Is Irrigation Real or Am I Imagining It?[*/]

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Abstract

Irrigation is an ancient practice of applying water to crops and/or plants to sustain their life so they can be productive for their intended purpose. Through the years and into today's literature there are many terms such as "artificial irrigation" and "supplemental irrigation." We know irrigation is real, not artificial! We know ALL irrigation supplements either precipitation (or just rainfall) resources, ground water uptake by crops, or existing soil water resources. Other terms such as "limited irrigation" and "deficit irrigation" emerged in the 1960s to 1970s, while more recently newer terms like "partial root zone drying (PRZD)" and "regulated deficit irrigation (RDI)" have emerged. We propose that "artificial" not be used to describe irrigation. We recommend that "deficit irrigation" should be the preferred term rather than "limited irrigation." We describe "regulated deficit irrigation" and illustrated clearly its difference from "deficit irrigation." We describe "partial root zone drying" as an irrigation management strategy, but we believe PRZD will be effective mainly in improving crop quality of tree or vine crops. It is important that irrigation literature utilize "correct" terminology to describe current technologies.

Keywords: terminology, deficits, water potential, irrigation scheduling

Introduction

Irrigation is an ancient practice mentioned in the Bible, early Egyptian writings, and likely predates the birth of Christ as practiced in Mexico and Central America. Several terms are ingrained into irrigation literature that are ambiguous or unnecessary while other newer terms are often misused or misunderstood. This brief article discusses several of these terms in the current irrigation technology context.

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Artificial Irrigation

The term "artificial irrigation" permeates irrigation literature (e.g., Eternal Egypt, 2005; DeJonge and Kaleita, 2006; Zelles et al., 1987). For anyone that has donned irrigation boots, worked a shovel, set siphon tubes, moved pipelines, etc., there is little about irrigation, especially the labor, that is "artificial." Yet, the term remains in relatively wide use today. It likely implies that sprinkler irrigation is like "artificial rain" instead of the term artificial irrigation used in most cases today. Nevertheless, it is a term that is unclear and confusing.

"Artificial" irrigation is in the language of the U.S. Statutes (U.S. Statute, 1877) that formed the basis for westward expansion of the U.S. to populate the land in 65 ha (160 ac) parcels in the western U.S. territories (that eventually became states) and thus rendered the land more productive and habitable. Even more recently, the U.S. EPA (Greening REPA, 2007) used the language "**Extensive Garden:** Extensive gardens have thinner soil depths and require less management and less structural support than intensive gardens. They do not require *artificial irrigation* {emphasis added}. Plants chosen for these gardens are low-maintenance, hardy species that do not have demanding habitat requirements. The goal of an extensive planting design is to have a self-sustaining plant community." It was used before the U.S. Supreme Court (1905) in Lee et al. v. Nash "That said land of plaintiff above described is arid land and will not produce without *artificial irrigation* {emphasis added}, but that, with artificial irrigation, the same will produce abundantly of grain, vegetables, fruits, and hay."

A Google (internet) search of the term "artificial irrigation" produced 38,000 hits. Clearly, "artificial irrigation" is simply irrigation. The Webster's New Collegiate Dictionary (Webster's NCD, 1980) defines "artificial" as "1, humanly contrived often on a natural model: man-made; 2, having existence in legal, economic, or political theory; 3, artful, cunning; 4a, feigned, assumed; 4b, lacking in natural quality; 4c, imitation, sham; 5, based on differential morphological characters not necessarily indicative of natural relationships." One could argue that 1, 2, and 5 might fit appropriately as irrigation is designed, constructed, and operated by humans, at least the hardware/software; but irrigation is certainly genuine and not an imitation in terms of 3 or 4, although in some eyes irrigation is certainly artful! We argue that the adjective, "artificial", adds marginally in describing irrigation. In fact, it likely detracts from the term "irrigation."

Supplemental Irrigation

Equally permeating irrigation literature is the term "supplemental irrigation." A Google (internet) search on this term reported 117,000 hits. The very nature of irrigation is to "supplement" the crop/plant water supply to achieve economic production. Clearly, in arid regions, little growing season rainfall occurs so irrigation supplies almost all crops water requirement with some additional water sources coming from ground water or harvested runoff (Oweis et al., 1999; Oweis and Hachum, 2006) or residual soil water. In more semi-arid regions, Oweis (1997) proposed adding small, but varying amounts of irrigation to traditionally dryland crops growing mainly on winter or pre-season stored soil water to improve crop yields and water productivity. Although the concept certainly has merit, we question its economic feasibility in regions to "spread" relatively small amounts of water. In addition, the on-farm or infrastructure costs must be recaptured leading one to favor a more fully irrigated system that might be more sustainable. It is widely known that supplying even rather small irrigation amounts (~80-150 mm) at critical crop growth stages can dramatically improve crop yields and thus water productivity, yet the logistical protocols to perform this task may be impractical. Hence, we offer that all irrigation is "supplemental" in its basic sense although there are wide variations in the need, amount, and timing for the "supplemental" irrigation. We prefer to simply describe all irrigation as just "irrigation" without the adjective "supplemental".

Limited and Deficit Irrigation

The term "limited irrigation" is widely used but ambiguous. We don't know its exact origin. We both attribute it largely to the pioneering research on irrigation by the late Jack Musick at the Bushland USDA-ARS laboratory. He used it to imply a single or perhaps two seasonal irrigations timed at critical crop development growth stages using predominately furrow irrigation (Musick and Dusek, 1971). Basically, it was aimed at ground water irrigation where the producer knew that a farm or field had inadequate water to meet the crop demand. The literature on "limited irrigation" is quite jumbled from constraints on irrigation amount (volume per unit area) to constraints on irrigation capacity (flow rate per unit area). Although not specifically intended to augment dryland water availability (like with "supplemental irrigation"), "limited irrigation" assumes an irrigation infrastructure and water availability, albeit inadequate, and aims to pinpoint applications at the crop development stage known to be the most sensitive to soil water deficits. A Google (internet) search on the term "limited irrigation" returned 50,500 hits.

The term "limited irrigation" was basically analogous to the term "deficit irrigation" that Miller (Miller and Aarstad, 1976; Miller, 1977) used in the northwestern U.S. English (English and Nakamura, 1989; English, 1990) further characterized the term deficit irrigation. Deficit irrigation as characterized by English et al. (1990) has the fundamental goal to increase water use efficiency (WUE; another term we'll discuss later). They stated that the fundamental goal of "deficit irrigation" was to increase water use efficiency, either by reducing irrigation adequacy {i.e., not fully meeting the crop water requirement evenly} or by eliminating the least productive irrigations." Fereres and Soriano (2006) recently reviewed deficit irrigation and concluded that the level of irrigation supply should be 60-100% of full evapotranspiration (ET) needs in most cases to improve water productivity. They indicated "regulated deficit irrigation" (RDI; another term we'll discuss later) was successful in several cases, especially with fruit trees and vines, to not only increase water productivity but also farm profit. We conclude for many reasons that the term "deficit irrigation" should be preferred over the term "limited irrigation" in future literature.

In using "deficit irrigation", it is important to distinguish irrigation amount (volume per unit area) from irrigation capacity (flow rate per unit area) or both. These constraints might be physical (e.g., well flow rate for the later) or regulatory (e.g., a water right for the former). One inherent characteristic with "deficit irrigation" is that dependence on precipitation and/or soil water reserves to meet a significant proportion of the crop requirement. During the course of the irrigation season, soil water reserves may become nearly depleted. Thus, deficit irrigation usually has less applicability in arid regions where there is little precipitation for replenishment of soil water reserves. Additionally, rainfall is difficult to predict, non-uniform, and perhaps occurs at a rate that exceeds the soil infiltration, and can occur at a non-critical crop development growth stage. Hence, the need for irrigation is enhanced to reduce risk, increase yield, stabilize profits, and improve water productivity (Lamm et al., 1994).

Water Use Efficiency

The term "water use efficiency" (WUE) is likely one of the most widely used irrigation terms, but it also is largely misused as often, too. A Google (internet) search on this term returned 795,000 hits. The term was popularized by Viets (1966), but it is the inverse of the early transpiration ratio used in the late 19th and early 20th century. One problem with WUE is that it encompasses scales from cellular, leaf, plant to field and time scales from instantaneous to a season (Sinclair et al., 1984). Typically, WUE is the yield per unit evapotranspiration (Bos, 1979), and as such it really isn't an "efficiency" at all.

A better term for WUE gaining popularity is water productivity (Zwart and Bastiaanssen, 2004). "Water productivity" is basically the same definition as WUE and has the same spatial-, time-scale shortcomings but without the confusing "efficiency" terminology for basically a bio-physical term. Water productivity places the emphasis properly on the productivity from a unit of water without implying an incorrect efficiency concept.

Regulated Deficit Irrigation

"Regulated deficit irrigation" (RDI) has been successful in tree and vine crops to enhance yield and, especially, crop quality (Kreidemann and Goodwin, 1995). Jim Hardie (Cooperative Research Centre for Viticulture, Adelaide SA) defined RDI as "the practice of using irrigation to maintain plant water status within prescribed limits of deficit with respect to maximum water potential for a prescribed part or parts of the seasonal cycle of plant development. The aim in doing this is to control reproductive growth and development, vegetative growth and/or improve water use efficiency {water productivity}." RDI is similar to deficit irrigation, but RDI varies the deficit level by crop development growth stage to either enhance yield or quality. Implicit with RDI is an irrigation capacity sufficient to increase irrigation rate or volume, if required, to reduce the soil water deficit (greater plant water potential) at a specific crop development growth stage.

With RDI re-wetting frequency should be determined by detection or prediction of a decrease in plant water potential (or some plant water status measurement) below a prescribed set-point. For convenience and cost saving, this set-point could be inferred from soil water depletion or estimates of evapotranspiration based on weather conditions or direct measurement of stem/sap flow.

Often RDI is utilized with "partial root zone drying" (PRZD). Jim Hardie (Cooperative Research Centre for Viticulture, Adelaide SA) defined RRZD as "the practice of using irrigation to alternately wet and dry (at least) two spatially prescribed parts of the plant root system to simultaneously maintain plant water status at maximum water potential and control vegetative growth for specific crop development growth stages." These alternating wetting zones have controlled vegetative growth or improved water productivity or both while maintaining reproductive growth and development. The re-wetting frequency under PRZD should be based on the measurement or prediction of soil water uptake from the drying side. In practice, this can be accomplished by soil water measurements or estimates of evapotranspiration based on weather data or direct measurement of stem/sap flow. PRZD is impractical for center pivot sprinklers, unless LEPA (low-energy, precision application) drops are in every furrow and alternated. PRZD might be accomplished by alternating furrows in surface irrigation, but PRZD seems more practical with microirrigation. But even with microirrigation, PRZD would require almost double the lateral line installations (with the increased costs).

Both RDI and PRZD depend on measurement of actual plant water potential compared with a known or controlled site having a full-irrigation regime. In practice, PRZD success should not be based on whether or not reproductive growth, berry or fruit size or mass has been decreased because this seems unlikely if maximum plant turgor has been maintained. PRZD will result in a plant/crop deficit (i.e., sub-maximal plant water potential), however, because the irrigation applications to maintain maximum plant water potential throughout the wetting cycle will have insufficient re-watering frequency, insufficient irrigation application, insufficient infiltration, and insufficient size of the wetted zone relative to canopy size and evaporative demand (Kreidemann and Goodwin, 1995).

Several issues that impact PRZD applications are:

- Determination of the allowable or desirable set-point in plant water potential (or soil water depletion) for any departure from the fully irrigated site?
- Determination of the consequences of regional/site differences in vapor pressure deficit or evaporative demand, crop rooting characteristics, or soil water redistribution as they impact the daily range of plant water potential of plants under PRZD regimes?

(Kreidemann and Goodwin, 1995) summarized that "relation to water deficit strategies in general, a barrier to implementation, apart from lack of convenient plant based measures of water potential, appears to be the lack of broad recognition that plant stress is a quantifiable continuum and that any attempt to regulate the deficit to achieve plant responses must involve defining, measuring and controlling the stress within prescribed limits. Satisfactory implementation of deficit strategies in warm areas i.e. high vapor pressure deficit, generally requires responsive watering systems and soils with high infiltration rates." In general, in the U.S., few experiments have verified the success of PRZD, but RDI has had success in tree and vine crops to improve yield and especially quality while enhancing water productivity (Castel and Fereres, 1982; Goldhamer et al., 2006; Teviotdale et al., 2001).

Summary

We reviewed widely used historical irrigation terms like "artificial irrigation," supplemental irrigation," and "limited irrigation. We suggest the first two are not descriptive and add little to just "irrigation." The third term has been largely replaced by the more descriptive term, "deficit irrigation;" however, it requires some clarification to the constraints (i.e., volumetric or capacity).

We believe the term "water use efficiency" (WUE) although still widely used should be replaced by the term "water productivity" as it doesn't perpetuate the incorrect use of an "efficiency" name and emphasizes the positive aspects of crop yield per unit water.

Newer terms like "regulated deficit irrigation" (RDI) and "partial root zone drying" (PRZD) were discussed, and they each require a measure of direct plant/crop water potential (or at least soil water depletion and/or estimated crop evapotranspiration). PRZD requires knowing or estimating the state of a "fully irrigated" crop, as well. In our opinion, RDI is a specialized case of "deficit irrigation" with a crop development stage set point for irrigation management.

Acknowledgements

We recognize the literature cited is just a selected subset of the vast information resource on this topic. We did not intend the cited literature within to be exhaustive, or even representative, but it is simply a limited sampling that can lead readers to a much greater and extensive literature body on this topic.

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