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Determining the Optimal Cropping Pattern with Emphasis on the Interaction between Risk and Profitability: Farmlands of Dehgolan Plain

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Abstract

Risk is an undeniable factor in agricultural activities, and its neglect can lead to inefficient resource allocation in the sector. Various theories and mathematical programming models have been developed to assist decision-making in cropping pattern management under risk conditions. This study aimed to determine the optimal cropping pattern for Dehgolan Plain, Iran, using data from 2014 to 2023. A linear programming model was employed to maximize farmers' gross income, and the results were compared with those from a Quadratic Programming Model and the Minimization of Total Absolute Deviation (MOTAD) model, both incorporating risk minimization. The findings revealed that risk factors can significantly influence cropping patterns. Under the highest level of risk, the profit-maximizing cropping pattern included only cucumber, alfalfa, and canola, indicating a preference for higher gross-income crops despite their greater water requirements. However, when risk was incorporated into the model, the cultivated area of wheat and barley increased compared to the risk-neutral scenario. This shift reflects a tendency toward lower water-requirement crops, even at the cost of reduced gross income. These results highlight the necessity of balancing income maximization and risk management for more sustainable cropping pattern.

Keywords: Cropping pattern, Linear programming model, MOTAD model, Quadratic programming model, Risk model

Introduction

Agriculture is one of the most vital sectors of the global economy (Gebbers & Adamchuk, 2010) which requires a comprehensive planning to achieve growth and address ongoing crises (Zhou *et al.*, 2022). Agricultural activities have long been characterized by high levels of risk and uncertainty, stemming from the sector's constant exposure to a wide range of unpredictable biophysical, economic, and institutional factors (Theuvsen, 2013). Unlike many other industries, agriculture is uniquely vulnerable to weather variability, pests and diseases, volatile market prices, and shifting policy frameworks, all of which can lead to substantial fluctuations in yields and incomes. This financial and operational uncertainty is not incidental but rather a defining feature of agricultural production systems (Adnan *et al.*, 2018). The cumulative effect of these risks extends beyond individual farms, posing

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serious challenges to food security, rural development, and the overall resilience of agricultural economies.

Agricultural risk is multidimensional, encompassing various factors that influence farm operations, productivity, and profitability. According to Ozerova and Sharopatova (2021), six primary sources of risk in agriculture (production, price, financial, institutional, technological, and personal) play a crucial role in shaping decision-making and outcomes in farming systems (Fig. 1). Identifying and addressing these diverse sources of risk is crucial for developing comprehensive risk management frameworks that enhance the stability and productivity of agricultural systems.

Farmers are often compelled to make decisions regarding resource allocation and crop production in environments where risks related to prices and crop yields prevail. The numerous risks inherent in the agricultural sector can significantly influence cropping patterns and the composition of cultivated crops (Wang *et al.*, 2022). The intrinsic nature of risk entails adverse outcomes such as reduced returns and income, which, in severe cases, may lead to crises like financial bankruptcy, food insecurity, and health-related challenges (Komarek *et al.*, 2020).

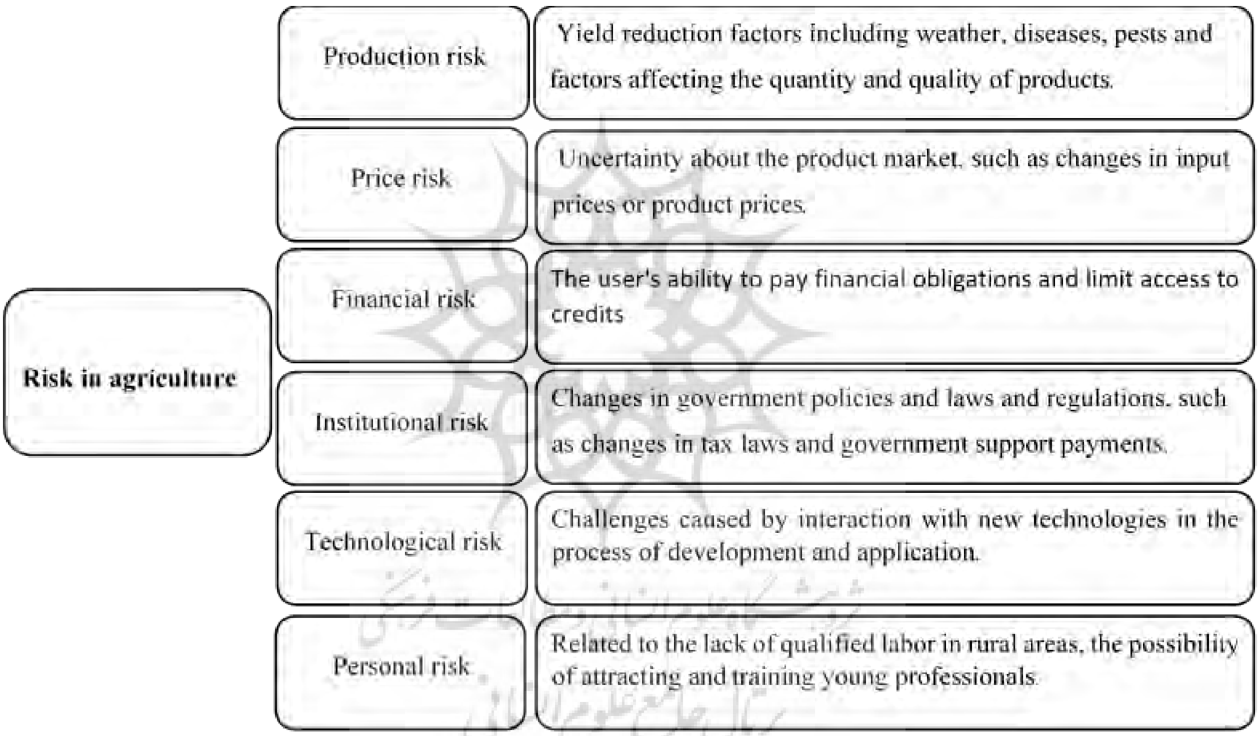

Figure 1- Classification of sources of risk in the agricultural sector

Simple mathematical programming methods, due to their inability to account for risk, often fail to provide farmers with optimal production plans. Faced with production risks and price volatility of future crops, farmers exhibit varying behaviors. Therefore, to better predict optimal cropping patterns, it is crucial to incorporate risk factors into the decision-making process for agricultural activities (Ahmad *et al.*, 2020). Consequently, to achieve agricultural development, it seems logical to integrate risk considerations into planning, policymaking, and decisions regarding optimal crop composition and cultivation levels (Bahadori *et al.*, 2019).

Although Iran's economic growth is not heavily reliant on agricultural production, agriculture plays a crucial role in the economy due to its significant contributions to employment, food security, non-oil exports, and foreign exchange earnings (Deylami & Joolaie, 2023). Additionally, the persistence of poverty in Iran has consistently influenced macro-level decision-making related to the agricultural sector. On the one hand, most workers in the agricultural sector are low-income rural residents, and on the other hand, agriculture provides food security for those working in this sector and others (Mousavi & Esmaeili, 2011). Therefore, agriculture holds a strategic role in ensuring food security for the country's growing population (Tahami Pour Zarandi *et al*., 2019). It is essential for farmers and policymakers to mitigate the adverse effects of common risks and optimize the utilization of the country's productive resources. Studies on risk programming models have analyzed farmers' decision-making processes and the impacts of risks, presenting optimal cropping patterns under varying levels of risk and comparing the results with linear programming models. A review of previous studies indicates that, while international research on risk models is more extensive, domestic studies in this field remain relatively limited.

The linear programming (LP) model is a mathematical method used to optimize a linear objective function—typically maximizing profit or minimizing cost—subject to a set of linear constraints representing resource limitations such as land, labor, water, or capital. Due to its clarity, computational efficiency, and versatility, LP has become one of the most widely adopted tools in agricultural planning and farm management (Singh *et al*., 2001). In the context of agriculture, LP models are especially useful for determining optimal cropping patterns by identifying the most efficient allocation of limited resources to maximize returns under assumed certainty.

However, one major limitation of conventional LP is its inability to incorporate risk and uncertainty, which are inherent features of agricultural production due to factors such as weather variability, market price fluctuations, pest outbreaks, and changing policy environments. To address this shortcoming, Hazell (1971) introduced the Minimization of Total Absolute Deviation (MOTAD) model, a risk programming approach that builds upon LP by incorporating income variability as a risk component. The MOTAD model retains the linear structure and computational advantages of LP while enabling risk-averse decision-making by minimizing the mean absolute deviation of income from its expected value. Unlike quadratic programming approaches—which can be mathematically complex and computationally demanding—MOTAD remains linear, making it suitable for practical application in large-scale farm models and regional agricultural planning. This feature has led to its widespread use in risk-sensitive agricultural decision-making, particularly in developing countries where farmers face substantial production and market uncertainties. By integrating both LP and MOTAD models, researchers and planners can compare risk-neutral and risk-aware scenarios, offering more comprehensive guidance for optimal farm planning that balances profitability with resilience.

Yu *et al*. (2022) used the MOTAD model to optimize input allocation for risk-exposed farming households in northern China, demonstrating that diversification significantly improves both risk management and productivity. Pyman (2021), using a quadratic programming model, found that while crop diversification in Malawi can reduce production and price risks, it may come at the cost of lower overall farm returns. Magreta *et al*. (2021) applied the Target MOTAD method to analyze smallholder maize farming in Malawi, revealing that farmers mitigate climatic risks through resource reallocation and crop diversification strategies. Negm and Abdullah (2021) evaluated cropping pattern risks using linear and nonlinear models, with MOTAD results showing that the risk-adjusted net return model outperformed the alternative by increasing net returns by 6.7%, optimizing water use, expanding cultivated areas, and enhancing self-sufficiency in strategic. Lu *et al*. (2020), using panel data and the MOTAD model, found that climate change—especially temperature shifts—significantly reduced crop yields in China, potentially decreasing cultivated area by 6%, and recommended a 15% reduction in total cultivated land with reallocation toward strategic crops for effective adaptation. Bahadori *et al*. (2019) optimized cropping patterns in Rey County using linear programming and multiple MOTAD-based risk models, revealing that while current resource use was inefficient, incorporating risk into the models showed a positive correlation between risk exposure and returns. Similarly, Bahadori and Hosseini (2018) used linear programming, quadratic programming, and MOTAD to determine optimal cropping patterns, finding that risk-based optimization led to increased cultivation of rainfed rice, wheat, and canola. However, under high-risk scenarios, the results aligned closely with those of linear programming. Both risk models confirmed a direct positive relationship between farm risk and program returns. A review of previous studies shows that most research on optimal cropping patterns has utilized deterministic programming models.

This study aims to evaluate the impact of production risk on the selection of optimal cropping patterns for irrigated crops in the Dehgolan Plain, using both linear programming and risk-based programming models.

Materials and Methods

The study focuses on the Dehgolan plain, located in the Kurdistan province of Iran. This region is characterized by its agricultural significance, with irrigated cropping systems being the primary source of livelihood for local farmers. The plain's climate and soil conditions make it an ideal case study for examining the impacts of risk on agricultural decision-making, particularly in terms of selecting optimal cropping patterns under various risk scenarios. Nevertheless, Dehgolan plain is one of the fertile regions of Kurdistan province, Iran, but it experiences inconsistent rainfall distribution and evaporation exceeding annual precipitation. This semi-humid, cold region is among the drier areas of Kurdistan, leading to significant variability in crop yields (Ghasabi *et al*., 2024). Selecting a cropping pattern that minimizes the adverse effects of these fluctuations is essential.

To determine the optimal cropping pattern, this study employs linear programming (LP) and risk-based models including the MOTAD and Target MOTAD models. The primary objective is to maximize farm profitability while accounting for the uncertainties inherent in agricultural production. LP model can be demonstrated as below:

$$Max \quad Z = \sum_{(J=1)}^{n} C_j X_j \qquad (1)$$

S.t:

$$\sum_{(J=1)}^{n} a_{ij} X_j \le b_j \qquad j = 1, 2, 3, ..., m \qquad (2)$$

$$X_j \ge 0 \qquad j = 1, 2, 3, ..., n \qquad (3)$$

In equation 1, Z represents the objective function, which maximizes the total gross income, C_j is the coefficient of the objective function (the predicted gross income for one unit of the jth farming activity), and X_j is the decision variable (the area allocated to the jth farming activity). Equation 2 expresses the resource availability or technical constraints a_{ij} are the technical coefficients (the amount of resource i used by one unit of activity j), b_i is the available quantity of resource i, and m represents the number of limiting resources. In this study, the technical constraints include agricultural land, water resources, labor, chemical fertilizers, pesticides, markets, and machinery. Equation 3 shows the non-negativity constraints of the variables, and n represents the number of activities.

On the other hand, quadratic programming is based on the idea that the utility function can be expressed in terms of the expected value (E) and variance (V). In this model, risk is estimated through the variance of income from various events (equation 4).

$$V = \sum_{j} \sum_{k} X_j X_k \sigma_{jk} \qquad (4)$$

X_j and X_k represent the levels of the jth and kth farm activities, respectively, while σ_{jk} denotes the variance-covariance matrix of the gross income between the jth and kth activities. When j=k, σ_{jk} represents the variance.

Hazell proposed the use of variance estimates based on the Mean Absolute Deviation (MAD) of the sample. If sample data and classical methods are used to estimate variances and covariances, the variance of income in the quadratic programming model is calculated as shown in equation 5 (Norton & Hazell, 1986):

$$\hat{V} = \sum_j \sum_k X_j X_k \left\{[1/T-1]\sum_{(T=1)}^{t} [C_{jt} - \bar{C}_j][C_{kt} - \bar{C}_k]\right\} \quad (5)$$

In this equation, t=1…T, T represents the sample observations, and C_{jt} is the gross income of the jth activity in the tth year, with the sample mean of gross income denoted by $\bar{C}_j$.

By summing over t and factoring, the estimated variance will be expressed as equation (6). (Norton & Hazell, 1986):

$$\hat{V} = (1/T-1)\sum_t \left\{\sum_j C_{jt}X_j - \sum_j \bar{C}_{jt}X_j\right\}^2 = (1/T-1)\sum_t [Y_t - \bar{y}]^2 \quad (6)$$

That is, the variance of farm income for a specific production plan can be expressed as an aggregated form of variances and covariances of each activity, or more simply, by calculating the farm income (Y_t) corresponding to each observation of the gross income of activities and estimating the variance of a single random variable. This transformation enables the use of the MAD estimator for the variance of Y. The MAD estimator is given by (Norton & Hazell, 1986):

In this equation, the term in brackets represents the sample MAD, and F is a fixed coefficient that relates the sample MAD to the population variance. Specifically, the relationship is given by $F = \frac{T\pi}{2(T-1)}$, where π is a mathematical constant (Norton & Hazell, 1986).

An important point regarding the MAD estimator is that if, in a quadratic programming model, the above relationship is substituted in the objective function instead of minimizing variance, the result can be a linear programming model.

The deviation of farm income from its mean in year t is represented as Z_t^+ if it is positive, and Z_t^- if it is negative (equation 7):

$$\sum_t (Z_t^+ + Z_t^-) = \sum_j C_{jt}X_j - \sum_j \bar{C}_j X_j \quad (7)$$

This equation measures the total absolute deviation in income for a given farm plan. Accordingly, the MAD estimator of variance is expressed as equation 8:

$$\hat{V} = F\left\{\left[\frac{1}{T}\right]\sum_j [Z_t^+ + Z_t^-]\right\}^2 \quad (8)$$

Since $\frac{F}{T^2}$ is a constant for a given farm plan, it can be divided by $\hat{V}$ to yield the equation 9:

$$W = \left(\frac{T^2}{F}\right)\hat{V} = \left\{\sum_t [Z_t^+ + Z_t^-]\right\}^2 \quad (9)$$

Moreover, since the ranking of farm plans is based on $w^{\frac{1}{2}}$, to rank the plans based on W, the square root of W can be calculated. In that case, the linear programming model formulated in equations 10 to 14 can be considered as a substitute for the quadratic programming model:

$$Min \quad W^{\frac{1}{2}} = \sum_{t=1}^{T} (Z_t^+ + Z_t^-) \quad (10)$$

S.t:

$$\sum_{j=1}^{n} (C_{jt} - \bar{C}_j)X_j - Z_t^+ + Z_t^- = 0 \qquad \forall t \quad (11)$$

$$\sum_{j=1}^{n} \bar{C}_j X_j = E \quad (12)$$

$$\sum_{j=1}^{n} a_{ij}X_j \le b_i \qquad \forall i \quad (13)$$

$$X_j, Z_t^+, Z_t^- \ge 0 \qquad \forall j, t \quad (14)$$

This above model can be solved using parametric linear programming to obtain the E-V efficient set of farm plans.

Since the total negative deviations of income from the mean $\sum_t Z_t^-$ must always equal the total positive deviations $\sum_t Z_t^+$, it is sufficient to minimize one of these sums and multiply the result by two to obtain $W^{\frac{1}{2}}$. Here, the negative deviations are chosen, and the compact

MOTAD model, considering the negative deviations, can be written as equation 15 to 19:

$$Min \quad 0.5W^{\frac{1}{2}} \cong \sum_{t\cong 1}^{T} Z_t^0 \qquad (15)$$

$$\sum_{j\cong 1}^{n} (C_{jt} \, 0 \, \bar{C}_j) X_j \, 0 \, Z_t^{;} \, . \, Z_t^0 \cong 0 \qquad (16) \quad \%t$$

$$\sum_{j\cong 1}^{n} \bar{C}_j X_j \cong E \qquad (17)$$

$$\sum_{j\cong 1}^{n} a_{ij} X_j \infty b_i \qquad (18) \quad \%i$$

$$X_j, Z_t^0 \propto 0 \qquad (19)$$

The data used in this study were collected through in-person visits to the Kurdistan Regional Water Company, the Kurdistan Agricultural Jihad Organization, and the National Water Demand System for six major crops grown in the Dehgolan Plain, including wheat, barley, potato, cucumber, alfalfa, and canola, over the agricultural years 2014 to 2023. These six selected crops account for more than 85% of the total cultivated area in the study area. It should be noted that Microsoft Excel Solver was used to estimate the models employed in this research.

Results and Discussion

Results of the Linear Programming Model

The total cultivated area for all crops in the studied plain is approximately 19,000 hectares. Wheat, with an area of 7,000 hectares (over 36% of the total), occupies the largest share of the cultivated land. The main factors driving the expansion of wheat cultivation in this region include government support (due to guaranteed purchase prices), lower water requirements, and resistance to adverse climatic conditions. Fig. 2 shows the average gross income, cultivated area, yield, and water consumption for the major crops in the Dehgolan plain. In the absence of resource constraints, the optimal solution of the model would lead to the sole production of cucumber, as each kilogram of cucumber generates a higher income.

The results of conventional linear programming model for studied area are presented in Table 1. According to the table, wheat and alfalfa hold the largest shares in the current cropping pattern. However, in the optimal pattern derived from linear programming (LP), crops with higher gross income per hectare are recommended, subject to the existing constraints.

The optimal cropping pattern for maximizing gross income in the Dehgolan plain prioritizes cucumber, alfalfa, and canola, while excluding wheat, barley, and potato due to their lower economic returns. Despite wheat and barley's lower water requirements and guaranteed market through government pricing, their reduced cultivation is economically justified but challenging for farmers to accept. The optimal scenario highlights an increase in cucumber and canola cultivation, with cucumber reaching its maximum production level, emphasizing its role in gross income enhancement. Conversely, potato cultivation is significantly reduced.

Table 1- The cultivated area of each product in the current and the optimal crop pattern of LP

Product	Current status (ha)	Optimum status (ha)	Amount of changes (ha)
Wheat	7000	0	-7000
Barley	1100	0	-1100
Cucumber	710	9493.82	8784
Potato	4260	0	-4260
Alfalfa	5400	5122.63	-277
Canola	518	4371.56	3854
Gross income (million Tomans)	753231.82	1764400.83	1011169.01

Source: Research Results

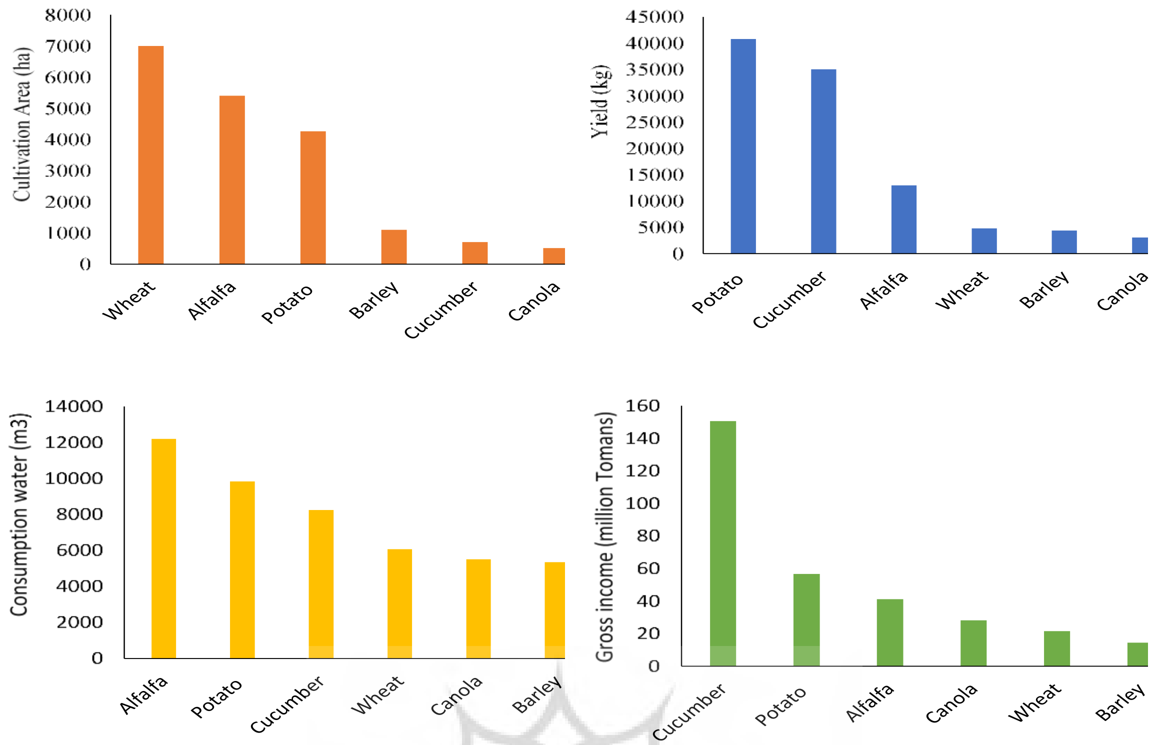

Figure 2- Cultivated area, yield, water use and gross income of each agricultural product

Maximizing gross income incorporates water-intensive crops with high returns, though this approach conflicts with the region's severe water scarcity. Expanding alfalfa cultivation is notable, offering both direct economic benefits and indirect advantages as a critical livestock feed, particularly given its rising market value. However, alfalfa's high-water demand poses challenges in a water-restricted plain.

The comparison between current and optimal patterns reveals inefficiencies in resource use, suggesting that income could be substantially improved under the optimal model. However, such patterns entail higher risks, making them better suited for risk-tolerant farmers. Ultimately, balancing economic gains with sustainable water resource management remains critical in this water-scarce region.

Risk Programming Models

To examine the effect of risk on the optimal cropping pattern, the income risk, which is influenced by two important parameters—price fluctuations and income fluctuations—was assessed. To achieve this objective, the variance-covariance matrix was first estimated, and then the objective function of a quadratic programming model was constructed to minimize the variance of gross income across activities. Technical constraints were incorporated into the model, which was then evaluated by varying the expected income parameter. Since the expected income level can be arbitrarily defined in the quadratic risk programming model, this study presents the optimal cropping patterns corresponding to eight different levels of expected income, as shown in Table 2. The results indicate that the cropping pattern responds to changes in the level of risk.

Table 2- The results of the Quadratic Programming Model

Plan	Expected income	Risk	Wheat	Barley	Cucumber	Potato	Alfalfa	Canola
1	1764401	1570263	0	0	9493.81	0	5122.63	4371.56
2	1760000	1517491	0	0	9493.81	0	5109.10	4366.61
3	1750000	1441616	0	0	9237.01	256.81	4939.54	4264.68
4	1740000	1311871	255.66	0	9176.72	317.09	4769.98	4058.77
5	1730000	1180683	527.15	0	9139.72	354.10	4600.42	4011.14
6	1720000	1050808	1098.64	0	9102.71	391.10	4430.86	3964.68
7	1710000	914203	1610.14	0	9065.71	428.11	4365.28	3500.30
8	1700000	777073	1861.63	100	9028.70	465.11	4141.42	3391.14

Source: Research Results

*Expected income and risk in millions of Tomans (10 Rials) and cultivated area of crops in hectares.

The first plan in Table 2 corresponds to the risk-neutral solution or the maximization of income, which is the preferred pattern for a farmer who aims to maximize income without considering risk. In fact, the results of plan 1 at the highest risk level are the same as those obtained from linear programming.

Moving from plan 1 to plan 8, the expected income decreases, and so does the risk level. The area under wheat cultivation increases as risk decreases. Given that wheat is the raw material for bread and one of the country's strategic crops, its production has always been a priority for agricultural policymakers. The government has implemented guaranteed purchase policies to support farmers and stabilize their incomes. The increase in guaranteed prices and the implementation of wheat-centered policies have reduced the production risk of this crop. Therefore, actions must be taken to ensure food security for the growing population. The area under cucumber, alfalfa and canola cultivation in the linear programming model has decreased compared to the current situation.

Comparison of MOTAD and Quadratic Programming Models

The comparison of the optimal values derived from the MOTAD model and the Quadratic Programming model indicates that both approaches exhibit similar behavioral patterns. Fig. 3 presents the efficient frontier, depicting the relationship between income and risk. The chart clearly demonstrates that as the level of risk increases, the expected income rises correspondingly, eventually attaining the maximum achievable income as determined by linear programming solutions. This observed relationship underscores the inherent trade-off between income and risk within these modeling frameworks, providing valuable insights into the decision-making process under uncertainty. By quantifying this trade-off, both models offer robust tools for optimizing resource allocation while considering varying levels of risk tolerance.

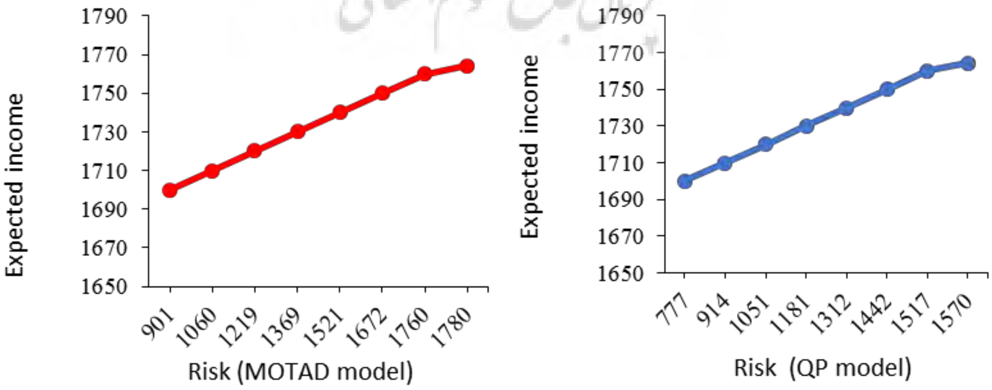

Figure 3- The efficient frontier of expected income and risk (billion Tomans)

At the risk level of 1,780,133 million Tomans, the highest risk level, the cropping pattern only includes cucumber, alfalfa, and canola, which have higher gross income, and with a decrease in expected income and reaching a risk level of 1,060,285 million Tomans, the area allocated to these crops decreases. In other words, as expected income increases, the cropping pattern shifts toward replacing products with higher gross income. The results from the MOTAD model also confirm that with a reduction in risk, crops such as wheat, barley, and potatoes become more attractive to farmers. Therefore, when a farmer seeks a more secure behavior and reduces risk, they must accept lower incomes.

The risk estimated by the MOTAD model is higher than that of the quadratic programming model. This discrepancy arises because the mean absolute deviation estimation used in the MOTAD model is less precise compared to the traditional nonlinear estimation employed in quadratic programming. A key advantage of the MOTAD model, however, is its compatibility with linear programming (LP) solvers. This feature allows for the inclusion of more detailed production and marketing strategies when formulating the model.

Conclusion

This study aimed to develop an optimal cropping pattern for the Dehgolan plain, Iran, under both risk-free and risk-based scenarios. The results from the risk-free scenario revealed inefficiencies in the current cropping pattern. Since price fluctuations of products and inputs (price risk) and yield variability (yield risk) contribute to income volatility, this study employed income variability as a risk indicator.

A key finding is that risk-based models demonstrate a direct relationship between risk and gross income. For crops like wheat, barley, and potatoes, incorporating risk into the model increases the cultivated area of wheat compared to linear programming outcomes, aligning with governmental strategic objectives and national food security goals. At lower income levels, potatoes emerge as a preferred choice among horticultural crops due to favorable market conditions.

Non-strategic crops such as cucumbers, which face limited governmental intervention in cultivation and market development, yield significantly higher gross income. This profitability offsets the higher risks associated with these crops. Additionally, the low cost of water in the Dehgolan plain compared to its shadow price (Ghasabi *et al*., 2024) results in a larger share of water-intensive crops in the optimal pattern. To address water scarcity, the study recommends shifting irrigated wheat cultivation to rainfed practices and implementing effective water storage techniques to enhance spring crop yields and mitigate warm-season water shortages.

While government interventions reduce production risks, they distort crop selection. A reduced governmental role in agricultural production and a reevaluation of policies are recommended. Farmers should prioritize cultivating low-risk crops to secure stable income under uncertain conditions. Multi-cropping systems and crop rotation are effective strategies to mitigate risk and reduce income fluctuations, addressing crop-specific pests, diseases, and price volatility. Government policies should focus on maximizing farmers' income while ensuring stability and sustainability in production.

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تعیین الگوی بهینه کشت با تأکید بر تعامل ریسک و سودآوری: اراضی کشاورزی دشت دهگلان

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چکیده

ریسک یکی از عوامل مهم در فعالیت‌های کشاورزی است و نادیده گرفتن آن می‌تواند به تخصیص ناکارآمد منابع در این بخش منجر شود. نظریه‌ها و مدل‌های مختلف برنامه‌ریزی ریاضی برای کمک به تصمیم‌گیری در مدیریت الگوی کشت در شرایط ریسکی توسعه یافته‌اند. هدف این مطالعه تعیین الگوی بهینه کشت در دشت دهگلان با استفاده از داده‌های دوره زمانی ۱۳۹۳ تا ۱۴۰۲ بود. در این راستا، از مدل برنامه‌ریزی خطی برای حداکثرسازی درآمد ناخالص کشاورزان استفاده شد و نتایج آن با مدل برنامه‌ریزی درجه دوم و مدل حداقل‌سازی انحراف مطلق کل (MOTAD) که هر دو به کاهش ریسک توجه دارند، مقایسه گردید. یافته‌ها نشان داد که عامل ریسک می‌تواند به‌طور معناداری الگوی کشت را تغییر دهد؛ در بالاترین سطح ریسک، الگوی کشتِ مبتنی بر حداکثرسازی سود با استفاده ار برنامه‌ریزی خطی ساده تنها شامل خیار، یونجه و کلزا بود که بیانگر ترجیح محصولات با درآمد ناخالص بالاتر، علی‌رغم نیاز بیشتر به منابع آبی، است. در شرایط در نظر گرفتن ریسک در مدل‌های برنامه‌ریزی ریسکی، سطح زیر کشت گندم و جو نسبت به حالت بدون در نظر گرفتن ریسک افزایش یافت که نشان‌دهنده گرایش به سوی محصولات با نیاز آبی کمتر باوجود کاهش درآمد ناخالص است. این نتایج بر ضرورت برقراری توازن میان حداکثرسازی درآمد و مدیریت ریسک به‌منظور دستیابی به الگوی کشت پایدارتر تأکید دارد.

واژه‌های کلیدی: الگوی کشت، مدل ریسک، مدل برنامه‌ریزی خطی، مدل برنامه‌ریزی درجه دوم، مدل MOTAD

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