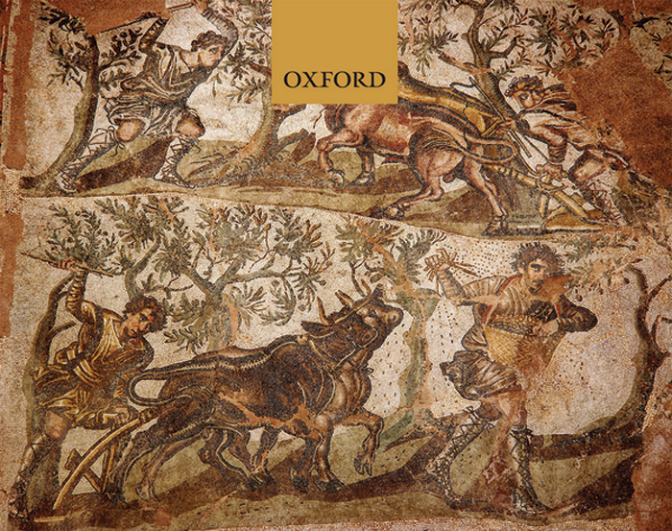


A detailed mosaic depicting a Roman agricultural scene. In the upper section, a man in a tunic and sandals is shown plowing a field with a wooden plow, guided by a man on a horse. In the lower section, a man is shown harvesting grain with a sickle, while another man stands nearby. The background features stylized trees and a landscape. The mosaic is composed of small tiles in earthy tones of brown, tan, and green.

OXFORD

OXFORD STUDIES ON THE ROMAN ECONOMY

THE ROMAN AGRICULTURAL ECONOMY

Organization, Investment, and Production

EDITED BY

Alan Bowman & Andrew Wilson

OXFORD STUDIES ON THE ROMAN ECONOMY

General Editors

Alan Bowman Andrew Wilson

OXFORD STUDIES ON THE ROMAN ECONOMY

The innovative monograph series reflects a vigorous revival of interest in the ancient economy, focusing on the Mediterranean world under Roman rule (c.100 BC to AD 350). Carefully quantified archaeological and documentary data will be integrated to help ancient historians, economic historians, and archaeologists think about economic behaviour collectively rather than from separate perspectives. The volumes will include a substantial comparative element and thus be of interest to historians of other periods and places.

The Roman Agricultural Economy

Organization, Investment, and Production

Edited by

ALAN BOWMAN

and

ANDREW WILSON

OXFORD
UNIVERSITY PRESS

OXFORD

UNIVERSITY PRESS

Great Clarendon Street, Oxford, OX2 6DP,
United Kingdom

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide. Oxford is a registered trade mark of
Oxford University Press in the UK and in certain other countries

© Oxford University Press 2013

The moral rights of the authors have been asserted

First Edition published in 2013

Impression: 1

All rights reserved. No part of this publication may be reproduced, stored in
a retrieval system, or transmitted, in any form or by any means, without the
prior permission in writing of Oxford University Press, or as expressly permitted
by law, by licence or under terms agreed with the appropriate reprographics
rights organization. Enquiries concerning reproduction outside the scope of the
above should be sent to the Rights Department, Oxford University Press, at the
address above

You must not circulate this work in any other form
and you must impose this same condition on any acquirer

British Library Cataloguing in Publication Data
Data available

ISBN 978-0-19-966572-3

Printed in Great Britain by
CPI Group (UK) Ltd, Croydon, CR0 4YY

Preface

This, the third volume in the series Oxford Studies on the Roman Economy, like its two predecessors, originates in the research programme entitled *The Economy of the Roman Empire: Integration, Growth and Decline*, funded by the Arts and Humanities Research Council in 2005–10 and directed by the Series Editors. The aims and nature of the research project are described in the preface to the first volume, *Quantifying the Roman Economy: Methods and Problems* (eds A. K. Bowman and A. I. Wilson, 2009), to which the reader is referred for more details. This volume focuses on the Roman agrarian economy, and in particular on systems of organization, and the nature and scale of agricultural production, and investment in it. Most of the chapters were originally delivered as papers at a conference on ‘The Agricultural Economy’ held in Oxford on 3 October 2008, and the introduction also reflects discussion there and at a workshop session on the following day.

We thank the AHRC for the award of the grant that supported the research programme. The project has also benefited greatly from the interest and support of Baron Lorne Thyssen, which have enabled us to continue the research programme well beyond the period funded by the AHRC. We are grateful also to the project’s postdoctoral research assistants, Drs Myrto Malouta and Annalisa Marzano, who did much of the conference organization, to the staff of the Stelios Ioannou Centre for Research in Classical and Byzantine Studies, where the conference was held, and to all those who contributed to the discussion at the conference and the following workshop.

Andrew Wilson
Alan Bowman
December 2011

This page intentionally left blank

Contents

<i>List of Contributors</i>	viii
<i>List of Figures</i>	xi
<i>List of Tables</i>	xvi
1. Introduction: Quantifying Roman Agriculture <i>Alan Bowman and Andrew Wilson</i>	1
2. The State and Production in the Roman Agrarian Economy <i>Dennis Kehoe</i>	33
3. GIS Models of Roman Agricultural Production <i>Helen Goodchild</i>	55
4. Agricultural Production in the Hinterland of Rome: Wine and Olive Oil <i>Annalisa Marzano</i>	85
5. Capital Investment and Agriculture: Multi-Press Facilities from Gaul, the Iberian Peninsula, and the Black Sea Region <i>Annalisa Marzano</i>	107
6. The Rural Landscape of Thugga: Farms, Presses, Mills, and Transport <i>Mariette de Vos</i>	143
7. Agricultural Production in Egypt <i>Alan Bowman</i>	219
8. The Agricultural Economy of the Mendesian Nome under Roman Rule <i>Katherine Blouin</i>	255
9. Mechanical Irrigation: Water-Lifting Devices in the Archaeological Evidence and in the Egyptian Papyri <i>Myrto Malouta and Andrew Wilson</i>	273
10. Agriculture in the Faynan: Food Supply for the Mining Industry <i>Hannah Friedman</i>	307
<i>Index</i>	323

List of Contributors

Katherine Blouin, Assistant Professor in Greek and Roman History, University of Toronto, Canada. Her work centres on Roman Egypt, and more specifically on issues dealing with multiculturalism, cultural identities, and ancient environments. Publications include: *Le Conflit judéo-alexandrin de 38–41: L'Identité juive à l'épreuve* (Paris, 2005); 'Environnement et fisc dans le nome mendésien à l'époque romaine: Réalités et enjeux de la diversification', *Bulletin of the American Society of Papyrologists*, 44 (2007), 135–66; and 'La Révolte des *Boukoloi* (delta du Nil, Égypte, ca.166–172 de notre ère): Regard socio-environnemental sur la violence', *Phoenix*, 64/3–4 (2010), 386–422.

Alan Bowman, Principal of Brasenose College, and Camden Professor Emeritus of Ancient History, University of Oxford. His areas of research are the social and economic history of the Roman empire, Ptolemaic and Roman Egypt, papyrology and the Vindolanda writing tablets. Publications include: *Agriculture in Egypt from Pharaonic to Modern Times* (ed. with E. Rogan; London, 1999); *Life and Letters on the Roman Frontier: Vindolanda and its People* (rev. edn; London, 2003); *Quantifying the Roman Economy: Methods and Problems* (ed. with Andrew Wilson; Oxford, 2009) and *Settlement, Urbanization, and Population* (ed. with Andrew Wilson; Oxford, 2011).

Mariette de Vos, Professore di Archeologia classica, Dipartimento di Filosofia, Storia e Beni culturali, Università degli Studi di Trento, Italy.

Hannah Friedman, Assistant Professor of Classics in the Department of Classical and Modern Languages and Literature at Texas Tech University, USA. Her interests include the ancient Roman economy, industry and technology, mining and metal supply, and the application of modern geospatial technologies to archaeology. She is a co-investigator of the Barqa Landscape Project in southern Jordan. She has published on viewsheds and observational control in Roman mining ('Imperial Industry and Observational Control in the Faynan Region, Southern Jordan', *Internet Archaeology*, 27) and excavations of Islamic farmhouses (R. Adams, J. Anderson, J. Grattan, D. Gilbertson, L. Rouse, H. Friedman, M. Homan, and H. Toland, 'Report on First Season of the Barqa Landscape Survey, South-West Jordan', *ADAJ* 54).

Helen Goodchild, Project and Fieldwork Officer, Department of Archaeology, University of York, UK. Her research interests include geophysics, topographic and field survey, and computer modelling in landscape archaeology. Publications include: 'Agriculture and the Environment of Republican Italy',

in J. D. Evans (ed.), *Companion to Roman Republican Archaeology* (Blackwell Companions to the Ancient World; Chichester and Malden, MA, in press); 'Modelling the Agricultural Landscapes of Republican Italy' (with R. Witcher), in J. Carlsen and E. Lo Cascio (eds), *Agricoltura e Scambi nell'Italia tardo repubblicana* (Bari, 2010), 187–220; and *Spatial Data Quality: From Process to Decisions* (ed. with R. Devillers; London, 2009); and V. Gaffney and R. White, with H. Goodchild, *Wroxeter, the Cornovii, and the Urban Process: Final Report on the Wroxeter Hinterland Project 1994–1997*, i. *Researching the Hinterland* (Journal of Roman Archaeology Supplementary Series 68; Portsmouth, RI, 2007).

Dennis Kehoe, Professor, Department of Classical Studies, and Andrew W. Mellon Professor in the Humanities, 2010–13, Tulane University, USA. His research interests include the economy of the Roman empire, especially as it was influenced by law and legal institutions. His publications include: *Law and the Rural Economy in the Roman Empire* (Ann Arbor, 2007); 'The Early Roman Empire: Production', in W. Scheidel, I. Morris, and R. Saller (eds), *The Cambridge Economic History of the Greco-Roman World* (Cambridge, 2007), 543–69; 'Law and Economic Institutions' (with B. W. Frier), *ibid.*, 113–43, as well as 'Food Production in the Long Term (Roman World)', forthcoming in A. Bresson, E. Lo Cascio, and F. Velde (eds), *Oxford Handbook of Economies in the Classical World*.

Myrto Malouta, Lecturer in Greek Papyrology, Ionian University, Corfu. Her research interests are documentary and literary papyri, the history of Ptolemaic and Roman Egypt, and Roman social, cultural, and economic history. Publications include: 'Families, Households, and Children in Roman Egypt', in C. Riggs (ed.), *Oxford Handbook of Roman Egypt* (Oxford, 2012); 'Talei: A Methodological Case Study in Papyrological Topography', in T. Gagos (ed.), *Proceedings of the 25th International Congress of Papyrology* (Ann Arbor, 2010); 'Fatherlessness and Formal Identification in Roman Egypt', in S. Hübner and D. Ratzan (eds), *Growing up Fatherless in Antiquity* (Cambridge, 2009); and 'Antinoite Citizenship under Hadrian and Antoninus Pius, 130–161', *BASP* 46 (2009).

Annalisa Marzano, Reader in Ancient History, University of Reading. Her main areas of interest are Roman social and economic history, the utilization of marine resources and aquaculture in antiquity, and the archaeology and socio-economic function of villas. Publications include: *Roman Villas in Central Italy: A Social and Economic History* (Leiden and Boston, 2007); 'Trajanic Building Projects on Base-Metal Denominations and Audience Targeting', *PBSR* 77 (2009), 125–58; 'Costly Display or Economic Investment? A Quantitative Approach to the Study of Roman Marine Aquaculture' (with G. Brizzi), *JRA* 22 (2009), 215–30.

Andrew Wilson, Professor of the Archaeology of the Roman Empire, University of Oxford. His research interests include the economy of the Roman empire, ancient technology, ancient water supply and usage, Roman North Africa, and archaeological field survey. Recent publications include: *Quantifying the Roman Economy: Methods and Problems* (ed. with Alan Bowman; Oxford, 2009); *Settlement, Urbanization, and Population* (ed. with Alan Bowman; Oxford, 2011); *Alexandria and the North-Western Delta* (ed. with Damian Robinson; Oxford, 2010); *Maritime Archaeology and Ancient Trade in the Mediterranean* (ed. with Damian Robinson; Oxford 2011); and chapters on 'Hydraulic Engineering', 'Machines', and 'Large-Scale Manufacturing, Standardization, and Trade', in J. P. Oleson (ed.), *Handbook of Engineering and Technology in the Classical World* (Oxford, 2008).

List of Figures

3.1. Map of the study area showing major towns, lakes, and the course of the Tiber (base data from the British School at Rome)	62
3.2. (a) Slope map coded from 1 to 255 (worst to best); (b) fertility based on underlying geology, coded as 1 = unsuitable, 127 = medium suitability, 255 = most suitable; (c) aspect maps showing south- and east-facing slopes as most suitable (255); (d) output of analysis incorporating all three factors into a single 'suitability' image	65
3.3. (a) Thiessen polygons showing farm and villa territories; (b) buffers created by graphing distances between sites and their nearest neighbours.	67
3.4. Results of a basic production model for wheat monoculture.	70
3.5. Results of a basic production model for intercultivation (wheat, vines, and olives).	71
3.6. Location map showing the <i>ager Veientanus</i> study area (boxed)	73
3.7. Results of the local production model for 9- <i>iugera</i> farms from the Middle Republic to the Early Imperial period.	74
3.8. Results of the local production model for 22- <i>iugera</i> farms from the Middle Republic to the Early Imperial period.	75
4.1. Area considered in this study as Rome's immediate hinterland (A. Marzano)	86
4.2. Numbers and types of presses attested archaeologically in the study area (n = 169)	89
4.3. Number of sites equipped with single or multiple presses (left) and breakdown of number of presses attested at various sites (right)	90
4.4. Chronological phases attested at elite villas in Latium (after Marzano 2007)	91
4.5. Origins of the wine (in litres) consumed annually in Rome on the basis of ceramic evidence and estimates of local produce, AD 100–150 (after De Sena 2005: fig. 3)	95
4.6. Origins of the olive oil (in litres) consumed annually in Rome on the basis of ceramic evidence and estimates of local produce, AD 100–150 (after De Sena 2005: fig. 4)	95
4.7. Attested presses (left) and suggested attribution to wine and oil production for the uncertain cases (right)	99

5.1. Gaul: number of presses per site (n = 45)	113
5.2. Gaul: chronology of periods of operation of all presses at multi-press sites, and according to type of production (n _{total} = 39 [6 undated]; n _{oil} = 17; n _{wine} = 22)	113
5.3. Gaul: installation date of all presses at multi-press sites, and according to type of production (n = 39; n _{oil} = 17; n _{wine} = 22)	114
5.4. Gaul: end of use of oil and wine presses (n = 39; n _{oil} = 17; n _{wine} = 22)	118
5.5. Iberian peninsula: number of presses per site (n = 140)	121
5.6. Iberian peninsula: chronology of all presses, and according to type of production (n = 87 [53 undated]; n _{oil} = 42; n _{wine} = 37 [8 uncertain])	122
5.7. Iberian peninsula: installation date of all presses and according to type of production (n = 87; n _{oil} = 42; n _{wine} = 37)	123
5.8. Iberian peninsula: end of use of oil and wine presses (n _{oil} = 42; n _{wine} = 37)	125
5.9. Black Sea: number of presses per site (n = 53)	129
5.10. Black Sea: chronology of all presses (n = 53)	130
5.11. Black Sea: installation date of presses (n = 53)	130
5.12. Cumulative total, chronology of all multiple presses (n = 179)	133
5.13. Cumulative total, installation dates of all multiple presses (n = 179)	134
5.14. Aggregated capacities of salting factories in Lusitania, Baetica, and Mauretania Tingitana (26 factories at 13 different sites) (Wilson 2006: fig. 3)	136
6.1. Map of the sites discovered around Thugga in Tunisia (R. Attoui, M. de Vos.)	144
6.2. Map of the road system, based on Salama (1951), with black dots showing the findspots of the 'great inscriptions' of the Bagradas Valley (R. Attoui)	145
6.3. Oued Arkou, <i>pagus Suttuensis</i> , site 66: boundary marker of <i>T. Statilius</i> <i>Taurus</i> <i>Imp(erator) iter(um)</i> (M. de Vos)	147
6.4. Map of the properties (R. Attoui, M. de Vos)	148
6.5. Oued Khaled near Teboursouk: <i>cultura promiscua</i> in an olive grove (M. de Vos)	150
6.6. Glia, site 396: limestone quarry (M. de Vos)	151
6.7. Oued Arkou, Aïn Wassel, site 25, partially excavated Byzantine farm: reused counterweight, rotated 90° (M. de Vos)	155
6.8. <i>Pagus Suttuensis</i> , site 66, cylinder (M. de Vos)	156

6.9. Oil farm, site 205; 3D reconstruction of double press (R. Attoui, A. Battisti)	158
6.10. Plan of farm site 207 with triple press (P. Tedesco, R. Attoui, M. Andreoli, M. de Vos)	159
6.11. Plan of farm site 49 with four single presses (R. Attoui, M. Andreoli, M. de Vos)	160
6.12. Chronological maps of pottery distribution (R. Attoui, S. Polla)	167
6.13. Aïn Zillig, site 570, farm with double press: (a) exterior of west and south walls <i>in opus africanum</i> ; (b) interior face of west wall with two mortise blocks and window. Lower right: the rim of the masonry basin (M. de Vos)	168
6.14. Oued Khaled, farm site 633: basin with overflow, and decantation and cleaning depression (M. de Vos)	170
6.15. Djebel Gorraa, site 131: unfinished nummulitic <i>catillus</i> (M. de Vos)	175
6.16. Oued Arkou, Aïn Wassel, site 25: flour (or oil?) collector; threshold reused as orthostat (M. de Vos)	177
6.17. Oued Khaled, Fadden Souk, <i>Pagus Assallitanus</i> , farm site 369: reconstruction model of kneading machine (A. Battisti, A. Andreoli, M. de Vos)	179
6.18. Oued Khaled, farm site 31, limestone water channel (M. de Vos)	181
6.19. Oued Khaled, Oued Nsira, tributary of Khaled, cistern (M. de Vos)	182
6.20. Aïn Zillig, farm site 570: kerbstone with pivot mortise for carriage door (M. de Vos)	189
6.21. The farm of the Gabinii, site 47: doorposts of <i>torcularium</i> with sculpted hook for tethering animals (M. de Vos)	190
6.22. The farm of the Gabinii, site 47: (a) post of window frame; (b) window lintel or sill (M. de Vos)	191
6.23. Oued Khaled, site 597: threshold with apotropaic phallus (M. de Vos)	191
6.24. Oued Khaled, site 69: lintel with mortise for vertical beam in which the lever beam was fixed, with apotropaic phallus (M. de Vos)	192
6.25. Djebel Cheidi, Henchir Batoum, <i>fossa regia</i> , site 390, dedication (M. de Vos, M. Andreoli)	198
6.26. Oued Khaled, Bir Tersas, site 388: inscription of the mausoleum of C. Passienius Septimus, reused in Byzantine fortress: (M. de Vos)	199
6.27. <i>Via a Kartagine Thevestem</i> , roadway substructure near Aïn Younes (M. de Vos)	202

6.28. <i>Via a Kartagine Thevestem</i> , Aïn Younes, column or milestone with dedication to Constantius and Galerius <i>Caesares</i> of the First Tetrarchy (293–305) (M. de Vos, M. Andreoli, C. Favretto)	203
7.1. The Nomes of Middle Egypt (A. Kotarba-Morley)	222
8.1. Map of the Mendesian Nome (K. Blouin and D. Nakassis)	256
9.1. Different functions of water-lifting devices represented in the archaeological evidence (n = 370)	277
9.2. Mosaic from the House of the Laberii, Oudna (Tunisia) showing a rural scene with a <i>shaduf</i> (Musée du Bardo, Tunis)	279
9.3. Number of <i>kelôneia</i> attested per century in the papyri (n = 59)	279
9.4. Mosaic from the colonnaded street at Apamea (Syria), showing a water-driven water-lifting wheel (<i>noria</i>), AD 469 (Z. Kamash)	281
9.5. Water-lifting wheel (<i>noria</i>) at Hama (Syria) (A. Wilson)	281
9.6. Painting from a tomb at Wardian (Alexandria, Egypt), showing oxen working a water-lifting wheel (A. Wilson; Greco-Roman Museum, Alexandria)	283
9.7. Rectangular shafts on the subterranean aqueduct between La Soukra and Carthage, probably for <i>saqiya</i> irrigation of the Ariana plain (after Renault 1912: 473–4)	287
9.8. Number of <i>kukleuteria</i> attested per century in the papyri (n = 38)	289
9.9. Number of (<i>kullai</i>) <i>kuklades</i> per century in the papyri (n = 11)	290
9.10. Number of <i>trochoi</i> attested per century (n = 29)	290
9.11. Number of <i>tympana</i> attested per century (n = 14)	291
9.12. Wall painting from the House of Publius Cornelius Tegeus in Pompeii, showing an Egyptian genre scene with a man operating an Archimedes screw to water crops (A. Maiuri, NSA, 1927, pl. IX)	292
9.13. Archaeological finds of bronze and wooden pumps by century (n = 22)	293
9.14. Number of <i>mechanai</i> attested per century in the papyri (n = 222)	294
9.15. Number of <i>organa</i> per century attested in the papyri (n = 72)	295
9.16. Number of unspecified water-lifting devices per century attested in the papyri (n = 124)	295
9.17. Types of water-lifting devices attested in the papyri (n = 583)	296
9.18. Chronological distribution by century of papyri mentioning water-lifting devices (n = 298)	297
9.19. Chronological distribution by half-century of papyri mentioning water-lifting devices (n = 298)	298

9.20. Chronological distribution by century of all papyri from the third century BC to the eighth century AD (graph adapted from Habermann 1998: 147, fig. 1)	299
9.21. Papyri mentioning water-lifting devices as a percentage of the total numbers of papyri, by century (total papyri data from Habermann 1998)	299
9.22. Types of water-lifting devices attested in the papyri, over time (n = 583)	300
9.23. Evidence for different categories of water-lifting devices over time—literary, papyrological, and archaeological	301
10.1. The landscape of the Wadi Faynan region (Barker <i>et al.</i> 2007: 310)	309
10.2. Plan of the ancient field systems in the Wadi Faynan and summary of their uses (Barker <i>et al.</i> 2007: 331)	309
10.3. Distribution of Early Roman/Nabataean sherds, and of rectangular structures, in the WF4 field system (Barker <i>et al.</i> 2007: 172, fig. 5.52)	312
10.4. The effect of proximity to the Khirbet Faynan slagheap on seed productivity (Pyatt <i>et al.</i> 1999: 307, fig. 15)	317

List of Tables

3.1. Variables used in Goodchild and Witcher (2009)	74
3.2. Comparison of mean productivity for farm sites in continual occupation and new Early Imperial foundations	76
5.1. Distribution of multi-press sites in Gaul, Iberia, and the Black Sea according to production type	110
5.2. Distribution of presses at multi-press sites in Gaul, Iberia, and the Black Sea according to production type	110
6.1. Comparison between agricultural processing elements found in surveys around Thugga and in north-eastern Algeria	154
6.2. Thugga survey, rural and urban presses	154
6.3. Distribution pattern of sites in the Thugga and Algerian surveys	156
6.4. Chronology of the sites in the Thugga survey based on the surface pottery	163
6.5. Family domains and estate sizes attested by inscriptions in the surroundings of Thugga	194
7.1. Estimates of land use in nomes of Middle Egypt	224
7.2. The assets of Calpurnia Heraklia	233
7.3. Relative sizes of Oxyrhynchite villages based on tax payments	235
7.4. Population, site size, and land in Fayum villages	237
7.5. Movement of land at Tebtunis (a) individual documents; (b) registers	240
7.6. Land and taxes at Karanis and neighbouring villages, mid-second to early fourth century AD	241
7.7. Production and consumption (a) mid-second century AD; (b) early fourth century AD	243
7.8. Oxyrhynchite cereal production	245
8.1. Agrarian typology and land classification in the Mendesian Nome under the Principate	259
8.2. Taxes on agriculture in the Mendesian Nome under the Principate according to papyri	261
8.3. The agricultural land of Psen- (Phernouphites toparchy) at the turn of the fourth century AD according to <i>P.Oxy.</i> XLIV.3205	267

8.4. The agricultural land of Psen-'s <i>koinon</i> at the turn of the fourth century AD according to <i>P. Oxy.</i> XLIV.3205	267
10.1. Yields of barley and wheat at Nitzana/Nessana according to <i>P. Ness.</i> 82	314
10.2. Yields of barley and wheat at Avdat farm (Evenari <i>et al.</i> 1982: 122)	314
10.3. Individuals supported annually from the northern fields based on calculations by Flannery (1973), and Foxhall and Forbes (1982)	316
10.4. Estimates of individuals supported annually by the polluted northern fields	319

This page intentionally left blank

Introduction: Quantifying Roman Agriculture

Alan Bowman and Andrew Wilson

INTRODUCTION

This volume has its origin in the third annual conference of the Oxford Roman Economy Project, on *The Agricultural Economy*, held on 3 October 2008, of which the theme was the agrarian economy between c.100 BC and AD 350.¹ It includes the nine papers from the 2008 conference, which exemplify a range of possible approaches to studying and, within limits, quantifying aspects of agricultural production in the Roman world, and casting light on the structure and performance of that sector of the economy, on the basis of widely different sources of evidence—historical, papyrological, and archaeological—for the modes of land exploitation and the organization and development of, and particularly investment in, agricultural production in the Roman world. It aims to move substantially beyond the simple assumption that agriculture was the dominant sector of the ancient economy, and to explore what was special and distinctive about the Roman economy in terms, for example, of state involvement and institutional infrastructure, elite investment in agricultural improvements and processing plant, or the phenomenon of market-oriented surplus production based around the villa system.

It will be obvious from the size and the content of the book that it makes no claim to a macroeconomic quantification of all agricultural activity over the whole of the Roman empire in a period of almost five centuries. Since our approach in this project has been to proceed on the basis of collections of quantifiable data from archaeological and documentary sources, it is evident

¹ We gratefully acknowledge the support of the Arts and Humanities Research Council, which funded the Oxford Roman Economy Project (OXREP) with a grant from October 2005 to September 2010. We also thank Baron Lorne Thyssen for his generous continued support of the Project.

that we cannot hope to produce a quantification of the whole agricultural economy on this basis, and we remain in doubt as to whether it is in practice possible to do that to any significant extent at all. Even given the huge amount of data, which has often been undervalued by ancient historians, there are too many gaps in the evidence and too many uncertainties about basic features such as population size² to produce reliable and robust results. That is not to say that we see no value in attempting to quantify the agrarian regime on the broadest macroeconomic scale, simply that this is not what we feel able to offer here. Rather, the focus is on marshalling a large quantity of evidence (chiefly archaeological and papyrological) to address large questions of the structure and performance of the agricultural economy of the Roman world. In particular, the papers collected here offer a means of analysing investment in agricultural facilities, and tracking variation in patterns across time and across regions within the empire.

A brief review of recent approaches to the Roman agricultural economy may set the scene for what we are attempting to achieve in this volume. If we look further back to the pioneering era, it is appropriate to acknowledge the work of Max Weber, though he paid virtually no attention to scale and volume of agricultural production or consumption in the Roman economy, emphasizing in his chapters on the late Republic and the empire rather the struggles for ownership and control of land and the comparison between Roman and medieval cities, particularly in respect of the character and role of the peasantry and the urban guilds.³ A considerable quantity of economic hard data was compiled in the various volumes of Tenney Frank's *Economic Survey of Ancient Rome*, which represented a characteristic (for the period) American empiricist approach to the economy, and still has much useful material to offer, even if the emphasis is rather on accumulation than analysis and the macroeconomic estimates and conclusions now look rather dated.⁴ From the 1960s onwards, works in English that commanded attention included the well-received book by K. D. White on Roman farming and J. M. Frayn's slighter work on Roman subsistence farming in Italy. These tended to rely heavily on literary evidence (Cato, Varro, Columella, and so on) and to avoid detailed quantified analysis of scale, although the choice of 'subsistence' farming as a subject, even if not very precisely defined, has an obvious implication of smallness of scale.⁵

In the context of Roman Italy, from our point of view the book by M. S. Spurr on arable cultivation marked a real advance, using a great deal

² See Bowman and Wilson (2011: ch. 1).

³ Weber (1924/1976: chs 6 and 7).

⁴ Frank (1933–40). The density of quantifiable evidence naturally varies significantly by region and period.

⁵ White (1970); Frayn (1979).

of literary evidence, dealing in detail with the technology and considering the characteristics of different crop regimes, as well as paying some attention to livestock, labour, and markets. Although Spurr found it quite difficult to draw quantified conclusions from his ancient evidence, the book is notable for its attempts to utilize medieval and modern evidence as comparanda for crop yields, in particular.⁶ Recent decades have seen considerable intensification of quantified studies of various aspects of Mediterranean agriculture, particularly olive oil and wine, whereas the third member of the triad has proved generally more intractable.⁷ This is perhaps not surprising, given the greater availability of useable archaeological evidence for wine and oil presses, while milling and storage facilities for cereals have proved harder to exploit.⁸ Naturally the evidence for wine and oil production exhibits considerable regional bias and reminds us that there are significant differences in the characteristics of the agrarian regime between different parts of the empire, not least in the comparative ratios of arable, livestock, and oleo- and viticulture.

From the point of view of quantification, Jongman's study of Pompeii marked an advance with a somewhat different focus, attempting a holistic picture of a single, well-attested town in its regional context.⁹ Conscious of the influence of Finley's *Ancient Economy* and alert to the possibilities offered by the methodology of the social sciences, Jongman reacted strongly against the overemphasis on the textile trade in the Pompeian economy¹⁰ and produced a more pluralistic analysis with a significant emphasis on the agricultural economy of town and region.¹¹ His detailed calculations deserve careful consideration and emphasize the necessity of achieving plausible estimates for population, land under cultivation, and crop yields in order to understand the balance between production and consumption and the likelihood of surpluses. The robustness of the exercise depends, as he concedes, on the plausibility of estimates of each of the three different variables that need to be combined, and none of these can be regarded as better than consistent. He estimated a territory of 200 km², populated at a density of 180/km², yielding a total population of 36,000 of which 8,000–12,000 (25–33 per cent) will be urban, a high but not impossible ratio, as he puts it.¹² More recent work, however, suggests a very different balance of land use from Jongman's

⁶ Spurr (1986), acknowledged by Scheidel (1994).

⁷ e.g. Tchernia (1986); Mattingly (1988a, 1988b); Hitchner (1993); Ruffing (1999). But see Erdkamp (2005).

⁸ Moritz (1958); Rickman (1971); Wilson (2002: 9–15).

⁹ Jongman (1988).

¹⁰ Moeller (1976).

¹¹ Jongman (1988: ch. 3).

¹² Jongman (1988: 108–12). Pompeii offers more possibilities than other towns in Italy and most provinces, for the obvious reasons, but there have been a number of studies of the agricultural economy of individual towns and villages in Ptolemaic and Roman Egypt (see Bowman, Chapter 7, this volume).

estimates, and a reconstruction of the original morphology of Vesuvius with significantly more available land for vines, leading to a greater local surplus; moreover, Jongman's calculations do not take full account of the possibility that the region produced a surplus in cash that was exported in return for staples.¹³ We also note, from the point of view of our interest in change and development, that Jongman's calculations offer a snapshot of a period just before the destruction of the town in AD 79 and therefore give no insight into the development of the town from the second century BC onwards, as the archaeology of the urban buildings can help to do.

We are fortunate in that the recently published *Cambridge Economic History of the Greco-Roman World* provides some excellent overviews of the character and the development of the agrarian sector of the empire and indicates some of the ways in which the subject has developed in the two decades since Jongman's book, in an organizational format that is largely dictated by region and by period.¹⁴ To oversimplify, prominent questions and themes that run through the contributions of the different authors include the crop regimes and diet (self-evidently the 'Mediterranean triad'), the balance of production and consumption within which levels of 'subsistence' and surplus might broadly be calculable.¹⁵ The approach itself suggests (and we would concur) that such analysis will not yield any sort of a comprehensive picture or widely applicable scenario of the 'agrarian sector' in the Roman Mediterranean, since regional and ecological diversity is so important. Only on the most general level can one envisage an order-of-magnitude estimate in terms such as agriculture accounting for (say) 80 per cent of the value of 'production' in the empire as a whole, the proportion of that value needed to feed the population at subsistence level (if one could be sure of the size of that population over time), and the overhead costs of the institutions and mechanisms needed to make sure that the food was available when and where required.¹⁶

Kehoe's contribution to *The Cambridge Economic History* succinctly describes the essential features of the agrarian regime.¹⁷ Wheat, the basic staple crop in regions with a Mediterranean climate, was mainly cultivated on the two-field system, perhaps with some progress towards more productive methods and some degree of integration of livestock farming.¹⁸ The Roman

¹³ De Simone (forthcoming).

¹⁴ Scheidel, Morris, and Saller (2007).

¹⁵ e.g. Scheidel, Morris, and Saller (2007: 597–600, 656–9, 678–82).

¹⁶ This would fit within the parameters of 75–85% that most scholars seem to envisage, but that are no more than plausible guesses. Representative are the statements of Jones (1974), that the vast majority of the empire's population were peasants (p. 30), that agriculture produced twenty times as much income as trade and industry in the sixth century and the proportion had not changed much (pp. 36–7), that about 90% of the national income was derived from land (p. 83). Population size is still robustly debated (see Bowman and Wilson 2011: ch.1).

¹⁷ Kehoe (2007).

¹⁸ Some contrast here with Pleket (1993: 329).

period is certainly marked by intensification of vine and olive culture. Modes of private land tenure and agricultural management naturally vary from region to region in configuration and balance, but the two predominant types of unit of management were the villa estate, especially in Italy and the west, and (increasingly from the second century AD in the west) large estates consisting of agglomerations of individual farms, with parcels let out to tenants or exploited through a combination of tenancy and free or slave labour. Until the third century AD, alongside private land, there was a very significant amount of publicly and imperially owned land, generally managed through a system of small-scale tenancy.¹⁹ The quantity of such land certainly increased in the early empire and significantly decreased after the third century.

Such a broad summary of the most general kind obviously tends to gloss over significant regional differences. On the larger scale, the most obvious emerge from the comparison between eastern and western parts of the empire,²⁰ between the development of a more intensive villa-based agriculture corresponding to demographic expansion²¹ in North Africa, Spain, Gaul, Germany, and Britain, and a lesser degree of growth in the east, where the complex patterns of landownership and exploitation were well established by the Hellenistic period. Nevertheless, there too one can observe the expansion of site numbers, with settlements appearing in previously unoccupied areas, the development of technology, particularly in irrigation, and increased agricultural activity in the early Roman Imperial period.²² It is obviously difficult to offer any general propositions that can characterize the agrarian economy as a whole across such a diverse empire and a long chronological span. Scholars who have addressed the issues on this scale have tended to think about the essential and defining characteristics of growth and development, which might then be identified (or not) to greater or lesser degrees in different regions. Pleket has usefully identified some of these characteristics that are germane to our discussion:²³

- increase in the quantity of land under cultivation, noting the importance of ‘marginal’ lands brought into cultivation;
- better methods of cultivation and crop rotation, decreasing fallow and increasing cultivation of fodder crops;
- increased output and high yield ratios;
- increased specialization and commercialization of expanding markets;

¹⁹ Imperial estates were effectively tenanted public land, although classified differently, at least in Egypt, from the category of public land, which comprised both *demasia ge* and *basilike ge* (former Ptolemaic royal land).

²⁰ See Alcock (2007); Leveau (2007).

²¹ Cf. Pleket (1993: 329).

²² Certainly in Egypt (see Bowman, Chapter 7, this volume), but clearly not only there.

²³ Pleket (1993).

- the rise of larger, more efficient estates and its corollary, the decline of the peasant economy.

It should be emphasized that we see these as propositions for testing, not necessarily accepting, and there are clearly significant modifications or nuances to be applied to all of them, in particular the last, which we do not think applicable as it stands to the agrarian economy of late antiquity; larger estates are not necessarily consolidated, not necessarily more efficient, and do not necessarily entail the ‘decline’ of the peasantry.²⁴ In any case, we should not fall into the trap of assuming that the rise of the large estate is a purely late antique phenomenon; scholarly focus on the large estates of late antique Egypt is chiefly a result of the abundant papyrological evidence, but the archaeological evidence of pressing facilities in North Africa, Gaul, and Istria implies very large consolidated villa estates in the western provinces in the second and early third centuries AD. Indeed, the villa system was a distinctive and crucial element of Roman agriculture in the western provinces, sometimes as a kind of plantation agriculture concentrating on cash-crop production for market sale. The capital-intensive nature of these enterprises may be judged from the degree of investment in, for example, large-scale wine- or oil-pressing facilities (discussed in the chapters by Marzano and by de Vos),²⁵ in the channel irrigation systems of Iberia and North Africa,²⁶ or cisterns for irrigated horticulture in the hinterland of Rome.²⁷ The need to commercialize agricultural surplus on a large scale meant that villa organization and urban markets were therefore closely linked, and villas tend to cluster more densely around towns. The system of intensive villa agriculture flourished under conditions of security and access to large overseas markets, but in the long run proved less resilient than the more diversified and often village-based systems of exploitation in the east, when these conditions broke down.

On cultivation and rotation we would certainly be more emphatic about improved technology and the failure by some ancient economic historians to recognize the existence of various rotation systems.²⁸ Pleket’s provisional conclusion, however, that there is no justification for seeing a gap between a

²⁴ Dossey (2010: 41–54) proposes to identify a large sector of ‘subsistence’ farmers, defined as peasants with little or no access to the market, in north Africa, but we would not want to see this phenomenon generalized without detailed demonstration; and cf. in any case the arguments against ‘subsistence’ farming propounded by Horden and Purcell (2000: 272–4). Scheidel and Friesen’s contention (2009) that archaeologically identifiable sites represent an upper echelon of settlement and that we are missing the vast majority of rural settlements that existed at subsistence level with no access to diagnostic material culture (pottery, coins, even durable building materials) is problematic and risks circular reasoning, which first postulates absence of evidence and then takes it as evidence of absence.

²⁵ See also Wilson (2002: 5–6).

²⁶ See, e.g., du Coudray la Blanchère (1895); Shaw (1982); Beltrán Lloris (2006).

²⁷ Wilson (2009b).

²⁸ See Kron (2000).

‘primitive’ Roman level and a more advanced ‘protocapitalistic’ level of medieval and early modern European agriculture in a highly diversified agrarian world is of interest to us and is broadly consonant with our position.²⁹

MACROECONOMIC MODELS OF THE ROMAN ECONOMY

Jongman’s study of Pompeii and much recent work by Scheidel, including the contributions to *The Cambridge Economic History*, exemplify the increased focus on the construction of quantified models of the performance of the Roman economy in particular, for which Hopkins’s well-known taxes-and-trade model had already blazed a trail a decade before Jongman’s book appeared.³⁰ In fact, such an approach should ideally be applicable to the ancient Mediterranean and the Near East on a broader geographical and chronological scale, but has perhaps proved most attractive for the Roman empire because of its perceived political (and eventually) economic unity. For all its weaknesses, Hopkins’s model has been very influential, not least methodologically, and it certainly deserves credit for addressing, among other matters, the issue of how the political unity of the empire stimulated economic growth and ‘smoothed’ inequalities in production and consumption across a vast geographical area. This has stimulated scholars to consider how the economy of the empire can be addressed as, in some sense, a coherent entity, through quantification. Hopkins himself modified his position in response to criticisms, and there have been numerous recent attempts to refine and develop this kind of approach. From our present perspective, intensification and decline of trading activity must be related in some way to stimulation, growth, and depression of agricultural production, and we perhaps do not need to be too concerned to weigh the importance of taxation as a driver of trade.³¹ We do, however, need to consider the parallel issue of rent structures as mechanisms that might either stimulate or inhibit agricultural production, an issue explored in Kehoe’s chapter. But we should question whether the level of cash-crop market-oriented surplus production, linked to villa culture, that we do see particularly in the western empire between the first century BC and the third or fourth centuries AD is explicable solely by the taxes-and-trade model; the villa phenomenon reflects a profit mentality that exploited the accessibility of larger distributed markets resulting from the lowering of transaction costs with the development of empire-wide political and economic institutions.

²⁹ Exemplified by Rathbone (1991).

³⁰ Hopkins (1980), with revisions in Hopkins (2002).

³¹ More in Wilson and Bowman (forthcoming).

Most of the recent attempts to gauge orders of magnitude of production and consumption on an empire-wide scale have adopted a top-down rather than bottom-up approach, as is characteristic of the *Cambridge Economic History*.³² That is to say, they make no attempt to identify and aggregate individual local or regional productions but assess, for example, what would be required for basic subsistence needs in wheat equivalent of a population of (estimated) given size. Thus, for example, the most recent attempt to model income distribution makes estimates of GDP in wheat equivalent consumption, at various levels, which can then be aggregated for (estimated) population figures and quantified by applying a cash value (again uncertain) within parameters.³³ Expressed in this way, such a calculation obviously has limited value as an actual quantification of the agricultural production of the empire as a whole. Estimates based on minimum subsistence for a hypothetical population figure do not, of course, tell us anything about the size of surplus that the Roman economy was actually capable of producing beyond supporting a population at a level above subsistence. Another analogous approach would be to construct an argument based on the assumption of the relative reliability of (for example) Duncan-Jones's estimate of annual turnover in the Roman imperial budget in the second century AD at 832 million sesterces, rounded up for the sake of simplicity to 900 million sesterces.³⁴ On the assumption that the generation of wealth through agriculture constituted something in the range of 75–85 per cent of the 'productive sector', as envisaged above, we could then calculate its value in the budget at c.675 million sesterces per annum and convert that to a wheat equivalent by applying an average or median cash equivalent value to the *modius* of wheat.³⁵ Some further calculation can be made as to what proportion of the diet wheat actually constituted (about 70 per cent?), and this will allow inferences about other sources of foodstuffs, including meat and fish but always bearing in mind that agricultural, or, perhaps more accurately, rural production is largely but not totally accounted for by foodstuffs (consider, for example, flax, flowers, sources of drugs, building materials such as reeds, balsam groves, and so on). Any such further calculation would also be in the nature of a guess-estimate and is bound to obscure significant regional diversity. But such an attempt at quantification would have no evidential value, being a product entirely of the assumptions used as inputs, and in fact would tell us nothing beyond what the model is assuming.

³² The most significant of these, by Hopkins (1980), Goldsmith (1984), Temin (2006), and Maddison (2007), are cited and discussed by Scheidel and Friesen (2009), along with references to many other relevant books and articles.

³³ Scheidel and Friesen (2009).

³⁴ Duncan-Jones (1994); cf. Scheidel and Friesen (2009: 68 n. 26).

³⁵ Cf. Scheidel and Friesen (2009: 68), using values of 2, 2.5, and 3 sesterces per *modius*, thus admitting the uncertainty of such average values.

Nevertheless, scholarly activity along the lines of macroeconomic quantification in the last twenty years or so has been noticeably increasing with some powerful advocates for its usefulness.³⁶ There is a tendency in some quarters to see this as a necessary initiative in a field regarded as ‘under-theorized’, sometimes without explicitly explaining or justifying the need for more modelling and theorization. Perhaps it is regarded as self-evident that such large-scale models are really the only useful tools for comparing agricultural or agrarian economies in different empires, regions, and periods and are the only way of doing this in contexts where (as in the Roman empire) some absolutely crucial factors (size of population, level of yields, and so on) can be estimated only with varying degrees of ‘notionality’.³⁷ Likewise, the greater the degree of notionality or the wider the parameters of the estimates, the more inevitable it is that the model will expand to allow for a wider range of possible scenarios that must take us further away from the empirical (and now to a large extent unrecoverable) reality. There are three further comments we would make about this. First, that such models of very large units such as the Roman empire often pay too little attention to regional or chronological variation, although we naturally recognize that some theoretical models such as Hopkins’s ‘taxes-and-trade model’³⁸ do recognize diversity within the whole (that, indeed, is a large part of the point of the model), as do the surveys in the *Cambridge Economic History*. Second, that they tend to ignore much of the actual evidence, particularly the archaeological evidence that is very much at the centre of our concerns. Third, that the actual figures used in the models are often, perhaps even usually, extremely fragile.³⁹ According to Scheidel, this does not matter (although the danger of subsequent misuse or misunderstanding of such figures seems to us to be a very real danger).⁴⁰

That said, we do recognize and acknowledge the usefulness of some models (not all of them) in advancing our understanding of the Roman agricultural economy, and this volume contains one contribution by Goodchild that explicitly discusses and offers a model-based approach to understanding Italian agriculture through the evidence of archaeological survey. We are convinced that some models of this sort can lead us to a sharper definition and comprehension of the key structural features (markets, mechanisms of exchange, land use, investment, vertical integration, and so on). We can refine

³⁶ Hopkins (1980, 1983, 2002); Goldsmith (1984); Manning and Morris (2005); Temin (2006); Maddison (2007); Scheidel (2007).

³⁷ Though this is not the approach of Pleket (1993).

³⁸ Hopkins (1980, 1983, 2002).

³⁹ For example, population estimates, but not only those.

⁴⁰ Scheidel (2009: 60–1). There is a clear example of such misuse in the quantified data for ancient shipwrecks compiled by Parker (1992), which have often been used by others to draw flawed conclusions in ways not intended by the author (for discussion, see Wilson 2009a, 2011).

our analysis of the institutional role of the state and of the balance of production, distribution, and consumption, which will in turn allow some estimate of the distribution of resources and of wealth in the society. We can gauge the value of proxy evidence in the debate about economic growth or decline.⁴¹ We can better understand the relationships between different factors or elements such as population, urbanization, state revenues, modes of production, and labour relations. Although we eschew an explicitly theoretical or model-based approach on the scale of the whole empire in this volume, many of these relationships are implied or discussed in the various contributions and will affect our estimates of macroeconomic features such as aggregate GDP, use of surpluses, tax revenue, and so on.

Furthermore, the actual figures used do matter to us, as Goodchild's contribution exemplifies. This, we emphasize, *is* built on hard archaeological evidence. Indeed, her chapter shows very clearly why the estimates produced to date for Roman GDP in wheat equivalent are largely pointless, since at some stage they involve a largely arbitrary multiplier of production as a factor above bare subsistence, and thus they assume precisely one of the most important things we would like to find out—how well did Roman agriculture do in producing a surplus? It matters greatly what data one plugs into such models, and Goodchild illustrates the very different results obtained, in terms of surplus production, by assuming a series of different models of landscape exploitation (farm size, crop monoculture, or polyculture) for the same region.

THE CONTENT OF THIS VOLUME

Having identified some of the obstacles to broad and robust macroeconomic quantification, we may now attempt to indicate positively how the contents of this volume might contribute to progress in understanding the agricultural economy. A brief synopsis will help to focus the discussion.

In Chapter 2, Dennis Kehoe analyses the institutional and political context by examining two main aspects of the Roman agrarian economy in relation to the state: the state as landowner and economic actor; and the various legal and administrative policies that the state developed for the rural economy.⁴² Under the first heading, Kehoe considers the effect of state taxes and of rents on imperial estates on the rural economy. Under the second, he analyses Roman legal policy in relation to private land tenure, including incentives for the exploitation of marginal land, and measures for safeguarding property

⁴¹ Cf. Lo Cascio (2007: 621–5).

⁴² Different aspects of the role of the state will be analysed in more detail in our volume on trade (Wilson and Bowman forthcoming).

rights and encouraging investment. He also examines state policy in relation to commerce in agricultural products, arguing that Roman rule developed more responsive legal institutions that provided protection not only to the wealthy and well connected, but also to the economically less advantaged.

Goodchild's chapter summarizes recent research on the use of GIS computer models for quantifying agricultural output, discussing the purpose of such modelling in archaeological research, and demonstrating where such models can contribute to historical debates. She applies multi-criteria modelling techniques to investigate Roman agricultural production in the middle Tiber valley in central Italy, and compares farm and villa production in the region under several different production regimes.

In the first of her two chapters, Marzano examines the intensity and organization of wine and olive oil production in the *suburbium* of Rome, by analysing the distribution of 169 oil and wine presses in the region. The density of presses per unit of area suggests that production of oil and wine in the region was considerable and supports de Sena's argument⁴³ that a significant proportion of the wine and oil consumed at Rome came from the surrounding hinterland. The lack of amphora evidence from the region suggests the products were transported to Rome in skins. The *suburbium* of Rome, in addition to *pastio villatica* and market gardening of fruit, vegetables, and flowers for the city of Rome, appears also to have been involved in intensive viticulture and even olive cultivation. The recognition of this phenomenon and the chronology of the sites also cast doubt on the idea of a crisis in Italian viticulture under competition from the provinces; Rome was absorbing a large proportion of Italian surplus.

In Chapter 5, Marzano extends the analysis of oil and wine presses as indicators of capital investment in agricultural crop processing to three areas exhibiting signs of large-scale production facilities; Gaul, the Iberian peninsula, and the Black Sea. Looking at sites with multiple presses, as an indicator of investment in very large-scale production, she reveals different investment chronologies in the three areas, especially with varying patterns in different areas for the third century. She also identifies, in Gaul, a different pattern between wine and oil investment. The chronology of multiple-press installations in the three regions shows that the second century is the period when the highest number of presses was in operation, and in Gaul and the Black Sea the decline in the fourth century is steep. The cumulative known installation dates for the press facilities indicate that the peak in investment in the creation of multi-presses occurred in the first two centuries of the empire; in both Spain and the Black Sea region, this is paralleled by the development and peak of the fish-salting industry.

⁴³ De Sena (2005).

The chapter by de Vos presents the results of archaeological survey in the well-preserved North African landscape of the middle Medjerda (Bagradas) valley, and also draws some comparisons with survey work in Algeria. The abundant epigraphic and archaeological record enables an extraordinarily rich analysis of the agricultural exploitation and landholding patterns: individual farms and villas with oil or wine presses can be situated within estates whose boundaries are known from marker stones; the development of the estates of T. Statilius Taurus into the imperial estate of the *saltus Neronianus* can be traced, and the landscape exploitation related to the *lex Manciana* and the *lex Hadriana de rudibus agris*, referred to on the well-known inscriptions governing tenancy rights on imperial estates (which are discussed in Chapter 2), a new copy of which was found at one site.⁴⁴ The chapter also examines irrigation infrastructure, and transport networks for conveying the surplus production to distant markets. This chapter presents much new material for the first time and provides an exceptionally rich analysis of a Roman agricultural landscape, both linking well with Kehoe's chapter and providing a wider landscape context for the kinds of large-scale oil and wine production analysed for other provinces in Marzano's chapters. The potential for connecting epigraphic and archaeological evidence for this area has long been recognized, and de Vos's chapter marks a significant step towards realizing this.⁴⁵

Three chapters focusing wholly or partly on Egypt follow. Bowman's study analyses various strands of quantifiable evidence for the scale and range of agricultural scenarios in regions, towns, and villages in Egypt. This includes an analysis of nome (district) sizes, and areas devoted to cultivated area, grain-land, gardens, and vineyards; calculations of grain yields and tax income for the Arsinoite Nome for the year AD 184/5; the distribution of land among landowners on the basis of tax registers and legal declarations for the nome capitals, and the rather different (and less unequal) patterns of distribution of landownership in village communities. At the village level, case studies are possible for intensive wine production at Philadelphia in the third century BC; land use at Theadelphia in the second century AD; and the sale and leasing of land at Tebtunis in the second century AD. Data from several regions indicate severe decline in agricultural production and tax revenues between the second and fourth centuries AD.

In Chapter 8, Blouin examines the fiscal and cadastral documentation for the Mendesian Nome in the Nile Delta, significant because documentary material from this fertile area is very rare and provides an important counterpoint to most papyrological studies of Egypt, which focus on evidence from the Nile valley. Using the carbonized archives from Thmuis, she identifies the

⁴⁴ See also Kehoe (1988).

⁴⁵ Hitchner (1995).

chief characteristics of the Mendesian agricultural economy, while an analysis of *P. Oxy.* XLIV.3205 offers a unique glimpse into the agrarian reality of a Mendesian village at the turn of the fourth century AD. The comparison of data from *P. Oxy.* XLIV.3205 with the agrarian and fiscal terminology in the Mendesian papyri shows that the agricultural economy of this region in the Roman period was characterized by a preponderance of cereal farming, with vine cultivation in second place. There are relatively few data relating to the growing of fruits and vegetables (including olives), lentil, and flax, but this is probably due to documentary bias as well as to the particular conditions in which these activities were practised and taxed. The diverse economic practices of the region, which also included livestock and fisheries, hunting and gathering, probably resulted, as in the Fayum and the Nile valley, from 'opportunistic' adaptations to the local deltaic environment. They are also symptomatic of a rivalry between the interests of those who held economic power (the state, large property owners, and merchants) and those of the small owners and managers, for whom diversification for domestic needs was advantageous, or even essential.

Malouta and Wilson compare the archaeological, literary, and papyrological evidence for water-lifting devices across the empire in an attempt to situate the evidence that we have for investment in irrigation machinery within the wider picture of evidence survival. Collection of the literary, documentary, and archaeological evidence for water-lifting devices over time shows a clear difference between the two categories of evidence, each of which is individually problematic; but comparison between the categories is revealing about the nature of the datasets. In the papyri, irrigation machinery constitutes the overwhelming bulk of attestations of water-lifting devices, whereas irrigation machines are rarely traceable archaeologically. The archaeological evidence increases sharply in quantity before the literary evidence does, in the second century BC, consistent with seeing the widespread diffusion of these technologies under the conditions of political unity and increased communication enabled by the Roman empire. The quantity of archaeological evidence drops considerably after the fifth century AD—in sharp contrast with the papyrological evidence for Egypt, which shows a major peak in the sixth and seventh centuries. The fifth- and sixth-century papyri contain proportionately more references to water lifting than before, perhaps for reasons connected with the type of document containing the evidence. Because of different biases in the different kinds of evidence, and the changing visibility threshold of different devices over time, it is clear that no single type of evidence—archaeological, literary, or papyrological—gives a reliable picture of the trends in usage of water-lifting technology (and, by extension, probably of other technologies too), and that any real understanding of the phenomenon must come from an analysis of all the types of evidence. What is, however, evident from the papyri is that artificial irrigation was not only a significant component of agriculture in

Byzantine Egypt, as is commonly thought, but also a prominent feature of the Egyptian agricultural economy of the Roman period, given the very large number of references to water-lifting machines in the second and third centuries AD. Where the context is given, the irrigation machines mentioned in the papyri were frequently watering intensively cultivated plots of high-value crops—orchards and vineyards.

In the final chapter, Friedman examines the relationship between industry and agriculture, which are too often viewed as separate ‘sectors’, showing how the integration of both provides insights into the operation of mining regions. The study focuses on the agricultural field systems associated with Khirbet Faynan, a settlement associated with the smelting activities for the nearby important copper mines of Faynan (ancient Phaeno). An analysis of the development and chronology of the field system produces a series of phased calculations over time for the number of people that could be supported from it; the effects of pollution from smelting in the agricultural activity of the region are also considered. The centralization of the field systems and creation of larger more sophisticated irrigation systems coincides with the periods of most intensive Roman period copper production. Food production was increased to supply the needs of the non-subsistence populations such as miners and smelters. The first means of accomplishing this was to import food; the second was to restructure the resources within the region. In practice, this second response resulted in the most important piece of arable land in the southern ‘Arabah being changed dramatically through the implementation of a single, carefully constructed and executed plan of land usage. If the centralized field system was created to supply the industry, the abandonment of this type of agriculture in the Late Byzantine period probably coincides with a downscaling of that industry. Greater food production benefited the supply of the region, supporting an increase in the size of populations devoted to mining and smelting, but this in turn led to more pollution and less food, thus adversely affecting the industry it was intended to sustain.

Plainly these studies will not amount to a quantified account of the whole agrarian regime of the Roman empire, which is beyond reach or plausibility for the reasons we have explained. They do, however, point up regional variations and also share common themes in their analysis of surplus production, and directed investment by the state, elite landowners, or even tenant farmers under rental arrangements designed to incentivize investment to increase output. We conclude this introduction by offering some suggestions as to how they might add up to more than the sum of the parts and illuminate some critical aspects of the agricultural economy, in the hope that the methods and perspectives can be applied to other kinds and other sets of data and to other areas that are not treated here.⁴⁶

⁴⁶ We recognize that three crucial elements must be central to any discussion of economic structures: capital, land, and labour. For a good summary discussion, See Erdkamp (2005: 12–54).

REGIONAL DIVERSITY

It will be observed that it is difficult, though in our view not impossible, to attempt economic quantification with any evidential basis except for a limited number of places. As Goodchild's chapter suggests, we can consider how to achieve something in the nature of a quantified model of the relationship of various factors in the agricultural sector focusing on a micro-region. We suggest, however, that the contents of this volume show that the limitations are not quite so severe as has often been alleged. For example, for Egypt, Rathbone's study of the Appianus estate along with Bowman's chapter in the present volume do offer some calculations along these lines.⁴⁷ More robustly, Van Minnen has suggested that Egypt is the only area for which one can construct a reliable and quantified 'taxes-and-trade model', although he has not actually done so.⁴⁸ It will, however, be obvious that any such Egyptian model will yield a result that generally shows substantial surpluses, with some temporal variation, across long periods of time. Van Minnen's position may seem too aggressive to those who are not Egyptian specialists, especially if they misunderstand him to mean that Egyptian conditions are replicated and applicable elsewhere. But there is a more nuanced expression of that position that would suggest that the Egyptian evidence does allow some quantification in the relationship between agricultural production, state revenues, and the movement of goods and financial resources around the empire: that is, although its agriculture was, atypically, based on the annual Nile flood, Egypt was not atypical in the structure of agricultural management, development of markets, level of monetization, and extraction of revenue by the state, only in the extent to which we can put some detail into the structural picture.

In contrast, there is as yet relatively little good archaeological evidence for Egypt, and we rely mainly on the documentary evidence in the papyri for a regrettably isolated glimpse of conditions of land use in the Delta in the second century (which will in due course be supplemented by a more detailed analysis⁴⁹) and for an attempt to analyse the scale and patterns of production in the Fayum villages and in the nomes of Middle Egypt. The evidence for yields, returns, and surpluses, as well as the changing patterns of land tenure and ownership, is more detailed than anything that can be derived from other sources and regions, but the trends that it suggests cannot be ignored in dealing with contemporary evidence from other places. In this respect, the contrasting study of the Wadi Faynan offered by Friedman is illuminating. The agricultural economy of the region responds specifically (and in quantifiable terms, within parameters) to the increase in mining activity, which must

⁴⁷ Rathbone (1991).

⁴⁸ Van Minnen (2000).

⁴⁹ Blouin (forthcoming); cf. Blouin, Chapter 8, this volume.

be directed by the central government. The region is very different from the agglomerations of agricultural villages in Egypt, but comparison of the governmental, technological, and economic drivers is nevertheless significant; the mining activities in the Egyptian eastern desert and the Red Sea quarries created a need to which the response took a very different form, dictated by total lack of a local agricultural infrastructure and the presence of developed communication routes and trading facilities.⁵⁰ Both cases emphasize the impossibility of making a clear demarcation between the agricultural economy and other kinds of economic activity.

The essence of the 'taxes-and-trade model' (discussed above) is, of course, that, in addition to supplying food to the megalopoleis, such surpluses will be directed towards making up for shortfalls in less productive areas, which have been identified in a general way as the less developed and more militarized frontier provinces, but it is not to be assumed that such provinces or regions could not have been self-sufficient if one discounted the costs of the military protection. Generally speaking, we lack the evidence to demonstrate this empirically. But Kristina Glicksman's recent thesis produces quite an optimistic picture of the economy of the province of Dalmatia,⁵¹ and we should remember that even in Moesia a governor of the reign of Nero, Plautius Silvanus, was able to settle 100,000 *transdanuviani* with their families *ad praestanda tributa*.⁵² Another approach might be through some case studies of particular crops or other types of foodstuffs such as meat and fish, for which pioneering exemplars already exist:⁵³ there are well-known studies of North African olive oil, but wine production, where there is surely significant expansion in several areas over the Roman period, partly but not solely in response to increased demand from large metropoleis, perhaps deserves more attention from this point of view.⁵⁴

Goodchild's chapter in this volume also articulates much more explicitly the nature of GIS-based models and the ways in which they can be used to model the agricultural economy of a specific region in the Tiber valley, using robust archaeological evidence derived from surveys that reveal farm and villa sites in the hundreds. It will be seen that the evidence offered for other regions by other contributors to this volume shows both similarities and contrasts and is not systematically modelled in the manner of Goodchild's material; the evidence is now becoming available to make this a possibility for some areas of North Africa in the future (De Vos's survey region around Dougga would

⁵⁰ Cuvigny (2003); Schörle (2008, 2011).

⁵¹ Glicksman (2009).

⁵² *ILS* 986.

⁵³ Meat: King (1999). Fish: Marzano and Brizzi (2009).

⁵⁴ Olive oil: Mattingly (1985, 1988a, 1988b, 1994, 1996); Mattingly and Hitchner (1991, 1993); Hitchner (1993, 1995); Brun (2003b, 2004). Wine: Tchernia (1983, 2006); Panella and Tchernia (1994); Brun (2003a, 2003b, 2004); Banaji (2002) for late antique Egypt.

be amenable to this kind of treatment). However, for many regions the methods of approach to different bodies of evidence and the aspects of the agricultural economy that they illuminate are different. Egypt, of course, benefits from a quantity of detailed papyrological evidence unparalleled elsewhere in the empire, but the relatively underdeveloped state of the archaeology of rural or village settlement pulls in the opposite direction; as Malouta and Wilson's chapter shows, the picture one might draw of certain phenomena, such as the chronology and extent of the use of water-lifting devices for irrigation, might differ considerably if one looked only at the papyrological or the archaeological dataset in isolation. The comparison of the detailed evidence for the Thugga region in North Africa presented in the chapter by de Vos, where the archaeological survey material can be linked to the epigraphic record, with that from the Tiber valley is suggestive. Here we have, once again, a large amount of quantifiable archaeological evidence derived from intensive survey and excavation that can be amplified by the epigraphic evidence to show, *inter alia*, intensive development of oleoculture, the history of family ownership of estates and the balance between public/imperial, private, and urban land, the survival of different regional technological traditions well beyond the period that we treat here. It is worth emphasizing that, with this valuable material, De Vos enables us for the first time to get to grips with fleshing out the picture for which the well-known Bagradas valley inscriptions yield valuable and well-known evidence for the management of imperial estates in the second and early third centuries.⁵⁵

INVESTMENT AND INTENSIFICATION

The archaeological evidence for agriculture consists chiefly of farms or villas, field systems, irrigation infrastructure, and the buildings and equipment used to process and store crops.⁵⁶ While buildings or irrigation systems may give a general indication of levels of investment, if we want to examine trends in what kinds of crops were produced, the evidence for processing equipment is most informative. However, our picture is directly influenced by the archaeological visibility and survival of different types of processing infrastructure. Some crops—for example, beans and pulses—do not require archaeologically distinctive equipment to grow, process, or store, and appear to have been transported in sacks that leave no archaeological trace. Grain production, as

⁵⁵ Kehoe (1988).

⁵⁶ Archaeological finds of carbonized or desiccated seeds, finds of agricultural tools and implements, or iconographic representations of agricultural activities may indicate a range of crops grown or harvested but can hardly form the basis for an assessment of scale.