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Exploring the Financial Viability of Greenhouse Tomato Growers under Climate Change-Induced Multiple Stress †

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Abstract: In this study, we implement a linear programming farm model to explore the impact of climate change-induced multiple stress on the financial viability of greenhouse tomato growers. The main results are that new technologies and innovations can compensate growers for any profit loss associated with climate change. However, if the cost of adaptation is high enough, then its financial benefits are constrained by how efficient these innovations are in terms of productivity. We did not observe significant differences in input use between 'innovative' and 'conventional' production, and the yield under the adoption of new technologies was higher compared to 'conventional' production.

Keywords: linear programming; farm model; greenhouse tomato; climate change

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1. Introduction

The relationship between climate change and agriculture has a long tradition in the scholarly literature, e.g., [1–3]. Additionally, during the last couple of years, the results of climate change, like high temperature and drought, have significantly affected the financial viability of producers [4,5]. To this end, many scholars call for the adoption of new technologies and innovations both as a mean towards environmental improvements but also as a mean towards producers' (or growers') financial stability [6].

Furthermore, mathematical programming farm models have been excessively used to understand farmers' (or growers) production choices, e.g., [7,8]. Among them, linear programming farm models (thereafter, LP-FM) have been used to analyze production plans in the agricultural sector, e.g., [9].

In this study, we are interested in the impact of climate change-induced multiple stress, namely increased heat, draught, and salinity. Particularly, we utilize a simple LP-FM to explore two vital questions. First, how climate change-induced multiple stress will affect the financial viability of Mediterranean greenhouse tomato growers. Second, how the adoption of new technologies and innovations can compensate growers for any profit losses due to climate change-induced multiple stress.

2. Materials and Methods

Our methodology can be divided into the following steps. First, we interviewed 22 greenhouse tomato growers (both in-person and online), where approximately 72.72% of the responders were located in Crete, whereas the remaining ones were located in the region of Peloponnese. The rationale of using Crete as the case study is because Crete, followed by Peloponnese, is the leading region in greenhouse vegetable production in Greece [10].

The second step was to design an LP-FM. Specifically, we assumed a representative greenhouse beef tomato grower whose objective was to choose their annual deci-hectare amount of fertilizers, chemical substances for pest management, the number of plants, and water consumption, such that her annual per deci-hectare gross margin was to be maximized, subject to both technical and financial constraints. The choice of these inputs (decision variables) was selected based on the answers given by the interviewed growers. Also, the upper and lower limits of the constraints were determined by the answers given by the growers.

The third step was to estimate the production coefficients. To do so, an approximated linear production function was used. The result of this estimation was used afterwards to the LP-FM to determine the optimal input use under the 'current situation' (or business-as-usual scenario). These values serve as a comparison between the current situation and our hypothetical scenarios.

The final step was to implement three hypothetical scenarios on the impact of climate change-induced multiple stress on both the production and financial efficiency of a 'conventional' production system: a low, a moderate, and a high impact scenario. In each of these three scenarios, further assumptions were made on the production and financial efficiency of a production system that utilizes new technologies and innovations that exhibit higher tolerance to climate change compared to 'conventional' one.

3. Results

The main results of our analysis can be summarized as follows. First, the adoption of new technologies and innovations can compensate greenhouse tomato growers, even in cases where the production efficiency of these technologies and innovations is close to the 'conventional' one.

Second, cost considerations might be important, especially when the production efficiency of these new technologies and innovations is close to the 'conventional' one.

Third, we did not find any significant difference in input use between 'conventional' production and production that utilizes new technologies and innovations. However, if the grower is constrained to produce a certain level of yield, then the adoption of new technologies and innovations that are more tolerant to climate change is likely to entail environmental improvements in terms of less input use, as well.

Finally, the yield been the produced crops in the latter cases exceeds that under the former one in almost every simulation. This result highlights potential social benefits because the adoption of new technologies and innovations can 'secure' a potential food supply under severe climate change conditions.

4. Conclusions

In this article, we tried to explore whether the adoption of new technologies and innovations can compensate greenhouse tomato growers for their profit losses due to climate change-induced multiple stress. The answer is yes, but the cost of adaptation should also be considered. Importantly, our analysis highlights that the adoption of new technologies and innovations can cover any excess demands for tomato. Thus, it might be down to policymakers to incentivize the transition to sustainable agriculture, especially if 'securing' food supply is their primal objective.

However, some limitations should be spelled out. First, our sample size is small, which may reduce the robustness of our estimated coefficients. Secondly, we gathered information by performing in-person interviews and by email. In most cases, growers did not keep a detail logbook regarding their production activities and the costs associated with them. Thus, our data are likely to exhibit some level of noise. The implication of these two limitations is that we exhibit high p-values, meaning that the estimated coefficients should be interpreted with caution. Finally, we focused our analysis on the identification of only four inputs. However, factors like labor, energy, and electricity consumption could be important as well. Thus, an extension of this study is left as an area for future research.

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Data Availability Statement: The raw data can be found at https://doi.org/10.5281/zenodo.8325730 (accessed on 7 September 2023). Also, we used a slightly modified version of the GAMS code that can be found at https://doi.org/10.5281/zenodo.7024627 (accessed on 26 August 2022).

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