1. Introduction

Food production and water use are inextricably linked. Water has always been the main factor limiting crop production in much of the world where rainfall is insufficient to meet crop demand. With the ever-increasing competition for finite water resources worldwide and the steadily rising demand for agricultural commodities, the call to improve the efficiency and productivity of water use for crop production, to ensure future food security and address the uncertainties associated with climate change, has never been more urgent.

To examine the pathways for increasing the efficiency and productivity of water use, the yield response of crops to water must be known. This relationship is complex in nature and various attempts have been made to provide simplified, though sound, approaches to capture the basic features of the response.

FAO's first publication that presented a relationship between crop yield and water consumed was *Irrigation and Drainage Paper* No. 33 *Yield Response to Water* (Doorenbos and Kassam, 1979). This approach, discussed in Chapter 2, is based on one single equation relating the relative yield loss of any crop (either herbaceous or woody species) to the relative reduction of water consumption, i.e. evapotranspiration, by way of a coefficient (k_y), which is specific for any given crop and condition. This approach has provided a widely-used standard for synthetic water production functions, still in use today. This simplification, however, made this approach more suitable for general planning, project design and rapid appraisal purposes, often providing a first-order approximation.

Over the last three and half decades, new knowledge has enlighten processes underlying the relationship between crop yield and water use and technology has improved. Further, novel needs have emerged related to the planning and management of water in agriculture, including those arising from climate change. FAO has, therefore, revisited the approach to quantify crop yields in response to water use and water deficit. The end product of this effort is a crop simulation model named *AquaCrop*, which balances accuracy, simplicity and robustness and is described in Chapter 3. The conceptualization and development of this modelling approach is the result of a number of years of consultation and collaboration with scientists, crop specialists and practitioners worldwide, consolidating the vast amount of knowledge and information available since 1979.

AquaCrop uses the original equation of Doorenbos and Kassam (1979) as a point of departure and evolves from it by calculating the crop biomass, based on the amount of water transpired, and the crop yield as the proportion of biomass that goes into the harvestable parts. An important evolution is the separation of the non-productive consumption of water (soil evaporation) from the productive consumption of water (transpiration). Furthermore, the timescale of the original equation is seasonal, or growth-stages that are weeks long in duration, while the timescale used in *AquaCrop* is daily, in order to better represent the dynamics of crop response to water. Finally, the model allows for the assessment of responses under different climate change scenarios in terms of altered water and temperature regimes and elevated carbon dioxide concentration in the atmosphere. *AquaCrop* simulates growth, productivity and water use of a crop day-by-day, as affected by changing water availability and environmental conditions. The results of calibration and testing of the model so far provide grounds for confidence in its performance.

The development of standard crop parameters has made the model accessible to several types of users in different disciplines and for a wide-range of applications. *AquaCrop* is mainly aimed at practitioner-type end users such as those working for extension services, consulting engineers, irrigation districts, governmental agencies, nongovernmental organizations, and various kinds of farmer associations for use in the development of irrigation schedules and management decisions. Economists and policy specialists can also use this model for planning and scenario analysis. In addition, research scientists should find the model valuable as a tool for analysis and conceptualization. Overall, *AquaCrop* allows proper investigation of strategic planning and management to improve the efficiency and productivity of water use in herbaceous crop production. It is not designed for use with trees and vines.

Chapter 3 not only describes *AquaCrop* but also provides samples of applications for specific purposes and guidelines for calibration.

Chapter 3 also provides the agronomic features of the sixteen crops for which the model has been calibrated and validated. The crops covered are: wheat, rice, maize, soybean, barley, sorghum, cotton, sunflower, sugarcane, potato, tomato, sugar beet, alfalfa, bambara groundnut, quinoa and tef. Additional crops will soon be calibrated and their agronomic features described. The goal is to provide an overview of each crop's physiology and agronomy for users interested in applying the model to a particular crop at a given location. Furthermore, the overview can serve as a reference when calibrating the model for different crop classes. The description of each crop includes crop growth and development, water use and productivity, responses to water deficits and expected yields.

Fruit production has risen in importance over the past decades for increasing the productivity and competitiveness of small-scale farmers around the world. Fruit not only provides better income opportunities for growers, but is also pivotal in providing more healthy diets to consumers. The yield response to water of fruit trees and vines forms the second major part of this *publication*, presented in Chapter 4. The complexity of tree crops resulting from carry-over effects from one year to the next and the large divergence among cultivars, however, precluded using a relatively simple modelling approach, as that used for herbaceous crops. Therefore, a *Guideline* is presented instead, which includes a *general section* on the irrigation of fruit trees and vines, and a special section covering physiological and agronomic features of each individual crop species. While the *general section* provides the technical background and guidelines for efficient irrigation management, the sections on individual crops give specific responses to water, with a common format, covering the following key items: growth and development, crop water requirements, yield response to water supply, and recommended strategies for deficit irrigation. The focus of Chapter 4, in fact, is to synthesize available data and to generate production functions to glean opportunities in many cases for reducing water supply without yield or net income penalties. Particular attention in this chapter is paid to safeguarding farmers' net income and, in some cases, to enhancing fruit quality. Crops covered in Chapter 4 include olive, citrus, apple, plum, almond, pear, peach, walnut, pistachio, apricot, avocado, sweet cherry, grapevine and kiwi. As more information becomes available, other fruit and plantation crops will be described and made available to users via the Internet.

Finally, Chapter 4 provides some closing remarks and the way forward from this FAO *I&D Paper* No. 66. A compact disc accompanies this publication, where the user will find most of the information products and guidelines relevant to her/his work.

This new publication will provide the practitioner with strengthened skills to: assess the effect of water shortages on crop production; investigate the impact of climate change on crop yield; compare the results of several water allocations plans; optimize irrigation scheduling (either full, deficit or supplementary); and enhance management strategies for increased water productivity and water savings.