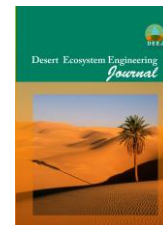




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## Dynamic Simulation of the Impact of Profitability Policies on Capital Outflow in Zanjan Province

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### Extended Abstract

**Introduction:** Water resources are critical yet finite, supplying a vast number of consumers. Their management, therefore, demands meticulous planning and heightened sensitivity. As human life and ecological stability depend on the reliable availability of these resources in specific quantities, locations, and times, strategic and foresighted approaches to water storage and allocation are paramount. The decisions made by policymakers and managers in this realm—whether for the short or long term—carry profound consequences, ranging from detrimental to highly beneficial. In a society characterized by one-sided and predominantly exploitative practices, the emergence of water-related disputes and challenges is not merely a possibility but an inevitability.

This study investigates this critical balance through a dynamic simulation. We defined 16 distinct scenarios for the agricultural sector to model the impact of two key policy levers—profitability incentives and water supply restrictions—on the outflow of water resources from Zanjan Province. The simulation was conducted on a monthly scale, covering a 30-year period from 1993 to 2023, to capture both seasonal variations and long-term trends.

**Materials and Methods:** The methodology of this study is grounded in System Dynamics (SD), a simulation approach specifically designed for modeling complex, non-linear, and multi-variable systems. Unlike static models, SD captures the dynamic interplay of variables over time, making it an effective tool for supporting complex decision-making in resource management.

Following the collection and verification of historical statistics and data, a system dynamics model was developed to simulate the effects of two key policy interventions—profitability incentives and water supply restrictions—on agricultural planning. The model explicitly represents how these policies influence the selection of cultivated areas for two key crops, wheat and alfalfa, and subsequently impact the hydrological balance of the province, measured as the ratio of water outflow to inflow.

The simulation was built upon a set of interconnected equations that dynamically determine crop yield and, consequently, the allocation of cultivated area through feedback mechanisms. These relationships were encoded in detail within the model structure. The statistical period (1993–2023) was divided into two phases to ensure model robustness: Calibration and Validation: The first segment of the data was used to calibrate the model parameters and verify its efficiency in replicating observed historical behavior. Policy Testing: The second segment was used to test and evaluate the outcomes of the 16 predefined policy scenarios. Finally, for each of the 16 scenarios, the model simulated output values for key variables, including total cultivated area, crop yield, economic benefit, and the critical water balance indicator—the ratio of the province's total water outflow to inflow.

**Results:** Following the simulation of the two policy types and their associated scenarios, key outcomes for cultivation patterns, economic benefit, and water balance were observed.

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**Impact of Profitability Policy (Price Increase):** Cultivated Area: A doubling of the selling price for a crop led to a significant expansion in its cultivated area, with a weaker cross-effect on the competing crop. Wheat: Cultivated area increased by an average of 43% (Note: The original text had a discrepancy between average (43%) and maximum (40%). This version uses the average. Please verify your data). Alfalfa: Cultivated area increased by an average of 37%. Crop Yield (Performance): Contrary to area expansion, crop yields decreased under the profitability policy. Wheat: Yield decreased by an average of 20%. Alfalfa: Yield decreased by an average of 11% when its price was doubled. Economic and Hydrological Outcomes: When prices for both crops were doubled, the model resulted in: A 71% increase in total profit. A 48% increase in the total cultivated area of the province. A 30% decrease in overall crop performance. A 69% decrease in the province's water outflow ratio.

**Impact of Water Supply Limitation Policy:** Cultivated Area: Imposing water supply limitations significantly reduced cultivation. When applied to both crops, the wheat cultivation area decreased by an average of 71% and the total provincial cultivated area decreased by an average of 68%. A single-crop limitation proved ineffective. For instance, limiting only wheat led to a 75% decrease in wheat area but induced competitive cultivation of alfalfa, making it an unsuitable strategy for water conservation. The same dynamic held true for alfalfa. Crop Yield: Under supply limitations, yields increased, likely due to a concentration of limited water on a smaller area. Wheat yield increased by 42%. Alfalfa yield increased by 25%. Economic and Hydrological Outcomes: Compared to the baseline, the supply limitation policy resulted in: A 44% decrease in agricultural benefit. A 23% increase in the province's water outflow.

**Policy Comparison and Synthesis** A direct comparison between the two policies reveals a clear trade-off: The profitability policy boosted economic returns (+71% benefit) and improved water retention (-69% outflow). The supply limitation policy reduced economic output (-49% benefit) and worsened the water outflow situation (+76% outflow). The scenario analysis further contextualizes farmer behavior. The maximum simulated cultivated area (141,979 hectares in the "wh Bnf & al Bnf 2-2" scenario) is lower than the actual recorded area of 161,544 hectares. This suggests that real-world farmers are operating at a profitability level equivalent to 2.3 times the base benefit, which aligns with a significant 84% decrease in the outflow ratio. Consequently, implementing the profitability policy would result in a relative outflow of just 16% of the baseline conditions.

**Conclusion and Discussion:** The simulation results underscore a critical dilemma: while a profitability policy aligns with farmer incentives, its long-term implementation in the face of finite water resources risks causing irreversible damage to the region's hydrological system. The model clearly demonstrates that a profitability policy, which is naturally preferred by farmers, leads to a dramatic reduction in provincial water outflow—exceeding 80%. This occurs because farmers, operating under the assumption of abundant water, prioritize profit maximization by expanding their cultivated area. This expansion compensates for the associated decrease in crop yield, making the strategy financially rational from an individual perspective, but hydrologically detrimental at a systemic level. Conversely, a policy of mandatory water supply limitation forces a reduction in the total cultivated area. While this may seem restrictive, it induces a more efficient and sustainable agricultural model. The simulation confirms that this policy leads to: Increased Crop Yield: A concentration of limited water resources on a smaller area enhances productivity per unit of land. Reasonable Economic Benefit: Farmers can maintain viable operations through higher efficiency rather than sheer scale. Significant Water Conservation: It directly curbs the irrational withdrawal and waste of water, preserving the resource base. In essence, by forgoing the short-term appeal of the profitability policy and implementing managed supply constraints, farmers are guided toward a more sustainable equilibrium. This approach secures better yields through improved management and prevents the over-exploitation that threatens the province's water future. The findings lead to an unequivocal recommendation for policymakers: maintaining the status quo is not an option. Without a decisive shift away from purely profit-driven water allocation toward an integrated strategy that balances economic incentives with physical supply limits, the cumulative damage to Zanzan Province's water resources will be severe and irreversible.

**Keywords:** Benefit, Simulation, Supply, Water Resource Limitations.