Evaluating the Benefits of Season-Specific Irrigation Strategy Adaptation

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Received: 10-Mar-2023, Manuscript No. jcwf-23-23686; **Editor assigned:** 12-Mar-2023, Pre QC No. jcwf-23-23686 (PQ); **Reviewed:** 14-Mar-2023, QC No. jcwf-23-23686 (Q); **Revised:** 21-Mar-2023, Manuscript No. jcwf-23-23686 (R); **Published:** 29-Mar-2023, DOI: 10.35248/2332-2594.22.11(3).1-2

Abstract

An often suggested approach to increase agricultural water production and reduce water scarcity is to optimize irrigation timing. The benefits of adaptive irrigation scheduling in comparison to fixed heuristics frequently employed by farmers are currently unknown, as is the best way to optimize and adjust irrigation decisions under weather and climatic unpredictability. A fixed irrigation plans that maximizes average revenues across a variety of possible weather events but is not altered year to year has an advantage over in-season irrigation strategy modification.

Keywords: Irrigation scheduling • Adaptive irrigation • AquaCrop-OSPy • AquaCropOptimization

Introduction

Policymakers across the globe are concerned about the mounting demands on the world's freshwater resources. Many regions are looking at measures to reduce agricultural water consumption in order to lessen conflicts over water and existing and future water scarcities, as irrigation accounts for about 70% of this global freshwater use. A focus on increasing agricultural water productivity (i.e., producing more crop output per unit of water input or consumption) is necessary to reduce or stabilize agricultural water demands given the concurrent need to increase food production to meet the needs of growing populations and their changing dietary preferences [1]. The use of explicit governmental constraints on abstractions, such as quotas, and initiatives to encourage increased water use efficiency and production throughout the growing season are some methods for achieving this goal. There is a substantial body of research that focuses on creating the best irrigation scheduling policies and procedures to allow farmers to maximize income or water production. As farmers have, at most, only partial foresight of weather conditions in the forthcoming growing season, it is difficult to establish irrigation management systems that are optimal across all possible weather scenarios [2]. The optimization of a single irrigation management method that maximizes the average profit over a variety of probable weather outcomes, such as those seen in a historical record, is a typical strategy in research and practice to overcome this uncertainty. As an alternative, other research have concentrated on choosing one 'average' year from a group of years (for example, in terms of total rainfall), and then optimizing irrigation management procedures for that particular average year [3]. Finding ways to modify typical irrigation tactics during the season as knowledge of the weather in a particular year grows would be one potential way to increase productivity and profitability of agricultural water use. In this regard, a number of studies have employed adaptive simulation-optimization frameworks to assess possible gains from modifying irrigation plans intra-seasonally in response to weather projections, coming to the conclusion that such strategies can result in considerable increases in producer profitability [4]. Researchers also used an adaptive simulation-optimization framework to assess the advantages of in-season re-optimization of irrigation decision rules, and the results showed that this method produced irrigation schedules that were nearly as effective as those that would be possible with perfect seasonal weather foresight. The disadvantages of adaptive irrigation techniques compared to fixed irrigation heuristics, which are frequently employed by farmers and have been extensively explored by researchers, are neither evaluated nor quantified in these studies. Because of this, these studies don't offer enough information regarding the potential advantages and disadvantages of adaptive irrigation scheduling, including possible dangers from maladaptation [5]. Improved agricultural water management decisions require a better understanding of these trade-offs, especially in light of the significant data requirements and expenditures that adaptive scheduling may involve in comparison to the use of fixed or average irrigation rules. Re-optimizing irrigation schedules, for instance, might necessitate more information about the crop's current condition (such as rooting depth, plant height, and leaf-area index), which could be expensive to gather in addition to the time and resources needed to set up and implement optimization techniques during the season [6].

Optimising irrigation techniques seasonally

Closing the gap between fixed (the same management strategy used every year) and potential (perfect adjustment to each year's weather) management techniques is the aim of adaptive intra-seasonal irrigation scheduling. We establish an adaptive simulation-optimization framework to evaluate the benefits of changing irrigation tactics seasonally. The irrigation strategy is re-optimized from this starting point in the framework when the simulation is interrupted at various periods during the season. The weather up to this point is known for sure because it has previously been seen by the farmer, and predictions for the rest of the season are made based on the entire ensemble of previous weather years [7].

Differences between fixed and potential strategies

The differential evolution optimization technique was employed in the first portion of the analysis to identify a set of soil-moisture thresholds that maximized average profits over 37 climate years; this set of thresholds is referred to as the fixed strategy. Researchers also computed the conceivable strategies (i.e., profit-maximizing techniques for each distinct year) to provide an estimated upper limit for what earnings could be realized with perfect seasonal information [8].

The importance of season-specific adaptability

The fixed irrigation strategy (set of soil-moisture thresholds) was re-optimized at the beginning of each growth stage after the re-optimization technique to determine the utility of re-optimizing irrigation strategies within the season. In comparison to the fixed strategy, which doesn't adjust irrigation management regulations during the growing season, our investigation indicated an average $4.87 ha1 gain in earnings with adaptation, or a 1% improvement in average profit. We also note, nevertheless, that growth-stage adaptation also led to an increase in the minimum earnings of 106% and a reduction in the profits' standard deviation of 2.95%. Due to in-season adaptation, the soil-moisture thresholds were raised during the drought year of 2012, which led to more irrigation events and a significant increase in minimum profits. In comparison to the fixed strategy, which doesn't adjust irrigation management regulations during the growing season, our investigation indicated an average $4.87 ha1 gain in earnings with adaptation, or a 1% improvement in average profit. We also note, nevertheless, that growth-stage adaptation also led to an increase in the minimum earnings of 106% and a reduction in the profits' standard deviation of 2.95%. Due to in-season adaptation, the soil-moisture thresholds were raised during the drought year of 2012, which led to more irrigation events and a significant increase in minimum profits [9, 10].

Conclusion

The improvement of agricultural water productivity in water-scarce places around the world has been widely advocated through the optimisation of irrigation scheduling, particularly by in-season alteration of scheduling rules based on weather forecasts and other data. This article's goal was to evaluate the value of adjusting irrigation strategies during the season and how this value is impacted by common information constraints (like in-season weather) and management constraints (like abstraction restrictions) that farmers encounter but have not been sufficiently taken into account in prior research. To do this, we connected a crop model to our re-optimization framework. When re-optimization is backed by in-season projections, the effects of risk reduction are greatest. Adaptive scheduling also substantially reduced risks of crop loss or failure events (for example, during exceptional drought years like 2012 in our research area). Our data revealed that when seasonal water limitations were added, the variability in adaption value across years drastically increased for excessively severe water quotas.

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Cite this article: Dubey, P. Evaluating the Benefits of Season-Specific Irrigation Strategy Adaptation. J Climatol Weath Forecast. 2023, 11 (3), 001-002