Advances in Irrigation Agronomy

Plantation Crops

Irrigation has been used for thousands of years to maximise the performance, efficiency and profitability of crops, and it is a science that is constantly evolving. This potential for improved crop yields has never been more important as population levels and demand for food continue to grow.

Recognising the need for a coherent and accessible review of international irrigation research, this book examines the factors influencing water productivity in individual crops. It focuses on nine key plantation/industrial crops on which millions of people in the tropics and subtropics depend for their livelihoods (banana, cocoa, coconut, coffee, oil palm, rubber, sisal, sugar cane and tea). Linking crop physiology, agronomy and irrigation practices, this is a valuable resource for planners, irrigation engineers, agronomists and producers concerned with the international need to improve water productivity in agriculture in the face of increased pressure on water resources.

Mike Carr is Emeritus Professor of agricultural water management at Cranfield University, UK. He has over 45 years of experience in the management and delivery of international research, education, training and consultancy in agriculture and natural resource management. He is former editor of the Cambridge University Press journal *Experimental Agriculture*.

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This book is dedicated to:
My mother and father
My wife
My children
My grandchildren and
Plantation workers and smallholders everywhere

Contents

Foreword

Water scarcity is one of the most pressing issues facing humanity. Globally, 70% of all water withdrawn from rivers and groundwater is consumed by agriculture and yet, surprisingly, water for producing food hardly gets onto the international development agenda except when there is drought and famine such as in the Horn of Africa in 2011. Despite the media attention there still seems to be little appreciation of water's critical role in producing food and fibre at a time when about 20% of the world's rivers run dry before reaching the sea, and more than 1.4 billion people live in water-stressed river basins – a situation that is set to worsen. By 2050 the world needs to produce as much as 70% more food on less land, using less water, energy, fertiliser and pesticides while at the same time bringing down sharply the level of greenhouse gas emissions. Climate change is yet another dark cloud on the horizon.

This is a daunting challenge but history tells us that we should be optimistic. Irrigated farming was, for example, one of the agricultural and engineering success stories of the twentieth century, witness the Asian 'green revolution' in the 1960s and 70s. Food production has more than doubled over the past 50 years in response to a doubling of the world's population and agricultural productivity has risen steadily over the past 40 years. Our understanding of the importance of water ecosystem services has also grown and so too has our appreciation of the need for sustainability and for a balance between the ever-conflicting water demands of people, industry, food and the environment.

Good science has underpinned this success. Research has served us well in the past and it will continue to play a crucial role in the future. Understanding the important relationships between crops and water will be a vital part of this process if we are to make the best use of our limited water resources.

In this context this book is most timely. It focuses on plantation crops which make significant contributions to both food security and the economic life of many of the less developed countries. Annual world sugar production, for example, is estimated to be over 160 million tonnes with a value in excess of US$20 billion.

Plantations also have a long tradition of good quality research on which their profitability depends. Mike Carr has tapped into this rich seam. He has searched globally and brought together widely scattered published and grey literature on the links between water and yield response for a range of plantation crops. I have

known and worked with Mike for over 30 years following his early career in East Africa researching the water requirements of tea – his favourite plantation crop. This book is typical of the thorough and uncompromising way he approaches his work. He offers us considered synthesis of (often) conflicting research results from a range of sources of varying reliability. He provides us with good practical advice for crop and water management professionals and offers an excellent foundation on which future researchers can continue to build sound knowledge of crop water relationships without having to 'reinvent the wheel'. What more can you ask?

In the current jargon – we need to become more 'water smart' in growing food crops. This book will help us to do just that.

Melvyn Kay[1]

[1] Melvyn Kay is a Chartered Civil Engineer with over 40 years' international experience in irrigation engineering and agricultural water management. Following a career in teaching, research and consultancy with Cranfield University, he now works as an independent consultant with UK farmers and various international organisations such as FAO and IFAD on water, agriculture and food production.

Preface

My first job was with the Tea Research Institute of East Africa. This institute served the tea industries in three neighbouring countries, Kenya, Tanzania and Uganda, each with diverse ecological conditions. The results of the research, which was largely funded by the industry, had to be interpreted and applied to areas distant from the location of the field experiments, and then communicated to smallholders as well as large estates in appropriate ways. There was little opportunity to undertake basic research as the industry wanted answers to immediate practical questions, but if the results were to have generic value answers to fundamental questions were also needed.

My second job was in the UK with Wye College (University of London) where the task was to support the introduction of maize, a 'new crop', into British agriculture. This might seem very different from the job in East Africa, but the challenge was the same. To undertake and report research of immediate value to enterprising farmers concerned about profitability, yet supported by good science. It also meant working with a multidisciplinary team of agronomists, engineers and economists.

My third job was with Cranfield University at Silsoe (in the UK) where I was responsible for teaching postgraduate students from all over the world soil/plant/water relations and irrigation agronomy. This was done alongside engineers teaching irrigation engineering and related topics. The students came with first degrees in agriculture, geography or engineering and the challenge was to bridge the disciplinary gap, as well as to ensure that the MSc courses were relevant to any part of the world where irrigation is practised. Whilst at Cranfield, I was able to continue working internationally with the plantation sector as a researcher, trainer and consultant, particularly with the tea industry.

The common themes in all three jobs were to convert science into practice and to facilitate effective communication of the outcomes from research to the stakeholders whether they were students, smallholders, estate managers, engineers, policy makers, or other researchers or consultants. Traditionally scientists are most comfortable when working within their own, often narrow, discipline, but the world does not work like that. Bridges need to be built!

That therefore is my background from which this book has evolved. Each of the nine core chapters covers one so-called plantation crop, although most of these crops are now primarily grown by smallholders, produced in the tropics or

subtropics. The topics reviewed extend from the centre of origin of the crop and its development stages, through fundamental water relations, water requirements and water productivity, to irrigation systems and scheduling (where appropriate), discussed in the context of the current farming system(s). Each chapter follows a common format, including interim summaries, and is designed to contribute towards putting science into practice by bringing together information from a diverse range of sources (over 800 references have been accessed and cited). Each chapter concludes with a summary of its content. In addition, there is an introductory chapter at the beginning of the book, and a synthesis at the end.

With one exception (sisal, for which there is limited research), each chapter is based on a paper that has already been published in *Experimental Agriculture*, an established refereed journal published by Cambridge University Press. The coffee chapter (originally published as a paper in 2001) has been updated. The chapters on cocoa and sugar cane were both co-authored. The other crops covered are banana, coconut, oil palm, rubber and tea. My hope is that people from a wide range of backgrounds will find the book useful and of interest.

Acknowledgements

This book would not have been possible without the help of many people. I begin by acknowledging the role played by (the late) Professor J.P. Hudson who inspired me as an undergraduate student at the University of Nottingham (UK), and subsequently to (the late) Ernest Hainsworth, Director of the Tea Research Institute of East Africa, who had the confidence to employ me as a 22-year-old to set up and run a small irrigation research unit in Tanzania. Without their guidance my career would have been very different, and this book would not have happened. Later, Cranfield University at Silsoe (UK) allowed me to continue my involvement with the international plantation sector, an involvement that continues to this day.

Continuing support and encouragement to write this book has come from Dr Rob Lockwood and Dr Hereward Corley. Many people provided helpful feedback on drafts of the papers on which the chapters in this book are based, as did anonymous referees for *Experimental Agriculture*. Specific help was provided on banana (by Dr D.W. Turner), cocoa (Dr G. Lockwood, co-author; Dr F. Amoah and Dr A.J. Daymond), coconut (Dr X. Bonneau, Dr R.H.V. Corley and Dr. G. Lockwood), coffee (colleagues at Cranfield), oil palm (Dr R.H.V. Corley and Dr I.E. Henson), rubber (Dr R.H.V. Corley and Dr F. Do), sugar cane (Dr J.W. Knox, co-author, and Dr D.J. Nixon), and tea (Dr P.J. Burgess and Dr D.J. Nixon).

Many people contributed to the research at the Ngwazi Tea Research Unit/Station summarised in Chapter 10, at all levels. Most of them are cited in the references listed. Their commitment and support is gratefully recognised. I name three, all sadly no longer with us: the late Galus Myinga, Julio Lugusi and Badan Sanga. The tea industry in Tanzania and the UK Department for International Development funded the work at NTRU.

Several libraries kindly facilitated access to their journals and textbooks, specifically Cranfield University, Warwick University, the Royal Agricultural College, Stratford upon Avon Library and Information Centre, and Google. Much 'grey' literature was provided by colleagues listed above.

Photographs have come from a number of different sources, including Luiz Minisola (LM – banana and coconut); Andrew Daymond (AJD – cocoa); Xavier Bonneau, CIRAD, PT Multi-Agro Corporation (XB – coconut); Hereward Corley (RHVC – oil palm, cocoa); Anisio Henrique Leite Santana

(AHLS – sisal). Specific images are acknowledged by these initials in the text. I thank them all.

I thank too my long-time colleague and friend, Melvyn Kay, for kindly writing the Foreword to this book.

I am grateful to the staff of Cambridge University Press for the supportive way in which they facilitated the production process.

Finally, my wife, Dr Susan Carr, kindly read and edited the whole script (several times!) with great patience and skill, but any remaining errors are all mine!