5. Epilogue

This publication, *Irrigation and Drainage Paper No. 66*, follows the tradition of FAO in producing papers addressing pressing land and water issues and providing guidelines to improve agricultural resources management.

With this new I&D paper, FAO is providing an enhanced set of tools, methods and knowledge, for the analysis and assessment of crop production in relation to climate, to water supply and shortage, to advance management strategies for improving crop productivity and water saving. The targeted potential users are agricultural practitioners, including farmer associations, irrigation districts, extension services, consulting engineers, governmental and non-governmental agencies, research scientists, agricultural and natural resource economists.

In the face of the increased threats of water scarcity worldwide, this publication comes at a time of great demand for maximizing the efficiency and productive water use. There is a need to sustainably intensify agricultural production in the face of incessant acceleration of competition for finite water resources, along with the uncertainties arising from climate change.

The tools and methods presented are effective as long as the user is fully aware of the strengths and limitations of their applications. The user is urged to carefully read the various Chapters, so not to fall into simplistic and inappropriate assessments.

Chapter 2 discusses the original FAO water production function method (*I&D* No. 33) of assessing yield response to water. This empirical approach is mostly suitable when a quick and first approximation of yield reduction related to water limitation is needed. This method has found many applications, particularly in various interdisciplinary studies at regional or even national scales, where generalized crop conditions prevaile and rapid assessments of yield reductions under limited water supply are required. Caution is necessary as the simplification introduced limits its applicability for accurate estimates of yield responses to water.

The use of *AquaCrop* (Chapter 3) is confined to herbaceous crops only, but with a wide spectrum of applications from the plot to field level and can be scaled up to watershed or regional level through aggregation. It can be used for yield gap assessment, to benchmark irrigation performance, and can assist in making informed water-related operational management decisions ranging from tactical to strategic. It can be used to optimize the cropping system in terms of crop and cultivar choice, planting time, and irrigation schedule for a given soil-climate combination where water is limiting. *AquaCrop* is also particularly suitable for the analysis of the impact of climate change scenarios on crop productivity, water requirements and consumption. Caution is required in the use of *AquaCrop* as its performance mostly depends on the accuracy of the input information and how well the crop has been calibrated. A well-calibrated crop and accurate local parameters, particularly the weather data, soil water characteristics, and phenology of the cultivar, are prerequisite for high-quality simulation results. Therefore the users are recommended to not rely solely on the crop file for the parameters of a particular crop, but check the *AquaCrop* web-page (www.fao.org/nr/water/aquacrop.html) for update of the crop parameters, and pay special attention to rough estimations or approximations involved in determining the local parameters. Questions and request for assistance regarding the model should be directed to the *AquaCrop* help-desk at its dedicated e-mail address (AquaCrop@fao.org).

The yield response to water of tree crops and vines is tackled through *Guidelines* for *Trees and Vines* (Chapter 4), as the current level of knowledge and the complexity of perennial crops prevented the development of a simulation model such as *AquaCrop*. Irrigation management of fruit and vine production must be based on accurate estimates of crop water requirements and on the crop-specific responses to water deficits, with emphasis on fruit quality. General concepts and applications are discussed first, followed by sections on specific crops where yield responses to water supply are generalized in the form of production functions. For many of these perennial crop plants, there are trade-offs between fruit quality and yield, as the maximum net economic return is achieved at irrigation levels below those needed for maximum yield. One outstanding example of this response is described in the section on grapes for wine production. Given such trade-offs and the increased water scarcity of many world areas, guidelines on the use of regulated deficit irrigation are included in every chapter, under certain assumptions on the restriction levels of water supply. The focus is on providing guidelines to optimize the use of a limited water supply, taking into account the sensitivity of certain growth stages to water deficits.

The perennial crops tackled in Chapter 4 are mostly grown in the temperate zones because insufficient information prevented inclusion of some important tropical tree crops. Given the growing demand for fruit, this subject matter is now receiving increased attention in research programmes. Guidelines for additional perennial crops will be introduced in future versions of this publication. The synthesis responses of fruit trees and vines to water presented here offers guidelines not only for improving the efficiency of water use in plantations but, also, for dealing with situations of water scarcity, which are a major threat to the viability and sustainability of fruit production in many areas of the world.

Included in this new publication is a CD containing a copy of each of the following: (i) this whole publication (*I&D Pape*r No. 66), (ii) the original FAO water production function (*I&D Paper* No. 33), (iii) the FAO guideline on crop evapotranspiration (*I&D Paper* No. 56), and (iv) a document listing potentially useful free-ware software and the internet link.

As next steps, the maintenance and development of the model *AquaCrop* has three aspects. (1) One is the continuous improvement of the model and refinement of the parameters for the crops already calibrated. It is anticipated that a new version of the model, prompted by feedbacks from users and testing with more extensive experimental data sets, may be released on the *AquaCrop* web-page as and when warranted. Regarding the crop parameters, as indicated on the *AquaCrop* website, the thoroughness of the parameterization varies from crop-to-crop. As more experimental data becomes available for calibration and testing, refinement in the parameter values are expected, and they will be posted on the website.(2) Additional herbaceous crops are and will continue to be calibrated. These may include common bean, millet, cassava, sweet potato, chickpea, forage crops and leafy vegetables. Some of these are among the so-called *locally-important* crops, to which particular attention will be paid. New crop sections, as well as the calibrated crop files with the calibrated parameters, will be provided on the *AquaCrop* web-page as they are finalized. (3) As part of the ongoing development of the software, special versions will be made available for use with various operating systems (e.g., Linux, Unix, etc.) and platforms for spatial analysis (e.g. GIS, DSS, etc.). For update, the user is recommended to visit the *AquaCrop* web-page periodically.

Special attention will also be given to the community of *AquaCrop* users and data and information providers. An *AquaCrop Network* is established with the purpose of sharing experience and scaling-up significant results. Particularly relevant is the scaling-up and propagation of 'training' in the use and application of *AquaCrop* and of the *Guidelines* for trees and vines, as well as of other related tools. *Face-to-face* workshops, *training-of-trainers* approaches, *distance*-and *e-learning* methods and other capacity development activities are being developed to respond to this need.

The overall goal is to reach out and engage a large community of users and potential users, and researchers with good experimental data, to enhance and expand the utilization of these tools, methods, and knowledge, and to improve them based on community input and feedback. This will ultimately lead to an augmented capacity of the users to sustainably manage water and crops while enhancing their productivity.

FAO IRRIGATION AND DRAINAGE PAPERS

1 Irrigation practice and water management, 1972 (Ar* E* F* S*)
1 Rev.1 Irrigation practice and water management, 1984 (E)
2 Irrigation canal lining, 1971 (New edition, 1977, available in E, F and S in the FAO Land and Water Development Series, No. 1)
3 Design criteria for basin irrigation systems, 1971 (E*)
4 Village irrigation programmes - a new approach in water economy, 1971 (F E*)
5 Automated irrigation, 1971 (E* F* S*)
6 Drainage of heavy soils, 1971 (E* F* S*)
7 Salinity seminar, Baghdad, 1971 (F E*)
8 Water and the environment, 1971 (E* F* S*)
9 Drainage materials, 1972 (E* F* S*)
10 Integrated farm water management, 1971 (E* F* S*)
11 Planning methodology seminar, Bucharest, 1972 (E* F*)
12 Farm water management seminar, Manila, 1972 (E*)
13 Water use seminar, Damascus, 1972 (F* E*)
14 Trickle irrigation, 1973 (E* F* S*)
15 Drainage machinery, 1973 (F* E*)
16 Drainage of salty soils, 1973 (C* E* F* S*)
17 Man's influence on the hydrological cycle, 1973 (E* F* S*)
18 Groundwater seminar, Granada, 1973 (E* F S*)
19 Mathematical models in hydrology, 1973 (E)
20/1 Water laws in Moslem countries - Vol. 1, 1973 (F* E*)
20/2 Water laws in Moslem countries - Vol. 2, 1978 (F E)
21 Groundwater models, 1973 (E)
22 Water for agriculture - index, 1973 (E/F/S*)
23 Simulation methods in water development, 1974 (E* F* S*)
24 Crop water requirements, (rev.) 1977 (C* E F S)
25 Effective rainfall, 1974 (C* E* F* S*)
26/1 Small hydraulic structures – Vol. 1, 1975 (E* F* S*)
26/2 Small hydraulic structures – Vol. 2, 1975 (E* F* S*)
27 Agro-meteorological field stations, 1976 (E* F* S*)
28 Drainage testing, 1976 (E* F* S*)
29 Water quality for agriculture, 1976 (E* F* S*)
29 Rev.1 Water quality for agriculture, 1985 (C** E* F* S*)
30 Self help wells, 1977 (E)*
31 Groundwater pollution, 1979 (C* E* S)
32 Deterministic models in hydrology, 1979 (E)*
33 Yield response to water, 1979 (C* E F S)
34 Corrosion and encrustation in water wells, 1980 (E)
35 Mechanized sprinkler irrigation, 1982 (C E* F S*)
36 Localized irrigation, 1980 (Ar C E* F S*)
37 Arid zone hydrology, 1981 (C E)
38 Drainage design factors, 1980 (Ar C E F S)
39 Lysimeters, 1982 (C E* F* S*)
40 Organization, operation and maintenance of irrigation schemes, 1982 (C E* F S*)
41 Environmental management for vector control in rice fields, 1984 (E* F* S*)
42 Consultation on irrigation in Africa, 1987 (F E)
43 Water lifting devices, 1986 (F E)
44 Design and optimization of irrigation distribution networks, 1988 (F E)
45 Guidelines for designing and evaluating surface irrigation systems, 1989 (E)
46 CROPWAT – a computer program for irrigation planning and management, 1992 (E F* S*)
47 Wastewater treatment and use in agriculture, 1992 (E)
48 The use of saline waters for crop production, 1993 (E)
49 CLIMWAT for CROPWAT, 1993 (E)
50 Le pompage éolien, 1994 (F)
51 Prospects for the drainage of clay soils, 1995 (E)
52 Reforming water resources policy, 1995 (E)
53 Environmental impact assessment of irrigation and drainage projects, 1995 (E)
54 Crues et apports, 1996 (F)
55 Control of water pollution from agriculture, 1996 (E* S)
56 Crop evapotranspiration, 2006 (E S)
57 Soil salinity assessment, 1999 (E)
58 Transfer of irrigation management services: guidelines, 1999 (E F R S)
59 Performance analysis of on-demand pressurized irrigation systems, 2000 (E)
60 Rev.1 Materials for subsurface land drainage systems, 2005 (E)
61 Agricultural drainage water management in arid and semi-arid areas, 2002 (E)
62 Guidelines and computer programs for the planning and design of land drainage systems, 2007 (E)
63 Modernizing Irrigation Management – the MASSCOTE approach. Mapping System and Services for Canal Operation Techniques, 2007 (E)
64 Manual on small earth dams. A guide to siting, design and construction, 2010 (E)
65 Guidelines on spate irrigation, 2010 (E)
66 Crop yield response to water, 2012 (E)

Ar – Arabic
C – Chinese
E – English
F – French
P – Portuguese
R – Russian
S – Spanish

Multil – Multilingual
* Out of print
** In preparation

Crop yield response to water

Abstracting from the scientific understanding and technological advances achieved over the last few decades, and relying on a network of several scientific institutions, FAO has packaged a set of tools in this Irrigation and Drainage Paper to better appraise and enhance crop yield response to water.

These tools provide the means to sharpen assessment and management capacities required to: compare the result of several water allocations plans: improve soil-moisture control-practices under rainfed conditions; optimize irrigation scheduling (either full, deficit or supplementary); sustainably intensify crop production; close the yield and water-productivity gaps; quantify the impact of climate variability and change on cropping systems; enhance strategies for increased water productivity and water savings; minimize the negative impact on the environment caused by agriculture.

These tools are invaluable to various agricultural practitioners including, but not limited to: water managers and planners; extension services; irrigation districts; consulting engineers; governmental agencies; non-governmental organizations and farmers´ associations; agricultural economists and research scientists.

CONTRIBUTING INSTITUTIONS

ISBN 978-92-5-107274-5 ISSN 0254-5284

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I2800E/1/06.12