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# Modes of greenhouse water savings

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## Abstract

As the global population rapidly increases, the need for bolstering worldwide food security is paramount. Scaling up food production to meet the needs of the growing population will strain the world's water supplies, which are already threatened by climate change. Agricultural technologies such as greenhouses are effective in conserving water while simultaneously enhancing agricultural productivity. Quantifying and understanding the modes through which greenhouses reduce water usage can help farmers make strategic changes to their horticultural practices so as to increase crop yields while conserving water. This article describes and quantifies the four primary modes of greenhouse water savings, and provides a simplified model for calculating the long-term water savings potential of a greenhouse using easily measurable data.

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*Keywords:* Greenhouse; Horticulture; Water savings; Water smart agriculture; Sustainable Intensification

## 1. Introduction

In the year 2014, it was estimated that 793 million people in the world suffered from chronic hunger [1]. Feeding the world's population and improving food security represents one of today's greatest challenges. The rapidly growing population of the Earth—which is expected to reach 9.2 billion by 2050 [2] requires enhanced agricultural innovation to scale up production with limited resources. The world's water resources will be strained with the population growth, as water demand is expected to rise 55% by 2050 [2]. The primary culprit of this increase in water demand is the agricultural industry, which accounts for 70% of all fresh water usage [2].These water demand projections do not account for climate change, which will continue to result in unpredictable weather patterns that threaten the world's water reserves. Climate scientists expect that in the coming decades, long droughts punctuated by heavy rainfall will become the normal in regions like Sub-Saharan Africa, where agriculture is primarily rain-fed and directly subject to climate variability [3].

To meet the demands of the rapidly growing population, farmers have been turning to agricultural technologies to scale up production and improve yields. Greenhouses, for instance, offer a stable alternative to traditional open-air farming practices, as they allow for consistent, year-round crop growth, all while reducing water usage. The protective covering on a greenhouse entraps moisture, diffuses solar radiation, and blocks wind, maintaining a controlled microclimate that protects crops from the variability of open-air conditions. Greenhouse crops, therefore, can be produced more predictably, in greater quantity, and with less water, than crops grown in the open air. This greenhouse microclimate also protects crops from climate change stressors,

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namely increased climate variability and fluctuations in precipitation rates. Greenhouses are particularly useful to farmers in regions like Sub-Saharan Africa, where the climate is characterized by distinct wet and dry seasons, as long bouts of drought and heavy rain are both detrimental to crop production [3].

While there is consensus that greenhouses do conserve water, the exact amount of water savings is difficult to quantify. The main source of greenhouse water savings comes from reduced evapotranspiration rates inside of the greenhouse, as previous works have concluded [4-6], but greenhouses do offer other modes of water savings: namely opportunities for drip irrigation, closer crop spacing, and abbreviated crop cycles. Previous efforts at quantifying water savings have focused solely on evapotranspiration, holding parameters like crop spacing and crop cycle length constant [4, 5]. This work contends that in order to obtain a more holistic water savings quantification, four distinct parameters must be considered: reduced evapotranspiration, closer crop spacing, drip irrigation, and a reduced crop cycle time. Herein, the four primary modes of greenhouse water savings are described and discussed, and a procedure for quantifying them is presented. The confounding variables inherent to these water savings modes are also discussed in relation to their limiting the precision of this model. This model of quantifying greenhouse water savings incorporates all aspects of a greenhouse's water savings ability, and informs greenhouse farmers on ways to conserve water while simultaneously demonstrating their effectiveness as water-saving technologies.

## 2. Determining open-air water intake

The water savings of a greenhouse are calculated with reference to open-air crop water requirements. These open-air crop water requirements are calculated from a simple procedure designed by the FAO that uses data from Tables 2 and 3 in Chapter 2 of their Irrigation Water Management training manual [7]. From this open-air water intake, the four modes of greenhouse water savings are factored in to yield the total water usage in a greenhouse. This figure can then be compared to the irrigation requirements for open-air crops—as depicted in Figure 2—to obtain the percentage of water that a greenhouse can save. Table 2 lists the average water intake of standard grass in different climatic regions. Table 3 then applies the standard water intake of grass and compares it to the water intake of other crops as an additional percentage of standard grass' water intake. The open-air water requirement calculated from these two tables is designated as the dry open-air water intake because it intentionally neglects precipitation that the crops would receive. Precipitation is neglected because the dry open-air requirement is used only as a reference to calculate water savings in the greenhouse, where rainfall is negligible due to the plastic or glass covering.

Rainfall is factored into the open-air water usage by simply subtracting the effective daily precipitation (mm/day) from the dry open-air water usage (Figure 1). The effective daily precipitation is an approximation of the amount of water that infiltrates a plant's root zone and is not lost to the surrounding soil or through runoff [7]. Table 3 lists the effective daily rainfall for each month for Maputo, Mozambique as an example that will be applied later in section 5 of this article. The average rainfall data was obtained from the BBC Weather service, and monthly effective rainfall was calculated from the guidelines in the FAO's Irrigation Water Management [7]. The FAO recommends effective rainfall as a metric for determining irrigation requirement for a particular crop. This irrigation requirement indicates a crop's water requirement while accounting for precipitation. This value is useful in comparing greenhouse water usage to true open-air water usage.

Fig 1. The irrigation requirement of a particular crop is determined by factoring in average daily rainfall to its daily open-air water usage. Adapted from FAO Irrigation Water Management Training Manual [7].

Table 1. Effective rainfall for Maputo, Mozambique. Data acquired from BBC Weather service. Table adapted from FAO Irrigation Water Management Training Manual [7]

| Month | Average Monthly Rainfall | Effective Monthly Rainfall | Effective Daily Rainfall |
|---|---|---|---|
| Jan | 130 | 79 | 2.55 |
| Feb | 125 | 75 | 2.68 |
| Mar | 125 | 75 | 2.42 |
| Apr | 53 | 21.8 | 0.73 |
| May | 28 | 6.8 | 0.22 |
| Jun | 20 | 2 | 0.07 |
| Jul | 13 | 0.6 | 0.02 |
| Aug | 13 | 0.6 | 0.02 |
| Sep | 28 | 6.8 | 0.23 |
| Oct | 48 | 18.8 | 0.61 |
| Nov | 81 | 39.8 | 1.33 |
| Dec | 97 | 52.6 | 1.7 |