and evaluates the implementation of the plan. According to this plan, CA-based Applied Research and Delivery (HUB) have been established in all provinces. HUBs are research, extension, and educational bases that accommodate the results of CA research projects with farmers' and local farm conditions. In HUBs, research activities are performed with the cooperation of researchers, extension agents, and pioneer farmers. Then, the results are trained to the farmers and extended among them. In addition, the development of technical guidelines for irrigated and rainfed lands and holding workshops and CA educational courses for experts and farmers are some key activities of this project (Figure 1).

Ataei et al[1] concluded that 58.1% of the farmers in Iran applied new skills, knowledge, and attitude from the extension training programs of CA at low and medium levels. Latifi et al[27] showed that CA has a weak organizational structure in Iran while it is a very significant driving factor for CA development in Iran. Strong driving power and weak dependence associated with this factor should be treated as a critical driver. They mentioned that to ensure more rapid expansion of CA in the future, Iran's government should invest in an

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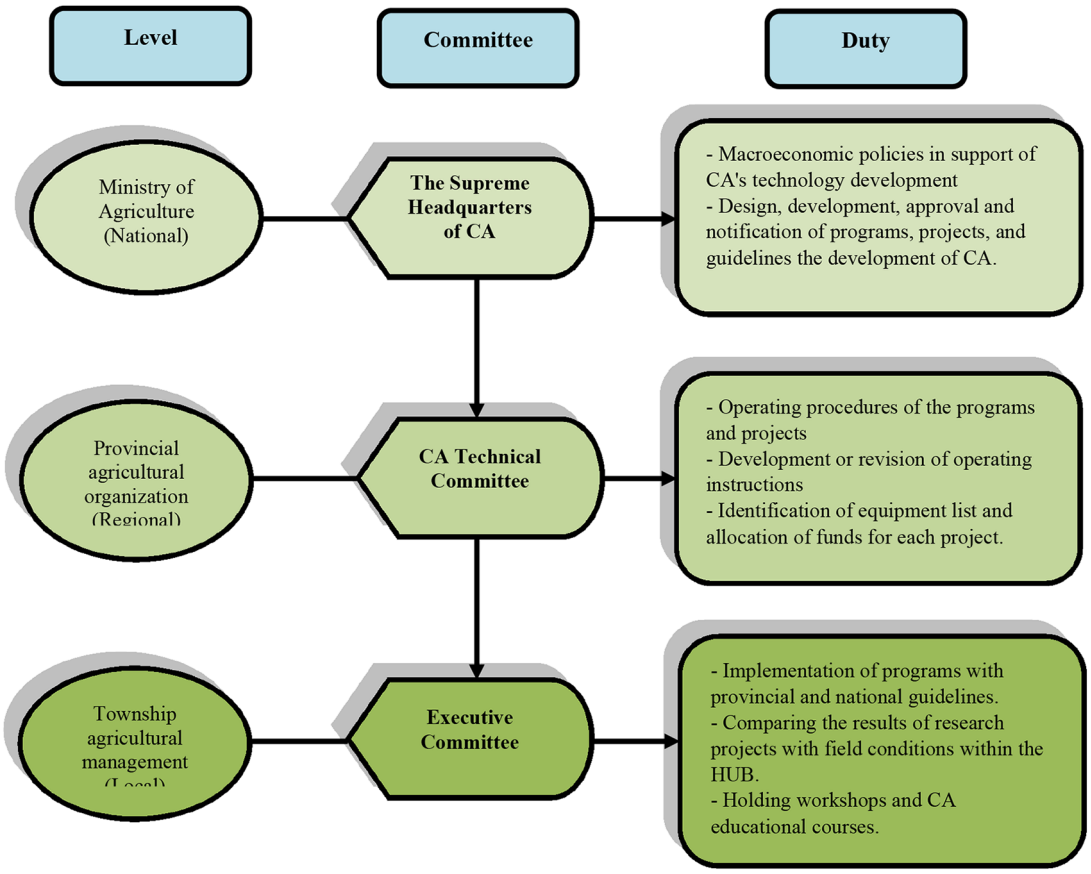


Figure 1. The main agents of CA at different levels and their roles in Iran. CA indicates Conservation Agriculture.

appropriate organizational structure for it. Movahedi et al[28] found that the lack of awareness and knowledge of farmers toward CA, a low rate of adoption of CA by farmers, and the lack of education and training services for CA were the most important issues of this agriculture type in Iran. Quilligan[29] stated that Iranian farmers need a multipurpose and multicrop machine to enable crop rotations required by CA and reduce the need for multiple devices. Razzaghi Borkhani and Mohammadi,[30] Abbasian et al,[31] and Bijani and Hayati[32] showed that soil and water conservation practices are used less in relation to soil and plant conservation practices in Iran. They indicated that farmers who participated in extension education courses, FFS programs, educational workshops, and farm advisory courses of plant clinics had a higher level of awareness and knowledge about CA compared with those who had not participated in these courses. Ataei et al[5] revealed a differing emphasis on the sustainability dimensions in the contents of CA training programs of Iran so that the institutional and social dimensions had the lowest frequencies. Furthermore, farmers are more likely to interact with local actors, and they interact less with the government and the actors outside the rural community.[4]

A comparison between other countries and Iran showed that some challenges and barriers are common and some specific to each region. Less production due to minimum tillage, difficulties in maintenance, lack of extension service were some major problems faced by the farmers in Bangladesh.[33] Gangwar et al[44] identified 6 main barriers to CA development in India: lack of trained human resources, lack of proper machinery, competition for the use of crop residues in rainy areas, weed management strategies, disease and pest infestation, and yield reduction. In Central Asia, crop residues are burnt or collected from the soil surface to feed animals due to the lack of robust and suitable tractors.[34] The access of small farmers to financial capital has been the main issue for the adoption of CA in Southeast Asian countries.[35] Nurbekov et al[36] concluded that various CA elements, such as permanent beds, seem to be technically suitable for the major cropping systems despite the heterogeneous conditions in Central Asia. Boboev et al[37] believed that many current challenges can be eased by implementing CA, with, however, unknown financial consequences under the predominating irrigated conditions in Central Asia.

Jat et al[38] and Kiran Kumara et al[39] argue that farmers and policymakers do not understand how CA can reverse the process of soil degradation and thereby accelerate sustainable agriculture so that knowledge gap and institutional barriers are the challenges to CA development.[40] Meanwhile, international and government supports are essential for CA development to increase local production and adaptation of equipment for local equipment, economic conditions, and skill levels of farmers.[41] Weed infestation and management is a major challenge to successful CA adoption[36,42] and a threat to yield performance.[43,44]

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The transition from conventional agriculture to CA transforms the nature of the weeds and weeding patterns.[45,46]

Keeping the soil covered with crop residues or cover crops is an essential requirement for obtaining CA benefits.[13] The supply of crop residues is one of the inhibiting factors of the development of CA. Also, the priority of using crop residues for small-scale farmers is the use of animal feed and forage (due to economic importance).[38] Jat et al[38] refer to a belief among farmers according to which it is necessary to plow the land to produce good yields. Hobbs and Govaerts[47] and Jew et al[48] have stated that coping with plowing is one of the important factors in CA development. It is hard to convince farmers (especially in less developed countries) about the potential benefits of CA. However, yield loss may undermine the morale of small farmers in the first years of CA adoption. Farmers do not know how one can gain many benefits from CA.[49,50]

The CA adoption rate is often high in countries where their farms are large. However, small farms require land-based machinery.[51] Conservation Agriculture calls for a variety of tools and instruments, with a variety of tools developed based on farm size, conditions, and type of activities. Many devices are still expensive or not suitable for certain areas so that the lack of local access to equipment for implementing CA,[34,45,52] especially for small farmers, is one of the major challenges. Conservation Agriculture is viewed upon as a prerequisite system of management and knowledge. Regardless of annual production costs, CA measures require a large initial investment.

Various scholars have recommended many solutions for CA promotion in communities: localized expertise, unbiased facilitation, subsidized inputs, and robust institutional system support,[53] improvement of personal capacity for applying CA, community support, opportunity to use, increasing farmers' motivation, and perceived content validity of CA,[3] collaboratively designed projects to better suit local needs and context with inclusive implementation arrangements, emphasis on climate resilience benefits of CA rather than economic benefits to manage farmers' expectations, intensification of multidisciplinary research that incorporates farmers' knowledge and experiences to develop suitable, flexible, and low-input CA packages, and stakeholders' participation.[54]

Materials and Methods

The focus group method was used to investigate the challenges of applying CA from experts and farmers' perspectives. The method is aimed to conduct a group interview and collect opinions on a subject matter (the phenomenon studied).[55] In other words, focus groups are organized to facilitate a discussion with a group of selected people because these people are thought to represent some classes and social strata.[56] Therefore, like most qualitative research methods, a purposive, qualitative, and criterion sampling method is used to form the focus group.[57,58] The main reason why the focus group method was used in this study was to identify the perceptions and experiences of a group of farmers and experts of the CA project about CA application in different areas of Iran. Stewart and Shamdasani's[59] plan was used in this study to operate the focus group. This plan consists of 8 steps in which the logic, stages, and characteristics of the focus group method are discussed. The first step is problem definition or research question formulation. The main question of the study was to examine the challenges and barriers of applying CA from different dimensions, which was stated as follows.

"What are the challenges and barriers of applying CA in different dimensions of Iran?"

The second step is to identify the sampling frame. At this step, the researcher identified how many participants were needed. The sample should reflect the views of the research community. Most focus groups are conducted with a maximum of 10 to 12 participants.[59] In this research, the research sample consisted of farmers and experts of CA projects in different provinces. The sample included 34 participants (19 experts: specialist and those involved in CA projects and 15 farmers as pioneer farmers in CA) from the provinces of Golestan, Khouzestan, Markazi, Fars, Khorasan Razavi, Tehran, Ilam, and Alborz (Table 1). The farmers were selected based on features such as participation in CA training courses and active cooperation in CA projects. Criteria for identifying experts included involvement in CA projects in rural areas, research activities and published papers in the field of CA, and memberships in the Department of CA. The response rates to the invitation by the experts and farmers were 94% and 81%, respectively. Two focus groups were formed, the first with 19 participants and the second with 15 participants. The interview guidelines were different for the experts and farmers. The farmers' interview guideline was designed as to the challenges to the application of the principles of CA in their farms. However, the experts' interview guideline was prepared based on the challenges for planning, organizing, communicating with farmers, and so on. In addition, the scheduled time was different for the farmers and experts; the farmers were first interviewed, and then the experts were.

The third step is to identify the moderator. The feature that distinguishes a focus group from interviewing or survey is the use of a moderator instead of the researcher. The moderator must have teamwork knowledge and a good reputation as a meeting leader. The moderator encourages the individuals' participation and prevents the domination of a few individuals in the focus group. In this research, a secretary of CA was selected as the moderator.

The fourth step is to recruit the participants. To invite and recruit the participants, it is necessary to determine the time and location of the focus group. Accordingly, an invitation letter in which the subject matter, time, and place had been described was sent to experts and farmers.

The fifth step is to generate and pretest interview guideline. The interview guideline, which contains the goals and general

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Table 1. Demographic characteristics of the participants in the focus group.

PARTICIPANTS	GENDER		AGE				TOTAL LAND				LAND UNDER CA			
	MALE	FEMALE	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
Farmers	12	3	48.8	8.16	39	54	22.4	6.2	10	28	14.4	7.1	7	19
Experts	13	9	40.14	10.01	36	44	—	—	—	—	—	—	—	—

	LAND UNDER CA				WORKSHOPS ORGANIZED BY PROJECT CA				NO. YEARS OF WORK			
	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
Farmers	14.4	7.1	7	19	10.8	3.2	7	12	26.6	9.21	20	33
Experts	—	—	—	—	12.71	3.11	10	14	13.71	7.87	8	17

Abbreviations: CA, Conservation Agriculture; SD, standard deviation.

questions of the research, is prepared as per the number of participants. The guideline was supplied to the participants and moderator before the meeting to stimulate their interest in participation, in addition to make them informed about the implementation of the focus group.

The sixth step is to conduct the focus group. At this step, the moderator directs the participants with the guidance of the interview questions. All participants (farmers and experts) discussed the challenges and barriers. In other words, all participants described the challenges and barriers of CA adoption. The discussions were jotted in addition to being recorded by a voice recorder. The focus group lasted about 2 hours and 40 minutes (each focus group started at 9:00 a.m. and ended at 11.40 a.m.). After the implementation of the focus group, the collected data must be analyzed and interpreted. Discussions should be summarized and analyzed. In this research, inductive content analysis and coding (open, axial, and selective coding) were used to analyze the farmers and experts' discussions. To have open coding, relevant texts of each interview were carefully studied line by line and then their concepts were extracted. The resulting concepts were carefully examined and compared in terms of similarities and differences. After that, the themes of the same nature or with relevant meaning were classified as categories. Axial coding is the process of relating codes (categories and properties) to each other via a combination of inductive and deductive thinking. Selective coding is the process of choosing one category to be the core category, and relating all other categories to that category. The underlying idea is to develop a single storyline around which everything else is draped. At this step, subthemes were also considered for each category, and the process of conceptualization continued. Then, the codes were counted. This method is called highlighting.[60] Data were analyzed based on the coding process (open, axial, and selective coding). First, the recorded discussions were transcribed. All participants' discussions were reviewed word by word and their key concepts (analysis unit) were extracted (open coding). A set of concepts, attributes, and subthemes was the output of open coding. Therefore, based on the key concepts derived from open coding, subthemes were defined (axial coding). Finally, the main themes were extracted from the common concepts among the subthemes and their integration (selective coding). At this stage, the relationship between the themes and subthemes was identified. The final step of the focus group was to prepare a research report.

Results

The challenges of CA adoption in Iran were divided into 6 general categories including institutional-infrastructure, economic, training-research, environmental, mechanization, and cognitive challenges. These categories have some subcategories or the so-called concepts. The findings indicated that economic challenges, which are the most frequent (83 repetitions), were ranked the first among the challenges of CA adoption. This category consists of 5 concepts including crop yield as the top priority for farmers, high costs of CA equipment and farmers' financial weakness, lack of funding for CA, deficient provision of facilities to farmers, and low fuel prices (Figure 2).

The challenge of "crop yield as the top priority for farmers" is most frequently referred to among the economic challenges. In this concept, experts and farmers consider crop yield as a decisive factor in the application of CA principles. However, if CA implementation at farms is accompanied by a decline in crop yields in the early years, farmers may be discouraged rendering CA development difficult. The second challenge of the economic category was the high costs of CA equipment and farmers' financial weakness. New CA machinery is expensive and farmers cannot afford them. However, CA will not be fully implemented if machinery is not provided. The third challenge of the economic category was the lack of funding for CA. The lack of organizational credit is another challenge that can hinder CA development. Lack of credit allocation reduces the participation of other sectors in the implementation of CA, the provision of training content, and the implementation of demonstration projects.

The second category of the challenges referred to most frequently was institutional-infrastructure challenges. These

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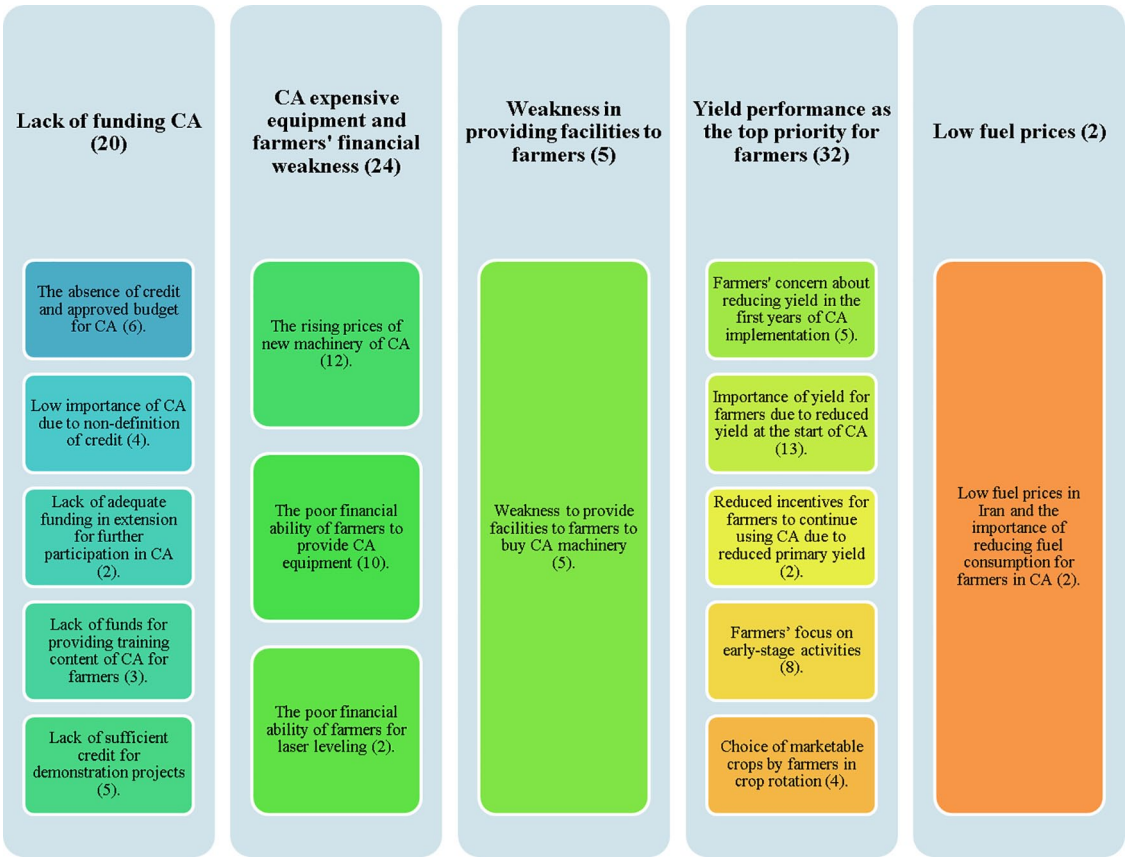


Figure 2. The economic challenges of CA applying. CA indicates Conservation Agriculture.

challenges consist of 7 concepts including inconsistent organizational policies, lack of organizational facilities, lack of organizational cohesion, weak organizational position for CA, poor laws and regulations, slow transition from conventional agriculture to CA, and low importance and status of soil conservation in organizations (Figure 3).

Inconsistent organizational policies had the highest frequency among institutional-infrastructure challenges. For example, "CA experts have recommended farmers to plant mushrooms in a greenhouse with summer rainfall, but experts in the field of plant conservation have recommended deep plowing to eliminate pests in winter." The second challenge in the institutional-infrastructure category was the lack of organizational facilities. Agricultural Jahad centers in rural areas suffer from a shortage of work force and facilities, so they cannot provide sufficient services to farmers. The lack of expertise will reduce the quality and quantity of services and slow down the development process of CA. Lack of organizational cohesion was the third institutional-infrastructure challenge. The Water and Soil Department, as one of the main areas in the protection of soil and water, does not have a specific program for participation in CA. Other departments have not been synchronized with CA programs yet. Therefore, these challenges have created organizational uncertainty in CA. Weak organizational position for CA is another institutional-infrastructure challenge. In many provinces, the administrative status of certain CA has not been set. Therefore, many programs have been implemented slowly and incompletely. In addition, CA in Iran has not been defined as a national plan. This challenge, besides creating institutional problems, has also led to economic challenges. As CA has not been defined as a national project, its development is not adequately funded.

Environmental challenges are another factor that disrupts CA development process. Environmental challenges were composed of 4 concepts: problems arising from maintaining crop residue on farms, diverse climatic conditions, animal grazing, and the distribution and ownership of farms (Figure 4).

The highest frequency was assigned to the problems arising from maintaining crop residue on farms. One of the main principles of the CA is to maintain crop residue. However, this is a major challenge for farmers in some cases. For example, the high level of crop residue causes problems in planting and harvesting, which in some cases forces farmers to burn them. In addition, maintaining crop residue on the soil surface may lead to the outbreak of pests, which will increase the consumption of chemical pesticides if farmers do not use integrated pest management. In some areas, crop residues are a source of income for farmers and they tend to collect residues from the soil surface. Grazing is another environmental challenge. Grazing by the livestock causes the soil to be compacted. However, some farmers rent their farms for grazing by livestock, and sometimes livestock enters the land of other farmers without permission.

The other challenge, which is the most frequent, is mechanization. This category includes 2 concepts of machinery

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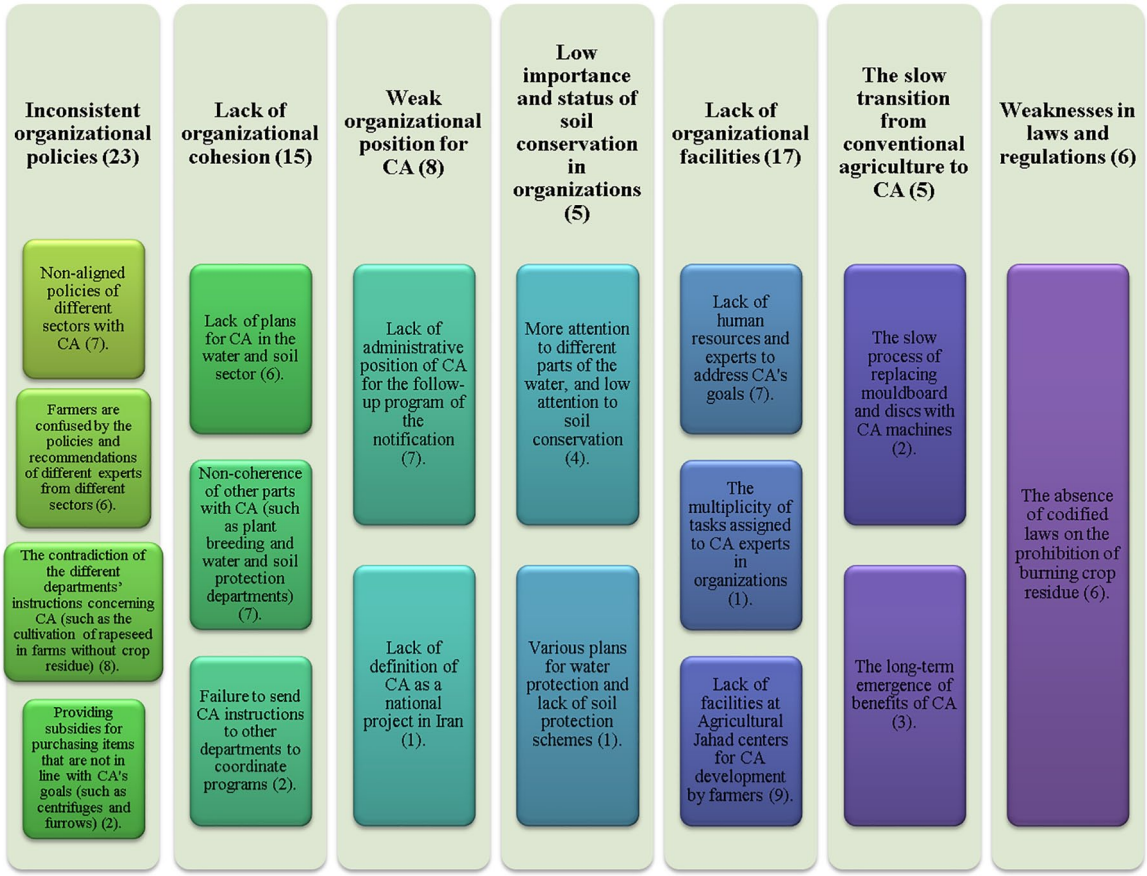


Figure 3. The institutional-infrastructure challenges of CA applying. CA indicates Conservation Agriculture.



Figure 4. The environmental challenges of CA applying. CA indicates Conservation Agriculture.

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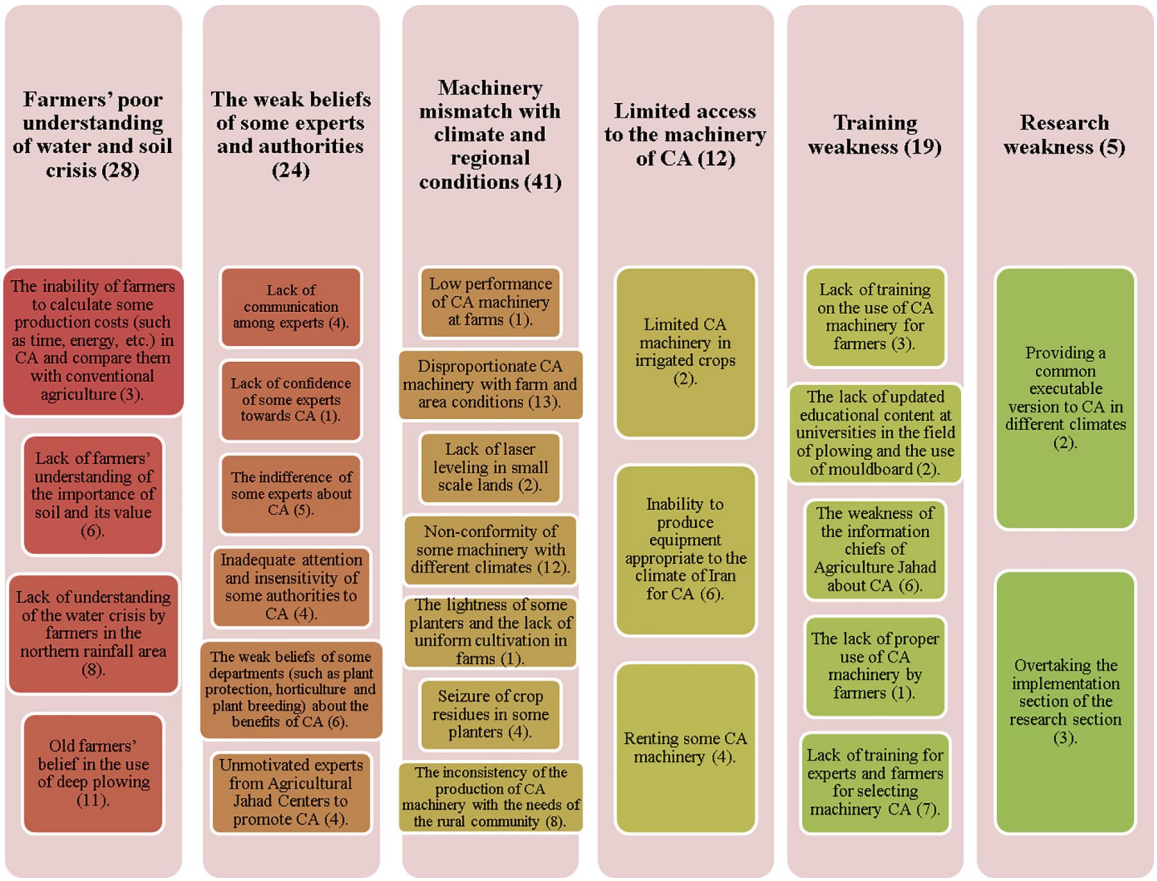


Figure 5. The mechanization, cognitive, and training-research challenges of CA applying. CA indicates Conservation Agriculture.

mismatch with climate and regional conditions and limited access to the machinery of CA (Figure 5).

Many CA machines have been imported and are not suitable for different farm and climate conditions in many cases. In addition, many farmers cannot afford to buy expensive CA machines. Therefore, farmers should rent CA machinery, which limits their access to CA machinery. In addition, industries are not capable of producing machinery that fits different climates.

Another obstacle to CA's development is cognitive challenges. Cognitive challenges were divided into 2 categories: farmers' poor understanding of the water and soil crisis and the weak beliefs of some experts and authorities (Figure 5).

Farmers do not have enough understanding of the importance of soil and its conservation, and they do not understand the water crisis in rainy areas. Some experts do not pay enough attention to CA and have no incentive to promote it. In addition, some departments of Jahad Agricultural Organization do not believe in the benefits of CA.

The last category of challenges to apply CA in Iran has been the training-research challenges. This category includes poor training and poor research (Figure 5).

The lack of training on the use and selection of CA devices and the weakness of information from CEOs about CA were important educational challenges. In addition, the provision of a common executable version of CA for different climates and the advancement of the implementation section of the research were the weaknesses of the research section.

Discussion

The results illustrated that economic challenges were the main obstacles in the development of CA in Iran. Other researchers[41,61,62] have acknowledged that the economic challenges of farmers and the government (such as organizational credit) will delay the process of CA adoption. Lack of credit allocation for CA causes it to be perceived unimportant among other projects. Farmers often focus on early-stage activities and choose market-oriented products in crop rotations. Farmers' concern for the loss of crop yields during the first years of CA implementation can be an important challenge for farmers in CA adoption.[7] Furthermore, Wall,[63] Jat et al,[38] Dalton et al,[61] Legoupil et al,[35] and Montt and Luu[64] argue that CA equipment is expensive and some farmers cannot afford it.

The other main category of the challenges was institutional-infrastructure challenges. Scholars such as Sims et al,[41] O'Reilly,[65] Boulal et al,[49] Friedrich et al,[66] and Lienhard et al[62] have identified institutional-infrastructure challenges as important factors inhibiting CA development. For example, paradoxical policies of different parts of the Agriculture Jahad Organization with respect to CA violate the instructions of the

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various parts of the organization, on the one hand, and cause farmers to confuse the use of expert advice, on the other hand. Therefore, inconsistency of policies and actions of the various parts of the organizations in the provinces will prevent the proper implementation of the CA principles. Environmental challenges (such as problems arising from maintaining crop residue on farms, different climatic conditions, animal grazing, and the distribution and ownership of farms) were the third obstacle of CA development in Iran. The findings are supported by Wall,[63] Rusinamhodzi et al,[67] Nurbekov et al,[34] and Duiker and Thomason.[68] Iran has a wide range of climates, which is a challenge for CA development. Different climatic conditions require different instructions for CA implementation. For example, soil salinity prevents cultivation on wide ridges, or tight soil limits the use of zero-tillage in rainy areas. In addition, Giller et al[69] and Legoupil et al[35] considered animal grazing on farms as a challenge for CA development. In addition, farmers have difficulty providing fodder for livestock and crop residues are used as fodder in arid areas.

Mechanization challenges are another factor that disrupts CA's development among Iranian farmers. Kassam et al,[52] Johansen et al,[45] Dalton et al,[61] and Li et al[51] have shown that limited access to CA machinery and their mismatch are important challenges to apply CA. They believed that the lack of CA's machinery leads to failure to implement the principles of CA. Cognitive challenges were another obstacle to applying the principles of CA in Iran. However, some researchers[38,47,63,70] have argued that cognitive challenges and farmers' mindset slow down CA development. Many old farmers still believe in the use of deep plowing so that they believe that the lack of plowing can reduce crop yields. The training-research challenges were the last obstacle that disrupts the process of CA's development. The results of various studies such as Belloum,[71] Bhan and Behera,[20] Nurbekov et al,[34] and Dougill et al[40] have also shown that farmers' poor knowledge and training are barriers to CA development.

Furthermore, the results indicated that farmers' participation could solve some challenges for the development of CA in Iran. This finding is consistent with the results of Ataei et al,[5] Aazami et al,[72] Sharaunga and Mudhara,[73] and Chinseu et al.[54] Sharaunga and Mudhara[73] argue that transparency and accountability in activities also encourage participation in the development of extension programs. The main philosophy of participation is to use collective thoughts and ideas in the decision-making process.[74] Aazami et al[75] mention that farmers' participation in the development process has reached the status that it now is considered both as a means and as an end for the development process. The results supported the construction of a comprehensive key framework of challenges/barriers to tackle the barriers of CA development.

Given the challenges, it can be inferred that different sectors must be involved in solving them. The government and relevant organizations to facilitate the development of the CA (such as institutional-infrastructure and mechanization challenges) should resolve a part of the challenges. Some challenges can also be solved by coordinating educational and research sections (such as training-research, cognitive, and environmental challenges). The 2 sections provide the basis for applying the CA principles to farmers. The industries also facilitate farmers' access to CA machinery by providing the necessary equipment. All these sectors are trying to resolve the challenges of applying CA by farmers. However, farmers themselves are also a major contributor to meeting the challenges of CA development. Therefore, farmers' communities should also participate in the transition from conventional agriculture to CA. It can be concluded that for further CA expansion, it is necessary to stop comparing conventional agriculture and CA and focus on the recognition and analysis of problems within the CA systems. In addition, moving away from the traditional linear model of agricultural technology development and disseminating the participatory model of farmers within the local innovation system will help to solve many CA development constraints. In addition, the transformation from traditional agriculture to CA needs a revolution in attitude and technology that requires a mindset in farmers and support of a set of different people such as researchers, extension agents, industry, and advisors. Therefore, the focus of extension agents as a farmer's information channel should be changed to organizing local innovation systems and facilitating the exchange of information among farmers.[76] To succeed in CA, in addition to changing farmers' attitudes, there is a need for new skills in product selection for better marketing, product grading, and postharvest practices.

In addition, more human and financial resources and a long time are required to demonstrate the economic and environmental benefits of CA at farms. Training should be considered one of the strategies for human resource development in CA. Training should not be limited to training sessions and field visits. Rather, it must be a permanent approach aimed at gaining technical knowledge. Training should include 3 important points: facilitating access to information, creating and supporting collective thinking at all stages of the program's implementation, and organizing training sessions to cover the technical, managerial, and legal aspects of CA.

Conclusions, Challenges, and Final Remarks

Recognizing the barriers and challenges of applying CA principles can lead to CA development. In this process, different dimensions should be considered. In other words, recognizing the barriers and challenges of CA development should be comprehensive. Therefore, the main purpose of this study was to examine the challenges of applying CA from the perspective of experts and farmers. The contribution of the research was a comprehensive model of challenges to contribute to overcome the barriers of CA development in Iran. It should be mentioned that CA is not widely adopted in Iran owing to a lack of

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economic incentives for smallholder farmers—that without a short-term cost saving of the kind achieved on mechanized farms in other regions of the world. Yield increases in CA are possible but uncertain given the low-average yields and large yield gaps, and yield gains are more likely to be observed after several years. The success of the development of any newly introduced agricultural system in Iran requires knowledge of the agricultural belief systems of the farmers, researchers, and extension agents, such that gaps in perceptions of the agricultural system are recognized and incorporated into the development of implementation strategies. Furthermore, simply understanding how farmers think and approach agricultural decision-making does not create solutions. It is through the supplemental discovery of the economic, institutional, environmental, and social basis driving these mindsets that a more complete picture of community needs and mindsets is developed, and sustainable productivity can be better improved. Overcoming the challenges requires research and development of strategies that maximize the long-term environmental and agroeconomic benefits of CA in Iran. Participatory research involving farmers, researchers, extension agents, equipment manufacturers, and other stakeholders is needed to develop integrated management that enables farmers to adapt to changing local and external conditions. The farmers mostly mentioned the challenges related to economic (such as expensive equipment of CA, weakness in providing financial facilities to farmers, and reducing yield performance), environmental (such as obstacles arising from maintaining crop residue on farms, and distribution of farms), limited access to the machinery of CA, and lack of CA training. However, most experts discussed the challenges related to cognitive (such as farmers' poor understanding of drought and lack of some experts and authorities' belief in the benefits of CA), institutional-infrastructure, climate diversity in Iran, and a few research in the field of CA in Iran. Therefore, the findings indicate that there are different perspectives about the challenges of CA between experts' and farmers' communities. It was helped to conclude that it should indagate perspectives of all stakeholders and authorities in the project. It helped to prepare a comprehensive model and program for the development of the project (not presented hereby). Furthermore, it can be recommended that farmers' participation is increased in extension activities such as analyzing their situation with respect to planning, implementing, and evaluating activities related to the development of CA. Future researches needed to investigate the relationship among these challenges and identify their emerging cycles. Future researchers can analyze farmers' social networks to mitigate the challenges of CA adoption by farmers. In addition, studying farmers' strategies to solve their challenges can be another suggestion for future researches.

Author Contributions

PA contributed in designing the study, conducting the interviews, collecting and analyzing the data, writing and reviewing. HS contributed in developing the content of the manuscript, and reviewing of the manuscript. TA conducted the selection of available studies for systematic review, drafted the first structure of the study. MC contributed in designing the proposal and reviewing. EA contributed in designing the study, preparation and characterization of adsorbent, writing and reviewing.

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