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Analyzing the Factors Affecting the Development of Agricultural Mechanization in Kurdistan Province

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Abstract

The purpose of this study was to analyzing the factors affecting the development of agricultural mechanization in Kurdistan Province. To collect the necessary data, 390 farmers were selected and surveyed using cluster sampling methods. The reliability of the questionnaire was assessed using Cronbach's alpha coefficient (0.85), while its validity was confirmed through the results of a pilot study and evaluations by agricultural experts and university faculty members. The effects of economic, social, and technical factors on the development of agricultural mechanization were analyzed using econometric methods and cross-sectional data from a single crop year in Kurdistan Province. Farmers identified several key obstacles to the adoption of mechanization, including fragmented land plots (56%), shortage of tractors and equipment (41%), high rental costs (70%), lack of timely access to machinery (60%), small land size (50%), inappropriate equipment (56%), and the wide geographical dispersion of their farmland. The estimation of the relationship between independent variables and the dependent variable (agricultural mechanization capacity) indicated that literacy, farming experience, educational attainment, access to credit, and the type of irrigation system had a positive and significant impact on mechanization development. Conversely, the number of land plots and the distance of farms from mechanization service centers and agricultural cooperatives had a negative and significant effect. These findings highlight the critical need for establishing localized mechanization service centers, promoting land consolidation strategies, and providing targeted technical training for farmers particularly in areas with dispersed land holdings as essential measures for advancing agricultural mechanization in Kurdistan Province.

Keywords
Agricultural Mechanization, Effective Factors, Development

1. Introduction

Agriculture is considered the cornerstone of sustainable development in rural areas, and agricultural mechanization serves as a critical driver for growth, transformation, and increased productivity in this sector (Zhou & Ma, 2022). Mechanization entails the integration of advanced machinery and modern technologies into farming operations, processing, and transportation, leading to improved economic efficiency, reduced labor intensity, enhanced resource productivity, and ultimately, better livelihoods for agricultural stakeholders (Guan et al., 2023; Sims & Kienzle, 2016).

Numerous studies underscore the pivotal role of mechanization in enhancing labor productivity, achieving sustainable food security, and reducing rural poverty (Lu et al., 2024; Van Loon et al., 2020). Efficient performance of critical farm operations such as tillage, planting, harvesting, and post-harvest processing is largely dependent on mechanized equipment, which increases operational precision and speed (Reid, 2011).

In high and middle-income countries, the majority of agricultural activities are mechanized, with only a few operations still performed manually (Sims & Kienzle, 2016). Zhou and Ma (2022) found that fully mechanized farming significantly outperforms semimechanized systems in terms of land productivity (Zhou & Ma, 2022). However, the rising costs of mechanization can hinder the provision and accessibility of related services, while a targeted and well-structured development strategy can enhance farm performance and contribute to rural development (Zheng et al., 2022).

According to Diao et al. (2020), in countries with abundant land and high labor costs, the adoption of farm machinery is accelerating. Nonetheless, concerns persist regarding the limited benefits of mechanization for smallholder farmers (Daum & Birner, 2020). Fragmented and small landholdings also necessitate the use of lighter and more adaptable machinery (Van Loon et al., 2020). In China, Zhao et al. (2025) observed that large-scale farms commonly employ mechanized services for plowing, planting, and harvesting. However, contrary to expectations, these services have, in some cases, negatively impacted agricultural productivity.

From a human capital perspective, Belton and Filipski (2019) reported that improved access to secondary education has delayed entry into the agricultural labor market and increased pressure on mechanization. Rising real wages have also served as a strong incentive for farmers to adopt technology-based solutions (Belton et al., 2021)

The development of agricultural mechanization is influenced by a complex interplay of environmental, economic, social, and cultural factors (Gavgani et al., 2022; Razu et al., 2025). Ignoring these dimensions may provoke cultural resistance and hinder the acceptance of new technologies in rural communities. Huo et al. (2022) identified land fragmentation and lack of technical training as major barriers and proposed strategies such as land consolidation, targeted subsidies, and specialized training programs to overcome them.

In addition, general structural characteristics of the agricultural sector such as farm size and number, cropping patterns, financial resources, and existing mechanization levels play a significant role in the adoption rate of new technologies (Amjadi & Chizari, 2006). Sharifi et al. (2025) found a negative but statistically insignificant relationship between access to machinery and farmers' environmental attitudes.

Alizadehnia (2024) highlighted the facilitative role of young human capital, technical infrastructure, and innovation willingness, while emphasizing obstacles such as financial limitations, weak educational systems, and outdated machinery. The absence of governmental support, competition with private firms, and public distrust in cooperatives further complicate mechanization efforts in cooperative farming systems.

In Nigeria, Iyere Freedom et al. (2024) found that farming experience, education level, and household income significantly influence the adoption of mechanized services. While there is widespread acceptance of basic technologies—such as improved crop varieties and conventional machinery more advanced technologies, such as data-driven smart systems and automated planters, remain underutilized due to technical knowledge gaps and limited financial access.

Kurniawan et al. (2024) demonstrated that access to technology, digital tools, and financial literacy has a positive and significant impact on the performance and sustainability of agricultural cooperatives. Similarly, Maklavani et al. (2025), through scenario-based analysis of rice production, showed that land consolidation combined with mechanization can lead to energy savings, increased productivity, and reduced environmental degradation.

In Pakistan, Liu et al. (2025) confirmed that mechanization across all stages of production led to a 55% increase in household income and a 125% rise in food security. Education, land size, farming experience, and access to credit were key contributing factors.

Moreover, increased non-agricultural employment has been shown to influence the cost structure of mechanized services (Zheng et al., 2022). In Vietnam, Chi (2010) emphasized that training, technological awareness, and regional investment are essential for mechanization expansion. Autio et al. (2021) further indicated that crop diversity, farming experience, and drought management strategies play important roles in technology adoption. In Sub-Saharan Africa, Merma et al. (2018) noted that agricultural activities are still predominantly labor-based, and the provision of mechanized equipment should be prioritized. Rahman et al. (2011) also pointed to land fragmentation, limited capital, and a shortage of skilled labor as persistent challenges in advancing mechanization.

In general, the development of agricultural mechanization requires a comprehensive identification of challenges and the formulation of actionable strategies based on a thorough understanding of regional conditions. The present study was conducted with the aim of identifying the key factors influencing the development of mechanization in Kurdistan Province, in order to design and implement practical, regionally tailored priorities and strategies for enhancing mechanization at the provincial level.

Kurdistan Province, situated in western Iran, features a temperate mountainous climate and encompasses an area of approximately 1,217,038 hectares accounting for nearly 5% of the nation's total agricultural land. The province is home to around 130,000 agricultural practitioners. A substantial portion of the region's agricultural land—approximately 96% is dedicated to annual cropping and fallow systems, while the remaining 4% is occupied by orchards and permanent horticultural land (Anonymous, 2023). This study was conducted in Kurdistan Province over a 14-month period during the years 2022–2023. The province exhibits relatively homogeneous cultural and social characteristics, a consistent temperate mountainous climate, and a broadly uniform topography. Nevertheless, no table intra-provincial variations exist in farm structure. Specifically, agricultural plots in Qorveh and Bijar are significantly larger compared to those in Marivan, Sarvabad, Baneh, and Sanandaj, reflecting regional disparities in landholding patterns (Figure 1).

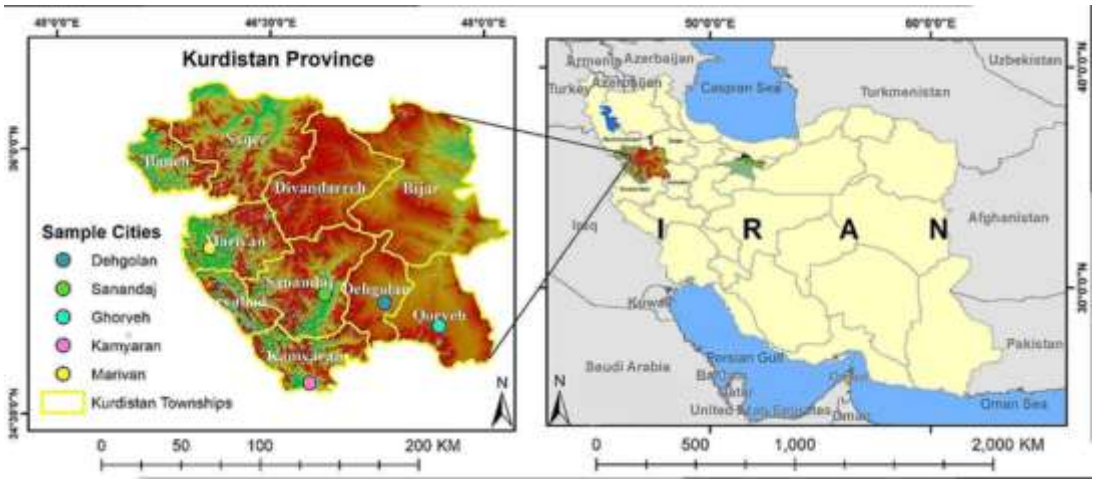

Figure 1: Kurdistan Province in Iran

2. Materials and Methods

This study employed by survey methods reserach. Due to the limited timeframe and the unavailability of some critical information during the research period, a cross-sectional survey design was adopted. Initially, a preliminary questionnaire was developed and distributed among university professors and experts in agricultural machinery and mechanization. This instrument included factors presumed to influence mechanization development such as income level, literacy rate, landholding size, and others. Experts were asked to assess the significance of each variable and subsequently rank them based on their perceived importance. The findings from this phase informed the design of the final questionnaire.

The main questionnaire, targeted at farmers, consisted of 26 structured items. It covered a wide range of topics, including the availability of repair shops, mechanization service companies, agricultural cooperatives, farmers' personal characteristics, type and duration of extension training, challenges related to machinery usage, characteristics of power sources (both mechanical and animal), types and amounts of credits received, labor availability, use of fertilizers and pesticides, and details about field operations.

The sample size was determined using Krejcie and Morgan's (1970) sample size table. Given the size of the statistical population, an effective sample of 384 respondents was calculated, but to enhance data reliability, 390 completed questionnaires were obtained.

To ensure instrument reliability, Cronbach's alpha was used. A pilot test was conducted with 30 farmers, and the data were analyzed using SPSS software. The resulting Cronbach's alpha value was 0.85, indicating a high level of internal consistency. Furthermore, the questionnaire's validity was confirmed through a pilot study and expert reviews by university faculty members, researchers, and officials from the provincial Department of Agriculture. Since the questionnaires were completed in person with the researcher's assistance, the credibility and accuracy of the collected data were considered to be high.

A multi-stage sampling method was applied in the selected counties. Based on local conditions, spatial distribution, and preliminary data, several rural districts were identified. From each district, villages were selected proportionally. These villages were grouped into homogeneous categories according to cultivated land area, topography, and infrastructural access. Representative villages were then selected from each group, and from each village, a number of farmers were randomly chosen for participation.

The independent variables in this study included the following: age (X_1), literacy level (X_2), experience in agriculture (X_3), education level (X_4), labor wage rate (X_5), distance to mechanization service providers and cooperatives (X_6), amount of agricultural credit received (X_7), cultivated land area (X_8), number of land plots (X_9), type of irrigation system (X_{10}), type of land ownership (X_{11}), and the condition of agricultural plots (X_{12}). The dependent variable was the Level of Mechanization Development (LMD).

A linear regression model was used to analyze the data. The model was tested and validated based on theoretical expectations concerning the impact of the selected variables on mechanization development, as well as appropriate model specification.

After data collection, all questionnaires were coded and numbered. Descriptive analyses were conducted, followed by the estimation of a linear regression model using SPSS and Microsoft Excel.

3. Results and Discussion

The results showed that only 64.1 percent of the respondents are literate and 35.9 percent are illiterate. Among the literate people, 33.4 percent have a diploma. The average age of respondents is approximately 47 years. Additionally, the average experience of respondents in agricultural mechanization activities was 9 years. Among them, 40% have more than 10 years' experience, 23% have between 5 - 10 years, and the remainder have less than 5 years' experience. Furthermore, 20% of respondents have participated in short-term training courses, while 10% of the remaining respondents have attended long-term training programs.

The level of mechanization across different counties of the province indicates that Marivan County has the highest mechanization level at 1.17 horsepower per hectare. However, given the small size of cultivated land parcels in this county, this level is still insufficient. Conversely, Kamyaran County exhibits the lowest mechanization level at 0.38 horsepower per hectare. The mechanization levels in Kamyaran, Bijar, Sanandaj, Dehgolan, and Qorveh counties are 0.38, 0.43, 0.47, 0.51, and 0.58 horsepower per hectare, respectively—all below the provincial average of 0.588 horsepower per hectare. Moreover, these nine counties Kamyaran, Bijar, Sanandaj, Dehgolan, Qorveh, Saqqez, Sarvabad, Baneh, and Divandarreh all fall below the national average mechanization level of 1 horsepower per hectare, highlighting the urgent need for increased investment in power resources in these areas. Nevertheless, it should be emphasized that quantitative increases in mechanization levels alone are insufficient; concurrent improvements in supportive services, infrastructural factors, and other influential elements must also be addressed.

In the linear model, out of 12 variables considered, 5 variables, age, plot leveling status, labor wage level, cultivated area, and ownership type, did not have a statistically significant effect on mechanization development and were removed from the final model (Table 1, 2).

Table 1. Regression coefficients of factors affecting the level of mechanization development

Model	Unstandardized Coefficients		Standard Coefficients	t	Sig.
	B	Standard Deviation	Beta		
Constant	269.921	35.96		7.506	0.000*
Literacy (X2)	13.280	3.924	0.225	3.384	0.001*
Background (X3)	0.756	0.353	0.129	2.140	0.036*
Education (X4)	39.022	15.496	0.202	2.518	0.014*
Distance of farm from companies (X6)	-1675	0.625	-257	-2.681	0.009*
Credits (X7)	0.00000414	0.000	0.260	4.207	0.000*
Number of plots (X9)	-5.620	2.594	-0.235	-2167	0.034*
Irrigation system(X10)	30.729	11.331	0.171	2712	0.009*

*Significant at the 1% level Dependent variable: Level of mechanization development

Table 2. Values of multiple correlation coefficient, R and R^2 square, (R^2) adjusted to the regression equation

R	R^2	R^2 adjusted	F	Sig. (F)
0.903	0.815	0.794	37.883	0.000*

Based on the results of Table (1), the linear regression model for the level of agricultural mechanization development is as follows:

$$LMD = 269.921 + 13.280X_2 + 0.756X_3 + 39.022X_4 - 1.675X_6 + 0.000414X_7 - 5.620X_9 + 30.7297X_{10}$$

In this model, it is observed that the obtained coefficients are consistent with the theories related to the effect of these variables on the development of mechanization and is in accordance with the expectation. The coefficient of R^2 and the adjusted R^2 indicate that the dependent variable (level of mechanization development) is explained by the

independent variables by 81.5 and 79.4 percent. The F-statistic, which is used to judge R^2, indicates that the independent variables as a set are significant for the changes in the dependent variable and the entire regression is significant.

Despite the idea that increasing age has a negative effect on the development of mechanization and in fact, older farmers are more resistant to the adoption of new methods and the use of new technologies, the results show that this is not true in Kurdistan province. Increasing the age of farmers does not have a significant effect on the development of mechanization. These results are consistent with those of Bigdeli (2009) and Yari et al. (2009) and are in contrast to those of Khumbulani et al. (2020), Dawane et al. (2025) and Agazhi et al. (2024).

The lack of significance of the coefficient of leveling status is also due to the fact that the Kurdistan region is mountainous and the land with a low slope is cultivated, and because farmers terrace their land in the sloping areas and also plow in the direction of the slope in the sloping areas, they consider the slope of the land to be effective only in transportation and commuting between plots and farms to the village. This is consistent with the findings of Qian et al. (2022), but contrasts with the findings of Bigdeli (2009) in Hamedan. The lack of significance of the level of labor wages is expected due to the low range of wage changes in different parts of the province. This result is consistent with the results of Bigdali (2009) and Pawlak et al. (2001), but contrary to the results of Napasintuwong and Emerson (2003), Belton (2021), and Diao (2020). In developed countries, because labor wages are very high, the mechanization process in the agricultural sector is greatly affected by the situation of the labor force. However, in developing countries, wages have not reached a level that has a significant effect on the process of agricultural mechanization. The lack of significance of the area under cultivation is due to the dispersion of agricultural plots, which neutralizes the positive effects of increasing size. This result is consistent with the findings of Daum & Birner (2020) and colleagues, but contradicts those of Zhao et al. (2025).

The variable of ownership type also does not have a significant effect on the development of mechanization, and the hypothesis regarding the improvement of mechanization development in collective systems is not confirmed. This finding is consistent with the results of Qian et al. (2022) regarding the mechanization of small-scale farmlands, but contradicts the patterns observed in the mechanization of large-scale farms. In fact, in collective systems, the lack of proper division of labor and duties causes numerous disputes and ultimately leads to land division. Hence, the issue of integrating the lands of multiple farmers and creating a piece of land that is managed collectively can only be effective in the development of mechanization if the necessary cultural foundations are created in this regard.

The results of Table (1) show that the effect of literacy on mechanization development is positive and highly significant. This result is consistent with the findings of Bigdali (2009), Belton and Filipski (2019) and Agazhi 2024. However, unlike the results of Yari's (2009) study in Arak County, the main reasons for this can be attributed to the specific cultural differences between Kurdistan Province and Arak County and the specialization of the dependent variable in Yari's study (variable costs of tractors). The average capacity estimate between the literacy variable and the level of mechanization development shows that the sensitivity of mechanization to the literacy variable is 13.3 units. In other words, on average, 1 unit change in the literacy level changes the level of mechanization development by 13.3 units.

The direct relationship between the experience variable and the level of mechanization development is due to the fact that with increasing experience of farmers and users, the quality of operations improves, which in the case of farmers causes correct operation and reduction of their time due to high experience and ultimately increases labor productivity. In the case of users, it also increases the quantity and quality of mechanized operations. In fact, part of the economic performance of a machine system is related to the driver's performance. If the driver's performance is not high, the performance of the entire system will decrease. An experienced and skilled driver is fully familiar with all controls and makes good use of these devices that the manufacturer has installed due to necessity. The calculation of the average capacity shows that the sensitivity of mechanization to the experience variable is 0.75 units. In other words, a 1-unit increase in the experience factor increases the level of mechanization development by 0.75 units. This is consistent with the results of Bigdeli (2009), Autio et al. (2021), Agazhi (2024) and Iyere Freedom et al (2024).

The alignment of the education variable with the level of mechanization development is one of the expected theoretical results of the model. As can be seen in Table (1), the education variable has a positive and significant relationship with mechanization. The higher coefficient of the education factor also indicates its greater importance among the social variables compared to the two variables of literacy and background. The results of studies Panta et al (2024), Agazhi (2024), Gavgani et al., (2022) and Chi, 2010) confirm this result. In fact, providing general and technical training to farmers and users in terms of improving the quality of operations and the type of methods used, as well as the use of highly productive and timely biological inputs, improves the economic and technical efficiency of farms and, consequently, the level of mechanization development of each farm. Estimating the average capacity between training and the level of mechanization development shows that a 1-unit increase in the training variable increases 39 units of mechanization. Given the possibility of increasing this factor compared to the previous two

factors, it is necessary to pay more attention to holding training and extension courses for farmers and users of agricultural machinery. Agriculture is felt. In particular, holding specialized technical courses for agricultural machinery users, according to the results of descriptive statistics that most (80 percent) have requested these courses, can have a significant impact on improving their efficiency.

The results of Table (1) show a direct and significant relationship between the amount of credits received by farmers and the level of mechanization development. The results of Gavgani et al. (2022) and Khumbulani et al. (2020) also support this result.

The negative and significant relationship between the variable number of plots and mechanization shows that increasing the number of plots of the exploitation system has a negative effect on the development of mechanization. The average capacity estimate shows that 1 unit change in this variable creates 5 units of change in mechanization. These findings are consistent with research reports Hiironen & Niukkanen (2014), Looga et al., (2018), Niskanen & Heikkilä (2015), Orea et al. (2015), Bradfield et al., (2021), del Corral et al., (2011) and Latruffe & Piet (2014). Therefore, the fragmentation of agricultural plots is considered one of the major obstacles to the development of agricultural mechanization. Therefore, the limitation in the development of mechanization is not related to the creation of plots of several hundred hectares. Because the results of descriptive and inferential statistics show that the size of agricultural land plots in the province is very small. As 86.4 percent were below 5 hectares, 9.8 percent were between 5-10 hectares, and 3.7 percent were above 10 hectares. The small size of the agricultural lands in the province requires appropriate and specific technology, and considering that half of the lands in the province are under 2 hectares in area, the province's need for small tractors with a power of less than 45 horsepower and tillers is quite evident. This is while 99.59 percent of the province's tractors have a power of more than 45 horsepower, and only 0.41 percent of the province's tractors have a power of less than 45 horsepower. The reasons for this can be attributed to the lack of promotion of small tractors and tillers, as well as the lack of distribution of these types of machines in the province.

The average number of plots per farmer was 4.7 plots, and most of the plots were one hectare in size, with an average size of 3.6 hectares. The average distance between the plots of a farmer was 967 meters. This limits the use of agricultural machinery. With these results, the concept of land consolidation is not the creation of very large plots, but rather the consolidation of the plots of land of one farmer and the creation of one plot of land for each farm.

The negative and significant relationship between the variable of distance of mechanization service companies from the village and mechanization shows that increasing the distance to the village has a negative effect on the development of mechanization. The average capacity estimate shows that 1 unit change in this variable creates 2 units of change in mechanization. These findings are consistent with research reports Bradfield et al. (2021), del Corral et al. (2011) and Latruffe & Piet (2014). Therefore, it is possible to create new cooperative mechanization production and service companies and also to allocate subsidies and grants to inactive companies to provide the necessary basis for activating these companies. This can be a fundamental step in the development of agricultural mechanization in the province.

5. Conclusion and Recommendations

The findings of this study highlight the critical role of socio-economic and infrastructural variables in the development of agricultural mechanization. Specifically, literacy level, formal education, farming experience, access to credit, and the type of irrigation system were identified as statistically significant and positively correlated with mechanization development. Conversely, the number of fragmented land plots and their spatial dispersion from mechanization service centers and production cooperatives exhibited a significant negative impact. These results imply that increased land fragmentation and greater distances between plots act as barriers to mechanization adoption, likely due to logistical inefficiencies and increased operational costs. Among all variables, education emerged as the most influential factor, underscoring its foundational role in enabling farmers to effectively utilize, manage, and invest in mechanized systems. This aligns with prior studies emphasizing the pivotal function of human capital in the modernization of agriculture.

Furthermore, the type of irrigation system particularly the adoption of pressurized irrigation was identified as the second most impactful variable. Farms equipped with such systems are inherently more adaptable to mechanized practices, suggesting a synergistic relationship between irrigation modernization and mechanization uptake. The influence of credit access on mechanization showed a non-linear trend; while moderate levels of credit facilitate mechanization, excessive or misallocated credit may divert investment toward non-agricultural sectors, ultimately hindering mechanization efforts.

Given the profound influence of education and literacy on mechanization development, it is strongly recommended that access to tractors and other agricultural machinery be conditional upon a minimum literacy threshold. Moreover, applicants should be mandated to complete certified technical training programs administered by accredited institutions. In this regard, it is proposed that a dedicated regulatory body be established within the Mechanization Department of the Ministry of Agricultural Jihad to oversee licensing and certification of machinery operators.

Practical training should encompass key areas such as cost-reduction strategies in machinery ownership, operational scheduling, standard agronomic practices, periodic maintenance protocols, and correct methods for attaching and calibrating farm implements. Such educational initiatives will ensure safer, more efficient, and economically viable use of machinery.

Additionally, considering the dual-edged nature of credit, it is essential to conduct in-depth studies on the optimal volume and allocation methods for financial support targeted at mechanization. Designing tailored credit schemes that align with farmers' mechanization needs, operational scale, and repayment capacities will enhance the effectiveness and sustainability of credit-based interventions.

In conclusion, a comprehensive strategy that integrates educational enhancement, infrastructure development, institutional regulation, and targeted financial support is essential for accelerating the mechanization of agriculture, particularly in regions with fragmented land holdings and varied resource access.

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