



Australian Government
Australian Centre for
International Agricultural Research

GRDC
Grains
Research &
Development
Corporation



Crop yields and global food security

**Will yield increase
continue to feed the world?**

**Tony Fischer, Derek Byerlee
and Greg Edmeades**

Contents

Foreword	iii
Preface	xix
1 Introduction	1
Key points	2
1.1 The problem	3
1.2 Growing demand for crop products	5
1.3 Supply side—our major crops	8
1.4 Supply side—crop area and its prospects	12
1.5 Supply side—crop yield, price questions and trade	19
1.6 Yield progress and prospects—the focus for this book	26
2 Definitions, procedures and underlying crop physiology	27
Key points	28
2.1 Yields and yield gap definitions	29
2.2 Measuring progress in farm yield and potential yield	34
2.3 New technology, farm yield progress and yield gap closing	40
2.4 Confounding factors in farm yield change	41
2.5 Other measures of efficiency and productivity under technical change	43
2.6 Weather and soil parameters and physiological determinants of yield	46
2.7 Concluding remarks	64
3 Wheat	65
Key points	66
3.1 World wheat and its mega-environments	67
3.2 WME1—Yaqui Valley, Mexico	71

3.3	WME1—Indo-Gangetic Plain and the Indian state of Punjab	82
3.4	WME1—Egypt	90
3.5	WME4—Australia, notably Western Australia	92
3.6	WME6—spring wheat at high latitudes	100
3.7	WME10-dominated wheat in China	107
3.8	WME11—United Kingdom and other parts of north-western Europe	114
3.9	WME12—Great Plains of the USA and other regions	121
3.10	Summary of yield progress in wheat	126
4	Rice	133
	Key points	134
4.1	Rice countries and mega-environments	135
4.2	RME1—Central Luzon in the Philippines, and other rice bowls of South-East Asia	139
4.3	RME2 and RME3—China	149
4.4	Irrigated rice in the Indo-Gangetic Plain (IGP) region of India	155
4.5	RME3—Japan, the first modern rice nation	161
4.6	RME4—Egypt	166
4.7	RME3 and RME6—Brazil	168
4.8	RME5 and RME6—rainfed rice in India, North-East Thailand and elsewhere in Asia	172
4.9	Summary of yield progress in rice	176
5	Maize	181
	Key points	182
5.1	World maize and its mega-environments	183
5.2	MME7—Corn Belt of the USA	189
5.3	MME7 and MME8—Northern China—large temperate maize mega-environments	201
5.4	MME1-6—Maize, a staple food crop in Sub-Saharan Africa	213
5.5	Maize in Brazil and Argentina	226
5.6	Maize cameos—Europe and Bangladesh	234
5.7	Summary of global maize	237

6 Soybean	241
Key points	242
6.1 Global soybean progress	243
6.2 Soybean in North America	245
6.3 Soybean—a new crop in the new lands of South America	252
6.4 North-eastern China—the old home of soybean	255
6.5 Summary of global soybean	256
7 Other crops	259
Key points	260
7.1 Introduction	261
7.2 Coarse grains other than maize	261
7.3 Pulses	267
7.4 Rapeseed (canola)	273
7.5 Other oilseeds—peanut and sunflower	276
7.6 Sugarcane and sugar beet	280
7.7 Cassava	285
7.8 Oil palm in South-East Asia and elsewhere	290
7.9 Potato and sweetpotato	293
7.10 Conclusion for other crops	295
8 Closing yield gaps	297
Key points	298
8.1 Yield gaps and methodologies	299
8.2 Causes of yield gaps	307
8.3 Technologies and policies for alleviating yield gaps	313
8.4 Effecting the adoption of improved varieties and practices	317
8.5 Some success stories	324
8.6 Conclusion on yield gap closing	331
9 Increasing potential yield	333
Key points	334
9.1 Introduction	335

9.2	Physiological components of progress in potential yield	337
9.3	Increasing the sum of intercepted photosynthetically active radiation	340
9.4	Increasing radiation use efficiency	342
9.5	Modelled predictions of potential yield and understanding record and contest yields	347
9.6	Physiological components of progress in water-limited potential yield	351
9.7	New agronomy for greater potential yield under limited and unlimited water	358
9.8	Hybrid vigour	361
9.9	Genetic engineering for yield	363
9.10	Genetic resources, and new tools and institutional structures for yield breeding	366
9.11	Intellectual property, breeding privatisation and transgenic regulation	373
9.12	Concluding comments—new technologies towards 2050	376
10	Climate change, crop yield, adaptation and mitigation	381
	Key points	382
10.1	Introduction to cropping under climate change	383
10.2	What time series tell us about climate change	385
10.3	Direct measurements and crop simulation modelling	397
10.4	Scope for adaptation to climate change, especially warming	412
10.5	Greenhouse gas emissions from cropping and their mitigation	420
11	Resource use efficiency, sustainability and environment	433
	Key points	434
11.1	Introduction	435
11.2	Water use efficiency	436
11.3	Nutrient use efficiency	443
11.4	Energy use efficiency	462
11.5	Sustainability in modern intensive agriculture	466
11.6	Off-site effects of cropping intensification	484
11.7	Conclusions on efficient resource use and sustainable cropping	491
12	Trends in total factor productivity	493
	Key points	494

12.1	Introduction	495
12.2	Explaining total factor productivity	496
12.3	Global and regional trends in total factor productivity	499
12.4	Brief case studies of total factor productivity trends by country	504
12.5	Synthesis of trends in total factor productivity	511
13	Policies and people	513
	Key points	514
13.1	Introduction	515
13.2	Investment in research and development to accelerate productivity growth	515
13.3	Other public investments influencing productivity growth	524
13.4	On-farm private investment	527
13.5	Other policies influencing productivity growth	528
13.6	Who will grow the food?	531
13.7	Conclusion for policies and people	537
14	Summary and conclusion	539
	Key points	540
14.1	The question unpicked	541
14.2	Assessing prospects for increased global grain yields	542
14.3	The story of crop yield change	543
14.4	Prospects for yield gap closing and progress in potential yield, including under climate change	547
14.5	Socioeconomic and policy perspectives	553
14.6	Resource use efficiency, sustainability and environmental effects	555
14.7	Overall conclusion	558
	Special recognition and acknowledgments	561
	Abbreviations and glossary	571
	Units	571
	Weather, soil and crop characteristics, and economic terms	572
	Other scientific terms and abbreviations	574
	General abbreviations	576
	References	579