Agribusiness

Agribusiness offers a unique introduction to the business of agriculture: what agribusiness is, why it matters, what the role of technology is, how trade fits into the picture, what its key risks are, who is lending and investing and why and what returns they are getting. It is both practical in orientation – focusing on the role of managers in the industry as well as that of lenders and investors – and international in scope – drawing on case studies and interviews with key figures all over the world.

The text ranges across various agricultural commodities to stress that there is no 'one size fits all' solution and successful management, lending or investment in agribusiness requires understanding specifics. Readers are introduced to the economics of the supply and demand of food, the role of agricultural trade, agricultural marketing and farm management along with key business aspects including:

- Main drivers of agribusiness value;
- Principal risks of agribusinesses;
- Agribusiness as an investment class; and
- Agribusiness lending: why, who and how.

This engaging textbook offers a complete guide to the international business of agriculture which is ideal for all students, scholars and practitioners.

A selection of eResources is also available to supplement this text, and instructors will find PowerPoint slides, discussion questions, case studies and further teaching materials available to them.

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Agribusiness

An International Perspective

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2020
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Roche, Julian, author.
Title: Agribusiness : an international perspective / Julian Roche.
Description: Abingdon, Oxon ; New York, NY : Routledge, 2019. |
Includes bibliographical references and index.
Identifiers: LCCN 2019017065 (print) | LCCN 2019019819 (ebook) |
ISBN 9781351039741 (Ebook) | ISBN 9781138488656 (hardback : alk. paper) |
ISBN 9781138488663 (pbk. : alk. paper)
Subjects: LCSH: Agricultural industries. | Agriculture–Economic aspects.
Classification: LCC HD9000.5 (ebook) |
LCC HD9000.5 .R5792 2019 (print) | DDC 338.1–dc23
LC record available at https://lccn.loc.gov/2019017065

ISBN: 978-1-138-48865-6 (hbk)
ISBN: 978-1-138-48866-3 (pbk)
ISBN: 978-1-351-03974-1 (ebk)

Typeset in Helvetica and Bembo
by Newgen Publishing UK

Visit the eResources: www.routledge.com/9781138488663

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Preface

The central challenge in writing this book has been how to select what to include from the vast quantity of information out there. Examples rather than catalogues are the rule in this book, not the exception. No doubt every reader will want an inclusion here, a changed emphasis there. It is the risk that every author embarking on a general introduction to a massive topic such as agribusiness must inevitably take. I have tried to indicate wherever possible where further information on particular topics is to be found. But the lesson to be learned, especially so far as agtech is concerned, is that it is now no more possible to corral all the investments taking place in agribusiness, or the available information, than it would be in telecoms or finance, or than it would be possible to assemble all the relevant scientific information about agriculture itself. All I can hope is that there is nothing major missed, whilst I sincerely hope that readers will take the trouble to send me, and through me all those who have bought the book, any additional information or thoughts – initially, at least, for the accompanying eResources for the book. This is especially valuable at a time of such rapid change in agribusiness, agtech in particular.

The eResources are an essential part of this book, especially from a teaching perspective. I have included there four types of resources:

- A set of PowerPoint slides for each chapter;
- The documents referenced in each chapter, except for those protected by copyright such as academic articles not available under open access;
- Some suggested questions for discussion; and

- Additional case studies and other materials, such as Excel files not referenced in the chapter but relevant to the subject matter and which I believe may be useful as teaching resources. As time goes on the number of these additional case studies and files can be expected to rise.

The eResources tab can be accessed at: www.routledge.com/9781138488663

Acknowledgements

My thanks to Mark Blundell, without whose decision to employ me decades ago in the agricultural futures market I would not have conceived an interest in agribusiness. Also to my editor at Woodhead Publishing, Neil Wenborn, who guided me through successive commodity and international trade books with tact and skill. I owe much to the wisdom and foresight of my colleagues in the Commodity Division at UNCTAD, with whom I worked for many years, especially Lamon Rutten and Leonela Santana-Boado. More recently my colleagues at the University of Western Australia, where I have had the privilege to be an Adjunct, are an inspiration. Especial thanks therefore to Professor David Pannell, who originally brought me on board.

During this project I have been helped by many.

I would also like to thank my farming neighbours, both in the Western Australian wheatbelt and in the Highlands of Scotland, whose daily endeavours to provide food are a source of inspiration for agribusiness academics everywhere.

My final thanks are to my wife Gowri and daughter Tabitha for their support during this project.

CHAPTER

1 The need for agribusiness

Introduction: what is agribusiness?

One of the most vexing questions about agribusiness is, perhaps alarmingly, its definition. Or more accurately, what are its boundaries? We might usefully paraphrase Wittgenstein's famous point about games, that there is nothing that all agribusinesses have in common, yet all are agribusinesses nonetheless. In an effort to throw a ring around the subject matter, there have however been over time a number of attempts to define an agribusiness.

The most successful, at least judged by frequency of citation, is still the original definition:

> the sum total of all operations involved in the manufacture and distribution of farm supplies; production operations on the farm; and the storage, processing and distribution of farm commodities and items made from them (Davis & Goldberg, 1957:9).

However there have been a number since:

- In a revised definition that included retailers, Sonker & Hudson (1999) defined agribusiness as a sequence of interrelated sub-sectors made up of: (1) genetic and seedstock firms, (2) input suppliers, (3) agricultural producers, (4) merchandisers or first handlers, (5) processors, (6) retailers and (7) consumers. Notably still absent from this definition were trading companies and land and timber investors.

- The Missouri Department of Agriculture's definition from 2003 was similar: farmers and ranchers producing food, fibre and other raw materials, but also processors, handlers, transportation agents and operators, wholesalers, and finally retailers (Ricketts & Ricketts, 2009:5). Again, traders and investors were left out.

- The Agribusiness Council of Australia said that it welcomed all definitions, because it is the commonly held perceptions about agribusiness that is relevant to its acceptance throughout the wider community. In summary, though, it says, the two concepts are:

(i) ‘In the context of agribusiness management in academia, each individual element of agriculture production and distribution may be described as agribusiness. However, the term ‘agribusiness’ most often emphasises the ‘interdependence’ of these various sectors within the production chain’; and
(ii) ‘Among critics of large-scale, industrialized, vertically integrated food production, the term agribusiness is used negatively, synonymous with corporate farming. As such, it is often contrasted with smaller family-owned farms.’ (ACA, 2018)

Generally, definitions have become wider over time, and as farming has become more technical and capital-intensive, it has been increasingly recognised as agribusiness, practitioners even being described as ‘production agriculturalists’ rather than ‘farmers’. In accounting for the heterogeneity of the agribusiness sector, it would at least be wise to distinguish between primary and manufacturing agribusiness products, most obviously by using the Standard Industrial Classification (SIC) system. Primary agribusiness includes three categories (agriculture; livestock; forestry), whereas manufacturing agribusiness includes ten categories to reflect the variety of traded products (canned; cereals; drinks; leather; meat; oils; paper; tobacco; wood; other). In addition, there are service agribusinesses, notably supermarkets. Finally, there are the traders and the investors, especially in farmland.

Agribusiness now includes all businesses whose raw materials are primarily products of the land and the sea. Finally, it is worth noting that not all ‘businesses’ are there to make a profit, or exclusively to do so, especially those owned by the public sector. But however broad the definition, there is no escaping the negative connotations of ‘agribusiness’ in certain quarters, which should neither be ignored nor celebrated. Rather, advocacy and criticisms of large-scale production should be treated alike, as calls for empirical analysis and evidence-based policymaking wherever possible. As with any contentious subject, this path is not easily trod.

The development of agriculture

The history of agriculture and farming should be swiftly summarised in a contemporary perspective on agribusiness.

Homo sapiens began as nomadic hunters and gatherers, eating wild vegetables, fish and fowl, using fire for cooking. This was followed by farming, and for millennia, agriculture *was* farming – following the seasons in planting and harvesting crops and domesticating animals – to which should be added fishing. Wooden sickles and ploughs gave way to metal in the Bronze Age, which although rainfall appears to have been higher than now also saw irrigation in Egypt and Mesopotamia (Araus *et al.*, 2014), and the use of the wheel; in the Iron Age crops first became part of a commercial system, with the Roman Empire for example prospering on a substantial Mediterranean grain trade (Kessler & Temin, 2007). In the Middle Ages in Europe, crop rotation, fencing, and even limited selective breeding began (Parain, 1966). Increasing efficiency was paralleled by progressively more crops and different animals introduced into agriculture (*National Geographic*, 2018). The use of grains and the development of more productive crops were central to population growth. And grow population did. When farming began, somewhere around 10–15,000 years ago, global human

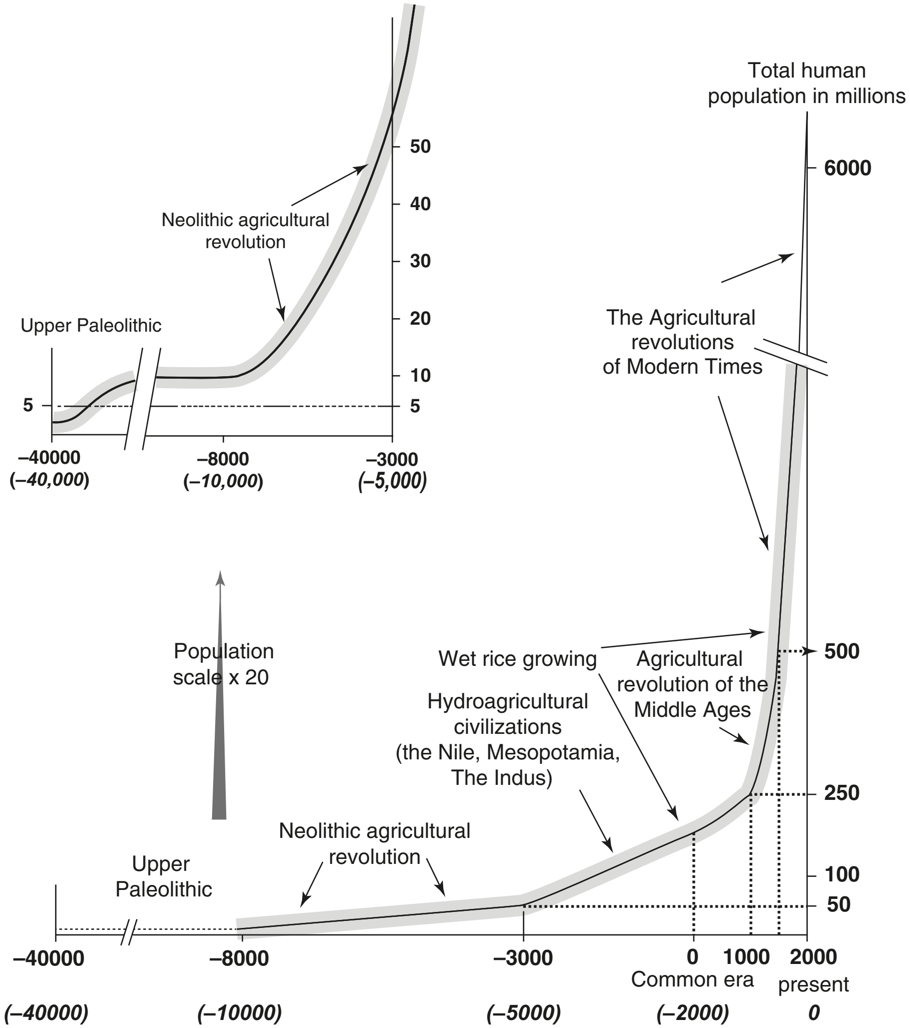


Figure 1.1 Population growth and agricultural systems
Source: Mazoyer & Roubart (2006:63)

population was probably only 1–10 million. Reaching 300 million around the time of Jesus' birth, it doubled in the next millennium and a half. It then rose from 1.5 billion in 1900 to about 7 billion now, and is still rising. True, fertility has declined in most countries, as the 'demographic transition' cuts in, especially in cities, but there are still important exceptions (Zaidi & Morgan, 2017), and the strategic trend is quite dramatic, as Figure 1.1 amply demonstrates. Although it does not include the additional billion people already added since the turn of the century, the figure demonstrates the close correlation between population growth and change in the agricultural systems necessary to support it:

In the later 20th century, artificial insemination for livestock, electric fencing, better ploughs, chemical fertilisers, insecticides and pesticides were all introduced into production

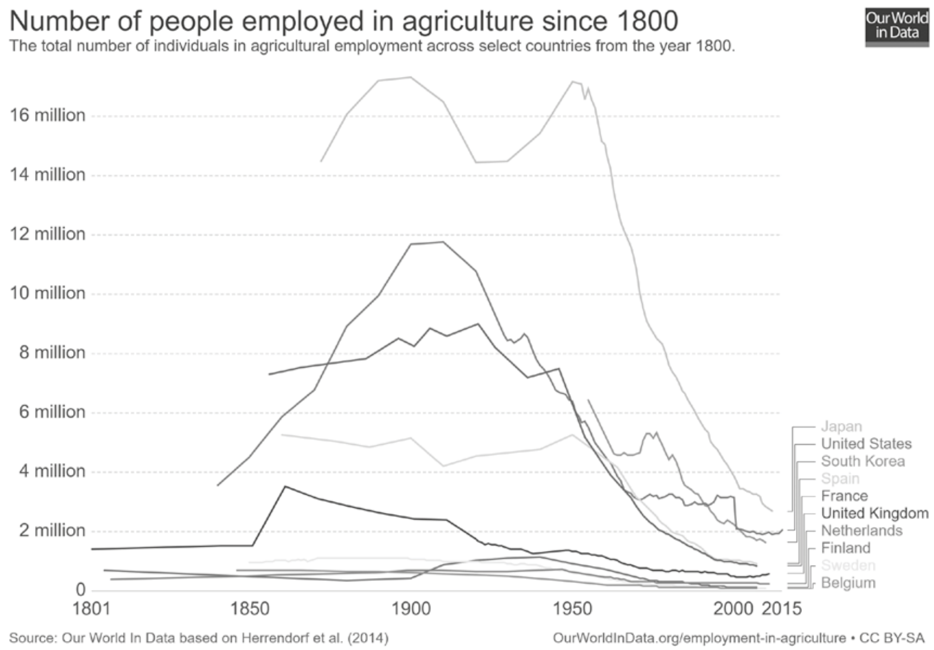


Figure 1.2 Number of people employed in agriculture over time
Source: Roser (2015)

agriculture (Federico, 2005). Risk management techniques improved and agricultural finance became far more widespread. Production grew dramatically, as Figure 1.1 shows, but the effect of the mechanisation that primarily drove production growth was also a dramatic decline in the number of people working in agriculture in advanced economies.

In the 20th century, economies of scale underlay the consolidation of farms that became the norm in developed economies. Whereas in 1900 in the USA there were 5.7 million farms covering 839 million acres, giving an average size of 146 acres (59 hectares), little changed by 1930, in 1997 there were 1.9 million farms covering 932 million acres, giving an average size of 487 acres (197 hectares) (USDA, 2017a). This compares to the EU-28, where in 2013 there were 10.8 million agricultural holdings covering 175 million hectares (some 40.0% of the total land area), giving an average size of 16.1 hectares per agricultural holding (Eurostat, 2015). In France the average farm size is around 50 hectares. And in Australia, home of the largest farm in the world at almost 2.5 million hectares, of all farms with grain in their enterprise mix, the national average for the annually cropped area per farm is just over 800 hectares (ABS, 2018).

In China, however, the average farm size is still just 1 hectares, whilst in Africa smallholders are working with even smaller landholdings (FAO, 2018). In the poorest 20% of countries the average farm size is 1.6 hectares, while in the richest 20% of countries the average farm size is 54.1 hectares, a 34-fold difference. In poor countries, very small farms (less than 2 hectares) account for over 70% of total farms, whereas in rich countries they account for only 15%. In

Table 1.1 ABARES categorisation of Australian broadacre dairy farms

	Small	Medium	Large
Turnover	<A$450,000	A$450,001–A$1m	>A$1m
% number	70%	20%	10%
% total value of sales	24%	27%	49%
Capital value	<A$5m	A$5–9m	A$9m+
% off-farm income	>50%	<50%	Small percentage

Source: ABA RES (2017:155)

poor countries, by contrast, there are still virtually no farms over 20 hectares, while in rich countries these account for 40% of the total number of farms (Adamopoulos & Restuccia, 2014).

The debate over the survival of family farms has been prolonged. On the one hand is the belief that only massive subsidies are preventing their total eclipse. 'Using smallholdings agriculture as a development policy is like promising an automobile to everyone in the world, but limiting construction to hand labor' (Blumenthal, 2013:112). On the other is the contention that many company farms are family companies, incorporated only for taxation purposes, and that even in developed countries, most farms continue to be operated by families, employing labour in addition to family members. But even Brookfield & Parsons (2007), the last celebrated enthusiasts for family farms, recognised that in what was for them the future there will be fewer of them than before, albeit that some farms will continue to grow whilst others ebb.

This is a far larger definition of 'small' than even the current USDA definition of a farm, which is 'any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the year' (USDA, 2014). The USDA's Economic Research Service (ERS) divides farms into four, based on turnover:

- Small family farms both low <$150,000 and medium $150–349,000;
- Mid-size family $350–999,000;
- Large-scale family $1m+, very large $5m+; and
- Non-family farms – primary operator's family does not own 50% or more of the business.

In the 2010s, the USA depended on 7% of its farms, about 155,000 farmers, to produce 80% of the country's agricultural production, and this percentage seems more or less to have stabilised. Dividing farms by income probably makes more sense than by size, especially in countries such as Australia: whilst in Victoria the minimum viable farm size is probably still around 50–100 hectares, even in the more fertile western part of the Wheatbelt of Western Australia 3000 hectares is probably an equivalent, whilst some farmers have more, especially in the East of the Wheatbelt, where the bush becomes the Outback. Generalising across large geographic areas is dangerous, though – parts of the WA Wheatbelt are very fertile, while in others, where the same production requires twice the area or even more, 'low rainfall eastern wheatbelt of Western Australia may cause the optimal farm plan to shift away from strategic cropping to a more extensive grazing system with opportunistic cropping' (Kingwell & Payne, 2015:32–33).

Now, in developed countries, farming is increasingly dominated by technology (Viviano, 2017) and there are sub-disciplines – agricultural production, agroscience and agribusiness. Employment is mainly in the supply chain, not working on farms themselves – in feeds, seeds, farm machinery, fertiliser, biotechnology, chemical supply, food-processing, finance, distribution and marketing (Ricketts & Ricketts, 2009:4) with more no doubt to come as agtech takes hold of production agriculture. But elsewhere in the world, these Organisation for Economic Cooperation and Development (OECD) definitions, and sub-disciplines, however much they may differ from one another, are still relatively alien. That does not however mean that the consequences for employment, a decline in farm employment in particular, seem just as likely, and are already starting to happen – even in Africa (Tschirley *et al.*, 2015).

Yield growth, varietal improvements and the effects of the Green Revolution

The term 'Green Revolution' was coined in 1968 by the US Agency for International Development and encompasses, *inter alia*, breeding of high-yielding crops that positively respond to fertilisers and irrigation. The crops that led the Green Revolution were wheat and rice. Agricultural production more than tripled between 1960 and 2015, owing in part to productivity-enhancing Green Revolution technologies and a significant expansion in the use of land, water and other natural resources for agricultural purposes (FAO, 2017:4). The International Rice Research Institute (IRRI) bred rice in similar ways to those of pioneer Norman Borlaug when he bred wheat in Mexico in the middle years of last century. A key feature was to shorten and strengthen the stems (straw) such that the plant could bear more grain without collapsing, since it is difficult to achieve a realised higher yield when the heads of grain fall to the ground. This shortening of the stem was the result of introducing 'semidwarfness' genes, which allowed the plant to make much better use of fertiliser and water in producing higher recoverable yields. Borlaug also bred for resistance to wheat diseases such as the devastating stem rust, a serious problem at the time but eventually overcome by the use of genes to provide resistance. Green Revolution technology has been extended to many other developing-country crops, including sorghum, millet, maize, cassava and beans. For many years, optimism about increased yields was the global norm.

But in fact, earlier rates of growth slowed: 'Since the 1990s, annual average increases in the yields of maize, rice and wheat at the global level have been slightly more than 1%, whilst those of soybeans and sugarcane have been even less (FAO, 2017a:48). Then in 1998 a new strain of stem rust was detected and reported in Uganda (known as Ug99). An estimated 80–90% of the world's wheat varieties are susceptible to this strain, and the pathogen was spreading to other countries. A huge effort was mounted to develop resistant varieties, largely funded by the Bill & Melinda Gates Foundation. Several varieties were eventually made

Note: Calculations based on FAOSTAT production statistics (downloaded on 20 September 2016). Growth rates estimated using the ordinary least squares (OLS) regression of the natural logarithm of crop yields on time and a constant term. The commodity group 'Cereals (total)' is from FAOSTAT and includes: wheat, rice (paddy), barley, maize, rye oats, millet, sorghum, buckwheat, quinoa, fonio, triticale, canary seed, as well as grains and mixed cereals not elsewhere specified.

Figure 1.3 The end of the Green Revolution? The slowing of yield growth over time
Source: FAO (2017a:48)

available for Africa with a reasonable degree of resistance to Ug99, but the problem was an early warning sign that the Green Revolution needed to be, at best, a permanent kind of revolution if it were to continue to succeed.

Optimism needed to come from another quarter. In low income countries, livestock production has been one of the fastest growing sectors. The increased use of land, irrigation and agrochemicals all played a major role. However, 'It is now recognised that the gains were often accompanied by negative effects on agriculture's resource base, including land degradation, salinization of irrigated areas, over-extraction of groundwater, the build-up of pest resistance and a decline in biodiversity. The challenge of any further 'Green Revolution' is to avoid these negative effects whilst still raising productivity' (FAO, 2011a). Here lay, and continues to lie, the real opportunities, which certainly still do exist: yields for the majority of crops and vegetables vary substantially across regions. Estimated yield gaps – the difference between actual and possible yields – exceed 50% in most developing countries. The cause is the difference between agriculture using technology, and that which does not.

Agribusiness matters because food matters

Notwithstanding this rapid growth in population, therefore, the overall picture, now relatively stable for many years, is that production is keeping pace with consumption globally. The importance of the sector is underlined by the fact that, globally, 30% of all employment is still in primary agriculture. The share rises to over 50% in India (Indian Government, 2018) and around 60% in sub-Saharan Africa and – perhaps surprisingly – still in China (Huang *et al.*, 2017:192), but falls to less than 10% in developed countries.

Volatility notwithstanding, in developed countries, the good news is that food is vastly cheaper in relative terms than in the past. In the USA, the USDA estimated that in 1960, 17.5% of household income was spent on food, falling to less than 10% in the 2000s. This compares to about 40% of household consumer expenditures in Guatemala and the Philippines and over half in Nigeria, whilst even the French and the Japanese spend about double US averages (World Economic Forum, 2016; USDA, 2018a).

The bad news is that sufficient production globally is not enough on its own to replicate this trend universally, or to prevent hunger, even starvation. This is now usually expressed in terms of a problem of food security in regions and countries. Africa has the highest levels of severe food insecurity, reaching over a quarter of the population, four times as many as any other region – and as the century wears on, the problem has appeared to grow (FAO, 2017:17). By the tail end of the second decade of the new century, the FAO reported that, after a prolonged decline, world hunger, the elimination of which is the principal goal of the FAO, appeared to be on the rise again. The estimated number of undernourished people increased dramatically and threatened to reach a billion. The worrying trend in undernourishment is not reflected in levels of chronic child malnutrition (stunting), at least, which continue to fall – but at a slower rate in several regions. Stunting still nevertheless affects well over 100 million children, in some regions one-third of children under five. Wasting continues to threaten the lives of over 50 million children, whilst almost one-third of women of reproductive age worldwide have suffered from anaemia, which also puts the nutrition and health of many children at risk (FAO, 2017:1). The World Food Programme, which has produced an annual report on food insecurity, reported that an estimated 124 million people in 51 countries were facing crisis-level food insecurity. However, the usual definition, 'a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 2003:296; Tadele, 2017) is relatively hard to achieve, as even in an advanced country such as the UK there is still poverty, and an estimated one in ten people do not eat properly (Taylor & Loopstra, 2016), a figure that rises to one in seven in the USA (USDA, 2017c).

Severe and persistent drought in eastern and southern Africa, and other climatic events, such as hurricanes in the Caribbean, have also reinforced food insecurity: 90% of production losses in sub-Saharan Africa were linked to droughts between 2003 and 2013. Since the production agriculture sector in sub-Saharan Africa on average contributes to a quarter of GDP (rising to a half when all sub-sectors of agribusiness are included), droughts have a clear negative multiplier effect on the economy (i.e. that when agricultural production falls, other sectors decline as well). Other regions affected by drought are Latin America (30%), the Far East (50%) and Asia (10%). Droughts directly affect agriculture through decreased yields and production, and have indirect socio-economic impacts such as unemployment, food scarcity or increased costs, lower tax revenues and increased loan foreclosures (World Bank, 2017:14).

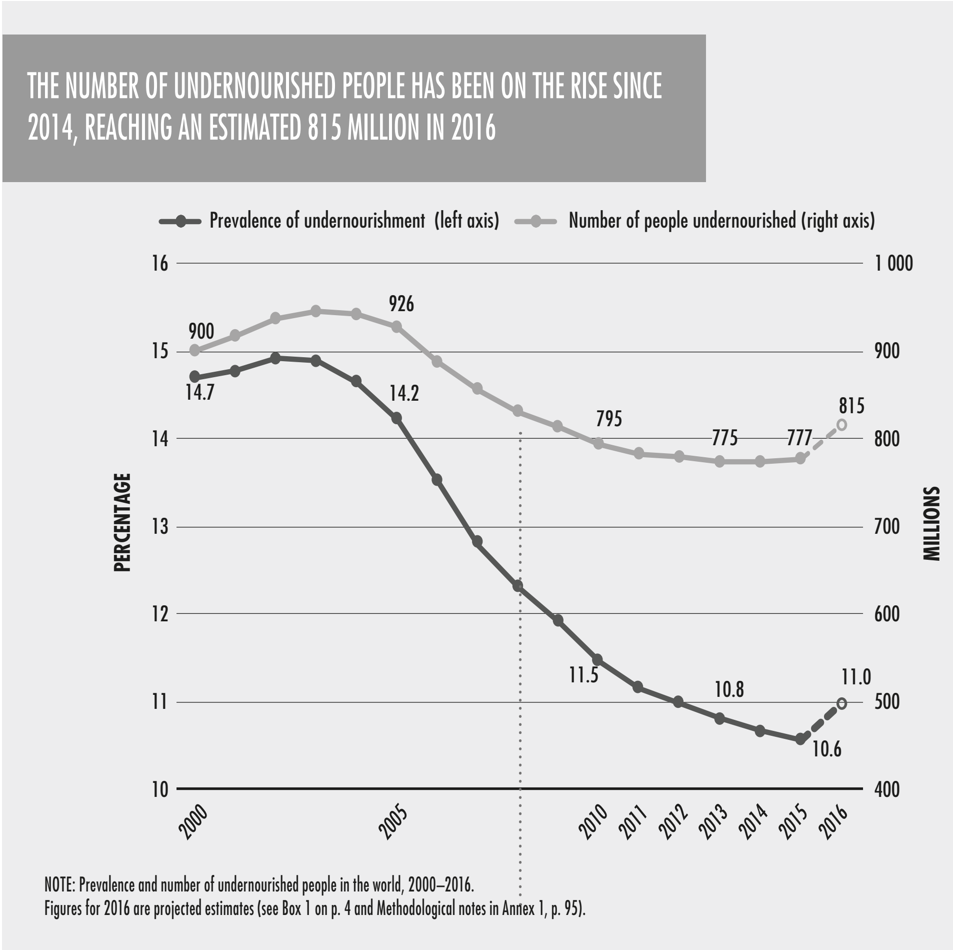


Figure 1.4 FAO reporting on world hunger in recent years
Source: FAO (2017:5)

Conflict and insecurity, however, exacerbated by climate change, continued to be the primary drivers of food insecurity in dozens of countries, such as the Yemen, the Democratic Republic of the Congo and South Sudan, where millions of food-insecure people remain in need of urgent assistance (WFP, 2018). South Sudan is a good example of the real problem and the reason for it.

Most – almost all, actually, although international organisations are wary of pointing blame – of the recent increase in food insecurity can therefore be traced to the greater number of conflicts, often exacerbated by climate-related shocks, as the number of UN interventions testifies. The remainder, especially in developed countries, can be ascribed to economic policies that permit widening inequality alongside freedom in individual decision-making that can frequently put family nutrition low on personal agendas.

South Sudan is an example of how conflict can affect the lives and livelihoods of the population in multiple ways, resulting in a humanitarian catastrophe on an enormous scale and with destructive longer-term impacts on livelihoods, as well as on the agriculture and food systems upon which these depend. In December 2013, two and half years after South Sudan gained its independence, large-scale violence erupted in the Greater Upper Nile Region and by 2016 had spread to Greater Equatoria and Western Bahr el Ghazal.

The ongoing conflict caused acute food insecurity to increase dramatically, with famine declared in parts of Greater Upper Unity State in February 2017 (see figure). More than 4.9 million people (over 42 percent of the population) are currently severely food insecure (IPC Phases 3–5), a number that is projected to increase to 5.5 million in 2017 if the situation is left unaddressed.[1]

Widespread acute malnutrition is giving rise to a major public health emergency: one in three children is acutely malnourished in the southern part of Unity State, and out of 23 counties, 14 have global acute malnutrition (GAM) at or above the emergency threshold of 15 percent. Rates of GAM of more than 30 percent were observed in Leer and Panyijiar and of 27.3 percent in Mayendit. These high levels are caused by reduced food access and by child, maternal and public health factors. The situation is exacerbated by a number of factors, including inadequate diets, low quality and coverage of water and sanitation facilities, as well as poor access to and levels of basic health services.

Armed conflict and communal violence are destroying rural livelihoods, decimating assets, deepening poverty and increasing the vulnerability of millions of people. Agricultural production and food systems have been disrupted, livestock production has declined significantly, and the spread of violence to cereal surplus-producing areas in Equatoria is severely affecting crop production. Violence is limiting market access and disrupting trade flows, affecting livestock producers, consumers and traders alike. The economic impact of the current conflict on the livestock sector – which constitutes 15 percent of GDP – has been extensive, as livestock have been direct targets of insurgency and counterinsurgency warfare. It is estimated that the loss of GDP attributed to the livestock sector is between US$1.4 billion and US$2 billion (2014–16).[2]

Food access has been hampered by sharp increases in prices, with inflation driven by shortages, currency devaluation and high transport costs owing to insecurity along major trading routes. The year-on-year inflation rate peaked at 836 percent in October 2016: the value of the South Sudanese pound (SSP) depreciated from SSP16 to the US dollar in August 2015 to SSP74 in November 2016. The conflict in Juba in July 2016 restricted inflows of imported food through the main southern supply corridor from Uganda, reducing food supplies and further driving up prices. In July 2016, cereal prices were more than double those of June and almost ten times higher than 2015 levels.[3]

A lack of financial and physical access to food is limiting individual and household food consumption, with real labour incomes and the relative price of livestock falling dramatically. Meanwhile, violence and insecurity have led to the depletion and loss of assets such as livestock and key household food sources such as standing crops and grain stocks.

In the worst-affected areas, food is being used as a weapon of war, with trade blockades and security threats leaving people marooned in swamps with no access to food or health care. Humanitarian access to the worst-hit areas is limited, as warring factions are intentionally blocking emergency food, hijacking aid trucks and killing relief workers. A lack of protection of civilians against violence has led to 1.9 million internally displaced persons and more than 1.26 million refugees, who have lost their livelihoods and are dependent on support for their survival.[3]

[1] IPC. 2017. *Key IPC findings: January-July 2017. The Republic of South Sudan.*

[2] Y.A. Gebreyes. 2016. *The impact of the conflict on the livestock sector in South Sudan.* FAO.

[3] FSIN. 2017. *Global Report on Food Crises 2017.*

SOURCES: IPC. 2013. *Acute food insecurity overview. Republic of South Sudan*; IPC. 2015. *Food security and nutrition analysis – key messages*; IPC. 2016. *Communication summary. The Republic of South Sudan*; and IPC. 2017. *Key IPC findings: January-July 2017. The Republic of South Sudan.*

Figure 1.5 South Sudan: FAO facts
Source: FAO (2017:42)

Agricultural production: sub-sectors

The structure of agricultural production globally is itself an increased focus of attention. Since the early 1970s, global per capita consumption of milk, dairy products and vegetable oils has almost doubled, fish has more than doubled (almost all from aquaculture), whilst meat consumption has almost tripled, the consequences of which influence the whole of agribusiness worldwide.

The generally agreed taxonomy of flowering plants is as shown in Figure 1.6.

Amongst the major staples

Rice.

> Worldwide there are more than 40,000 different varieties of *Oryza sativa*, classified into four major categories: indica, japonica, aromatic and glutinous. *Oryza sativa* contains two major subspecies: the sticky, short grained japonica or sinica, and the non-sticky, long-grained indica. Japonica varieties are usually cultivated in dry fields, in temperate East Asia, upland areas of Southeast Asia and high elevations in South Asia, while indica varieties are mainly lowland varieties, grown mostly submerged, throughout tropical Asia (Ricepedia, 2018).

Is rice production stable? Yes, and growing slowly. It is the most produced food crop and makes up more than 20% of human calories (Giraud, 2013). In Asia, where 90% of rice is grown, it is of course a dietary staple. China is the leading producer: Hunan is the largest rice-producing province, and most rice production is in the Yangtze River Valley (or farther south) where ample supplies of water are available. However, rice production in northern China has increased substantially in recent years, in Heilongjiang and the other two north-eastern provinces of Jilin and Liaoning, but also in Henan and Shandong (CGIAR, 2012). In the USA, rice production is concentrated in the Southern States: California and along the Mississippi River. Rice forms a vital part of food aid programmes. Information on rice is plentiful: the Food and Agriculture Organisation of the United Nations (FAO), the international system's food intergovernmental organisation, maintains a large database on rice production and trade, and reports regularly on the rice market (FAO, 2018a). Information is also readily available from the International Rice Research Institute (IRRI) in the Philippines. Private sector databases and subscription services also provide information on production, trade, prices and deals even more frequently, intra-day, as well as a regular newsletter and consult (Oryza, 2018). Making sense of the information, however, is not easy.

Wheat. There are thousands of wheat varieties (KSU, 2018), but wheat taxonomy has generally divided them into six. It is a robust crop which can be grown in many different climates, for example the north-western USA and Pakistan, as it can survive in dry and cold weather. China produces most, India next, the USA third. Hard wheat has high protein and is used for bread, buns, pasta, pizza crusts, etc. Soft wheat is the opposite, and is used for biscuits, cakes, pastries, crackers, noodles and steam bread. White wheat, which needs no breaching, is also the least bitter in taste, and is used for making bread (Kansas Wheat, 2014). Overall, although worldwide wheat demand is softening, it is still sown on more land than any other crop.

As an example of what information is publicly available, Figure 1.9 shows what the United States Department of Agriculture (USDA)'s monthly report had to say about the global wheat market in May 2018.

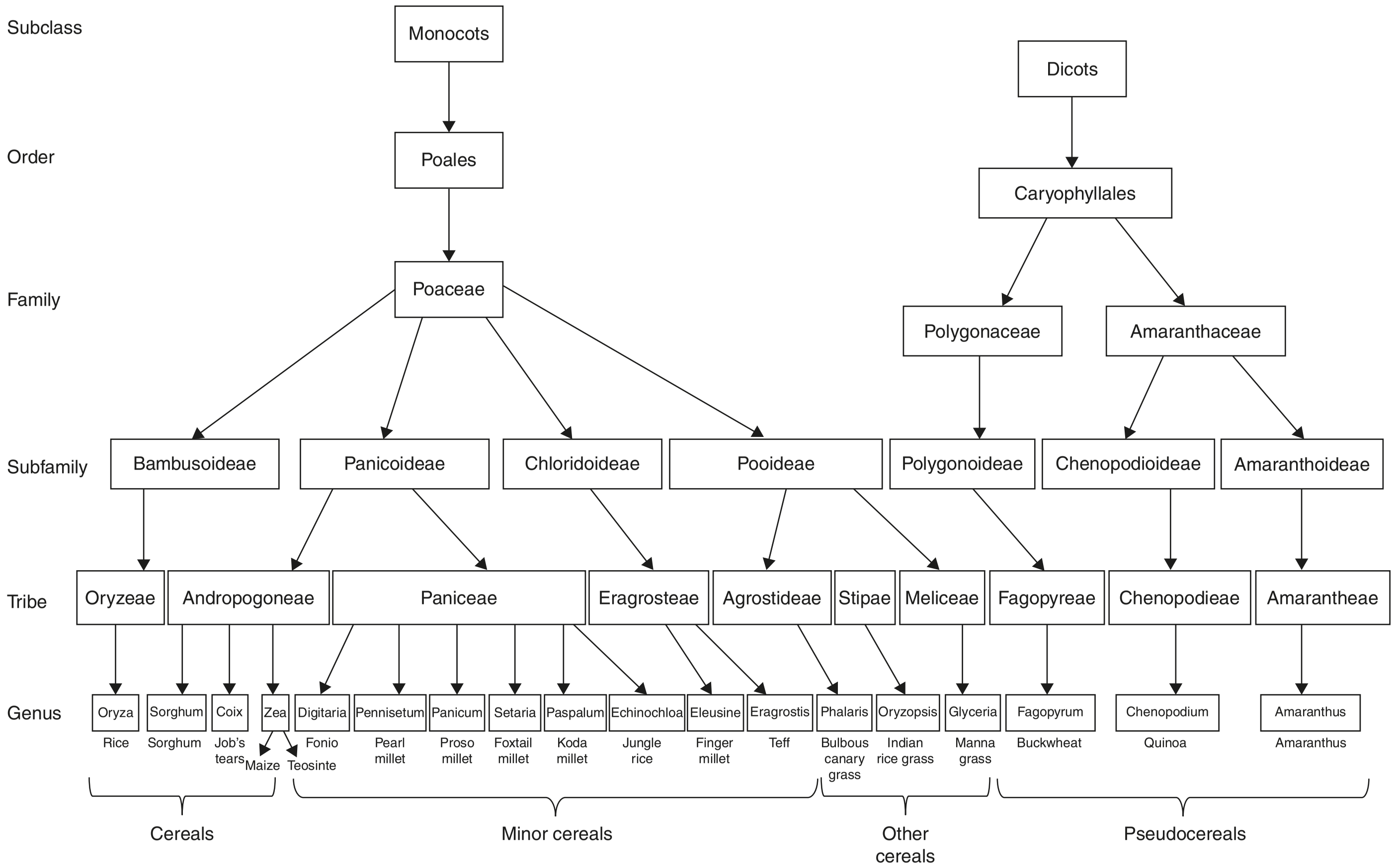


Figure 1.6 Plant taxonomy
Source: Moreno *et al.* (2014)

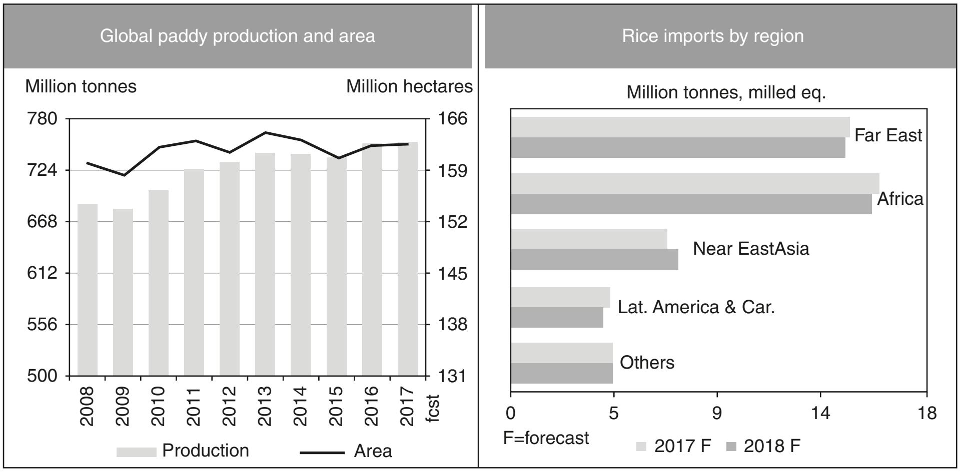


Figure 1.7 FAO rice statistics
Source: FAO (2018a)

Similar reports are produced by the International Grains Council (International Grains Council, 2018). Actual production in the EU, by comparison, has been relatively stable for almost a decade; Eurostat (the EU's statistical service) provides detailed information on production and use.

Maize, or corn, *Zea mays*, is the world's most important grain based on production volume, with around 1 billion tonnes harvested annually. Less than 0.2% is the 'sweet corn' consumer product. The remainder is field or dent corn, for animal feed, ethanol and corn products (corn syrup, starch, etc). Just over a third is grown in the USA, mainly in Iowa, Illinois and Nebraska, and most of the remainder in China, Ukraine, Argentina and Brazil. The USA is the world's leading corn exporter, though exported volumes have been relatively stable (Statista, 2018). Importing countries use US corn mainly to feed livestock, as in China where it is used to feed pigs, but also poultry and fish – a sharp contrast with US domestic use, where almost half goes for ethanol production (see the section below). Analysis drew attention to the potential risk that climate change poses to maize yields worldwide (Tigchelaar *et al.*, 2018), which in turn could have significant effects on the cost of raising livestock.

Soybeans (*Glycine max*) are of the legume family, which includes dried beans, peas and lentils. An annual crop, they are used for food and oils, and add nitrogen to soils, often alternating with corn. They are high protein producers – twice other crops, and many more than animals. Production is now greater than maize in the USA, although there are held to be significant environmental risks from soy production, especially connected with deforestation in the Amazon.

Animal husbandry refers to the best – most cost-effective and yet sympathetic – method of keeping animals for agricultural production. In developed countries, the main animal enterprises with the greatest value of production are beef cattle and calves, dairy cattle, sheep, hogs and poultry. There are, for example, about a billion head of cattle in the world,

Figure 1.8 Wheat taxonomy
Source: www.appreciategoods.com

USDA United States Department of Agriculture

ISSN: 1554-9089

World Agricultural Supply and Demand Estimates

Office of the Chief Economist	**Agricultural Marketing Service Farm Service Agency**	**Economic Research Service Foreign Agricultural Service**

WASDE - 577 Approved by the World Agricultural Outlook Board May 10, 2018

Note: This report presents USDA's initial assessment of U.S. and world crop supply and demand prospects and U.S. prices for 2018/19. Also presented are the first calendar-year 2019 projections of U.S. livestock, poultry, and dairy products. Due to spring planting still underway in the Northern Hemisphere, and being several months away in the Southern Hemisphere, these projections are highly tentative. Forecasts for U.S. winter wheat area, yield, and production are from the May 10 *Crop Production* report. For other U.S. crops, the March 29 *Prospective Plantings* report is used for planted acreage. Methods used to project 2018/19 harvested acreage and yield are noted in each table.

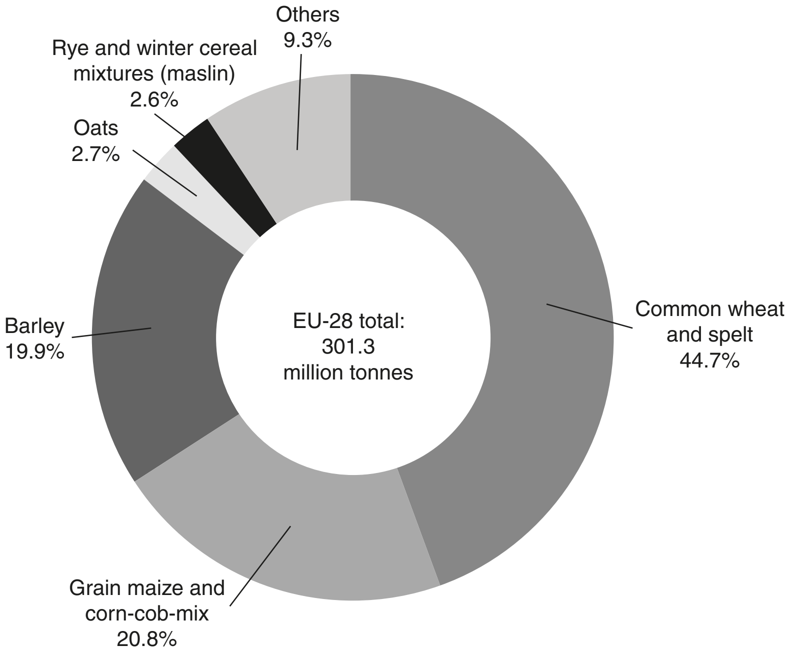
WHEAT: The 2018/19 U.S. wheat crop is projected at 1,821 million bushels, up 5 percent from the prior year. The year-over-year increase is due to greater harvested area and slightly higher yield. Reduced beginning stocks and imports bring total supplies down 49 million bushels from the previous year. The all wheat yield is projected at 46.8 bushels per acre, up slightly from 2017/18. Winter wheat yields are below average in the drought affected states of Kansas, Oklahoma, and Texas. Combined spring wheat and Durum production for 2018/19 is projected to increase 34 percent from the previous year's low, which is due to both increased area and yield.

Total 2018/19 use is projected up 3 percent on higher food, feed and residual, and exports. Food use is projected at a record 965 million bushels, up 2.0 million bushels from the previous year's revised estimate. U.S. feed and residual use is projected at 120 million bushels, up 50 million bushels from last year's low level but still below the 5-year-average. Exports are projected at 925 million bushels, up 15 million bushels from the revised 2017/18 total. Ending stocks for 2018/19 are projected down 115 million bushels to 955 million, which if realized would be a 4-year-low. The season-average farm price is projected at a range of $4.50 to $5.50 per bushel. The midpoint of this range is up $0.30 per bushel from the previous year and the highest since 2014/15.

Global wheat supplies for 2018/19 are projected to increase fractionally as higher beginning stocks are partially offset by a production decline following last year's record. Global wheat production is projected at 747.8 million tons, down 10.6 million from the previous year's record. Most of the year-over-year production decline stems from a 13.0-million-ton reduction for Russia. Global wheat consumption is projected at a record 753.9 million tons, up 10.1 million from 2017/18. Global imports are expected to increase 3.5 million tons in 2018/19 for the sixth consecutive record. With total use rising faster than supplies, global ending stocks are projected to decline 6.1 million tons to 264.3 million.

Figure 1.9 World agricultural supply and demand estimates
Source: USDA (2018)

of which just under a third are for dairy. India has over 30% of the total,[1] Brazil 23%, China 10% and the USA and the European Union both around 9% (Beef2Live, 2018). In the USA approximately 750,000 ranchers command $500 billion in annual revenue, but production is very fragmented: only 5,000 ranches own more than 500 cattle. Breeding cattle for dairy production is a relatively recent activity, less than a century old, but dairy has risen in importance: milk production has been, in the 2010s, the main purpose of selecting breeds and evaluating individual cow performance, with the poor-performing cows – and many calves – sent for slaughter. Although most dairy operators are still small family farms, they contribute less than a fifth of annual US dairy production. Milk production is rising, using more cattle, in regions such as South-East Asia, including countries not traditionally noted for their milk consumption, and China, which now has over 12% of its total cattle stock as



Note: 'Total cereals' includes cereals for the production of grain (including seed). 'Others' includes rice, triticale, sorghum and buckwheat, millet, canary seed, etc.)

Figure 1.10 EU production and use of cereals
Source: Eurostat (2015)

dairy. As for sheep, kept not only for meat (an A$3-billion industry, increasing annually) but also for their wool and, increasingly, their milk. Australia still leads the way in numbers and experience, although China is now the world's leading wool producer. Most notably in Australia, too, grain farmers have lost the fences and shearing sheds they need to return to livestock. Shearing labour is now also at a premium (Barrett & Packham, 2018).

Keeping animals is neither easy, nor cheap.

The main issues in Africa, for example, are:

- Limited amount of feed – availability of feed is low, especially during the dry season. Preservation of animal feed is very rarely practised.
- Susceptibility to parasites and diseases – due to a lack of closer management attention, insufficient feeding and unfavourable weather and housing conditions common in many systems, animals are very susceptible to disease and parasite infections.
- Limited knowledge on proper animal breeding – in many situations, animals move together in mixed groups of females and males. They mate randomly without much control from the farmer, hence propagating inferior traits (Organic Africa, 2018).

Just bringing African and other developing country animal husbandry practices into line with best international practice, as agribusiness firms seek to do, can alone significantly improve productivity, as well as animal welfare, which is already of great importance to consumers in the developed world (Heise & Theuvsen, 2017) and which eventually will become a concern of the whole world.

Fibre. Not all agriculture is for food. The most well-known agricultural fibres are *cotton* and *wool*, where volume and price information are plentiful. Cotton is the most produced and used natural fibre worldwide.

> Specifically, 50% more cotton is produced worldwide today on the same amount of land as compared to 40 some years ago. And though cotton occupies less than 3% of the world's agricultural land, cotton production provides two crops with each seasonal harvest: cotton fiber, which currently supplies 30% of the world's textile fiber needs; and cottonseed, a source of nutritious cooking oil and a protein-rich supplement for dairy cattle and aquaculture feeds (Cotton Today, 2018).

India, China and the USA are the largest producers, responsible for more than the half of the world's total production volume. Though part of agribusiness, cotton is also an important component of the textile industry, and the global market is dominated by China (Quark & Slez, 2014; Gu & Patton, 2018).

There are, however, many other types of natural fibre:

> Natural fibres have been used to reinforce materials for over 3000 years. More currently they have been employed in combination with plastics. Many types of natural fibres have been investigated for use in plastics including flax, hemp, jute, and banana. Natural fibres have the advantage that they are renewable resources and have marketing appeal (Sakthivei & Ramesh, 2013:1).

One of the most important of these is *jute*, a versatile fibre which can be used either on its own or combined with other fibres and materials, mainly for sacking. Although threatened by synthetic materials in many of its uses, its biodegradable nature, is of benefit in, for example, containers for planting young trees, or geotextiles for soil and erosion control where the application is designed to break down after some time and where no removal is required. Limited price statistics for jute and other minor fibre markets are available from the FAO, but jute is an example of a highly specialised and not especially transparent market, especially as the majority of transactions take place in the Indian subcontinent.

Another very detailed market is that for *silk*. Silk is claimed to be 'the most elegant textile in the world with unparalleled grandeur, natural sheen, and inherent affinity for dyes, high absorbance, light weight, soft touch and high durability and known as the "Queen of Textiles" the world over' (Central Silk Board, 2016:1). On the other hand, it provides millions of jobs in China and India, as it is labour-intensive in cultivation. India is the only country producing all the five known commercial silks, namely mulberry, tropical tasar, oak tasar, eri and muga, of which muga is largely only produced in India.

Horticulture is the culture of plants for food, as well as for general welfare purposes. The word itself derives from the Latin for garden culture. It now includes several distinct divisions, each with its own key performance indicators. Planting, harvesting, storing, processing and marketing – vegetable food crops like sweetcorn, lettuce or tomatoes is *olericulture. Pomology* refers to an analogous activity with fruit and nuts. Amongst fruits, in the USA the leaders are grapes, oranges and apples, whilst amongst nuts almonds lead the production table, although Asia-Pac now produces more fruit and vegetables than any other region. To this can be added *viticulture,* the same for grapes and the production of wine, where traditional production countries such as France, Spain and Italy have now for decades been challenged by New World wines from Australia, the USA and Argentina, themselves now facing new competition even from China. *Ornamental* horticulture is about decoration, including both flowering and foliage plants for internal and external use – think garden centres or nursery production: a huge business in developed countries, $41 billion in the USA alone in 2016.

Fruit and vegetables are of huge alimentary benefit, although the quantity consumed is almost universally lower than the 400g daily recommended by the World Health Organisation. Largely this is for reasons of taste: generally, people do not enjoy eating fruit and vegetables so, unfortunately, they do not feature highly either in ready meals or in dining out. Urban areas are often not well served, whilst the picture in at least some rural areas, especially in agricultural regions, is quite different. Demand for all-year round supply of a wide range of fruits and vegetables is increasing worldwide, along with demand for 'organic' produce and associated concerns about conventional production methods. Developing markets will end up where OECD consumers already are, highly aware of the health benefits and risks of particular foods, even if they do not always, or even frequently, act accordingly.

Aquaculture is the farming and husbandry of aquatic organisms under controlled or semi-controlled conditions. These organisms may be plants, fish or shellfish – clams, crayfish, mussels, oysters, prawns, shrimps, etc. Aquaculture is used for a variety of ends, not just intensive food production: fish may be raised for leisure or commercial fishing, for example. In developed countries, sophisticated systems enable each fish cage to receive its own supply of feed depending on the number and size of the fish, temperature and time of year. This has enabled the production time for salmon from 100g to harvest size, 4–5 kg, to be cut drastically, from three years to just 18 months (Adoff, 2018). Whilst aquaculture is already well established in developed countries, its biggest opportunities probably lie elsewhere. It is little wonder that the Russian government, for example, is anxious to encourage it (USDA, 2017b). Most aquaculture in Africa is still in Egypt, where 80% of the continent's farmed fish production takes place. Although most African countries have water to support aquaculture, historically development has been in inland countries like Zambia, where the population has a custom of eating fish and the fish in rivers and lakes have been exploited to the maximum. The species fish-farmed in South Africa have been very different from in Europe – abalone, yellowtail and dusky cob – as the country has legislation that makes it difficult to bring in other species that are not indigenous and farm them there. In the rest of Africa, the most commonly farmed fish is the indigenous tilapia, which are easy to cultivate even on a small scale; a smallholder can dig out a pond and fertilise it and fish live off natural production from nutrients and sunlight (Karen, 2012).

Forestry. In virtually no area of agribusiness has the impact of land values, public policy, including taxation, and that of climate change been greater than in the case of silviculture. Commercial forestry for pulp and paper as well as for tourism, specific production uses (e.g. sandalwood) and the use of forestry for carbon offsets are the principal drivers of the industry. It is a straightforward argument that over the last 30 years, the context of forest management in the USA, along with other developed countries, has gone through one of its most dynamic periods in history. Record accumulation of fuel loads (the aboveground organic biomass components that can contribute to wildland fires), extreme fire events (megafires), and epidemic insect outbreaks, often as a result of extended drought, fire exclusion and management policies (Rego *et al.*, 2018), have affected forests, especially in the West. In addition, during this period, changing ownership and land tenure patterns, rural land urbanisation, increased globalisation of forest markets, decreases in demand for wood products, operational-scale adoption of forest certification standards and best management practices (BMPs), and conservation easements have all influenced silvicultural decision-making. With the exception of private, intensively managed forestlands, forest management objectives have been broadened and go beyond the historical importance of managing for sustained timber yield. Contemporary silvicultural prescriptions for a range of land ownerships may also include elements of invasive species management; conserving old forest ecosystems and riparian reserves; enhancing water quantity and quality; recreation; aesthetics; augmenting biological diversity; and the restoration of endangered, threatened and sensitive species and ecosystems' (D'Amato *et al.*, 2018). None of these objectives, however laudable, are necessarily easily compatible with high financial returns.

Bioenergy and biofuels have been the subject of much debate. According to the FAO (2017), about two-thirds of the bioenergy used worldwide is for cooking and heating, mainly by burning wood inefficiently. Biofuel production itself has risen, more than doubling in the last decade with continued growth expected. The FAO pointed out that in the first decade of the new century, world cereal consumption increased by 1.8% annually – almost a third went to US biofuel production, which has also taken much vegetable oil production. The FAO also noted that 'the greater competition between food and non-food uses of biomass has increased the interdependence between food, feed and energy markets' (FAO, 2017a:35).

Ethanol production. Ethanol, derived mainly from sugarcane and corn, but which can be extracted from a wide range of crops, can be blended with gasoline for gasohol, to be used for fuel. Brazil is the second-largest bioethanol producer and the greatest exporter. E85, the main product, is 85% ethanol and 15% gasoline. The USA (the greatest producer) and Brazil have together been responsible for 70% of the world ethanol, with the sugar cane industry accounting in the last decade for as much as 2% of Brazil's GDP: Brazil's sugarcane in the 2010s accounted for about 20% of world supply and 60% of global trade. One of the biggest domestic uses of sugarcane is ethanol. Almost all passenger vehicles in Brazil are flex-fuel; they run on gasoline or a biofuel with as much as 85% ethanol (Kostreva, 2014). Europe follows, supplying around 5%, followed by Canada supplying 2%. This is an example of a complex political issue within agribusiness: the US Renewable Fuel Standard (RFS) programme in relation to ethanol was introduced in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007, and has in fact prompted significant changes in agricultural markets (Sant' Anna *et al.*, 2016). But in 2016, after a lengthy battle, the Renewable Fuel Standard (RFS) was finally put 'back on track' when the Environmental Protection Agency (EPA) announced blending requirements would be returned to statutory levels. Meanwhile, farmers harvested a record corn crop, ensuring ample feedstock supplies. Excessive production costs have continued to limit the quantity of non-corn-based biofuels, placing a greater burden on corn to fulfil the mandated ethanol production requirement and leading to a reallocation of corn away from its traditional uses in domestic livestock and poultry feed. Technological advances that allowed a corn-ethanol by-product – distillers' dried grains (DDGs) – to be used as a supplement to livestock feed became a partial saving grace during this market transformation. The result was a quickly emerging domestic market (and more recently an international market) for DDGs (Bekkerman & Tejeda, 2017:175). However, this remains a volatile industry and ethanol producers continued to face a number of important challenges.

- *Biodiesel*. This is a domestically produced, renewable fuel that can be manufactured from vegetable oils such as soybeans, animal fats or recycled restaurant grease, either pure or in e.g. an 80:20 blend with oil-based diesel, for use in diesel vehicles. It is the most widely used renewable agricultural energy source.

- *Methane*. This amounts to approximately two-thirds of biogas production. Feed or dairy is the main source of production, and its use as fuel eliminates the need for its disposal. Even the residue, humus, is a good fertilizer.

- *Wood burning*. Millions of people worldwide rely on wood-burning stoves for some or all of their home heating and cooking. The rising cost of home fuel together with social trends towards 'natural' fuel use is responsible, although there is medical evidence to suggest that prolonged exposure to fumes from burning wood is highly undesirable (Taleb *et al.*, 2014).

International distribution of production and consumption of major agricultural commodities

This changes constantly and is most frequently reported from monthly to annually. Information can be found in publicly available research documents, such as those published by agencies including the USDA (USDA, 2018), FAO (FAO, 2017) and private sector organisations such as Rabobank (2016, 2017, 2018). But for anyone attempting to understand the progress of agricultural markets, e.g. for trading purposes, there is simply too much information produced from too many sources to make an overall view of agricultural commodities even possible for one person. AI systems can do it: but developing reliable investment or trading algorithms on the basis of publicly available information is hard to do. The best advice possible is to start by specialising – by commodity, and then by market.

Some examples:

- At 157 million hectares, India holds the second largest amount of agricultural land in the world. Agriculture plays a vital role in India's economy. Almost 60% of rural households depend on agriculture as their principal means of livelihood. The share of primary sectors (including agriculture, livestock, forestry and fishery) was estimated to be about a fifth of gross value added (GVA) in the 2010s. India's food grain production reached 276 million tonnes in 2016. With at least 20 distinct climate regions, all the major climates in the world exist in India. The country also possesses 46 of the 60 soil types in the world. India is the largest producer of major agricultural and horticulture crops: spices, pulses, milk – India has been the world's largest producer of milk for the last two decades and contributes 19% of the world's total milk production – tea, cashew and jute; and is the second-largest producer of wheat, rice, fruits and vegetables, sugarcane, cotton and oilseeds (IBEF, 2017, 2018).

- In Nigeria, the northern region supports grains (such as millet, sorghum and maize) and groundnuts; the centre, which produces most of the country's food, rice, tubers (crops such as potatoes and sweet potatoes, as opposed to roots such as beets and carrots), fruits and vegetables; the eastern belt, tubers as well as oil palm; and the west, cocoa. Cattle graze in the open fields of the north, fishing is concentrated along the coast and rivers, and poultry are everywhere. On the one hand, agriculture is the mainstay of the economy, contributing 24.18% to real gross domestic product in Q4 2015 (PwC, 2016:3). On the other hand, of an estimated 71 million hectares of cultivable land in Nigeria, only half is currently used for farming; there is similar potential for an expansion of irrigation, which now only covers 7% of irrigable land. Most of the rural population farms on a subsistence scale, using small plots and depending on seasonal rainfall. A lack of infrastructure such as roads further exacerbates food-poverty in rural areas by isolating rural farmers from needed inputs and profitable markets. Pressure from growing populations, and in the north, conflict, is also impacting already diminished resources, further threatening food production in Nigeria. As a result, food insecurity in Nigeria is of major concern (Omatayo *et al.*, 2018).

- For China, the USDA reported on the publication of China's annual agricultural goals that the bottom line for the Chinese government was 'absolute security' in the area of staple grains (i.e. rice and wheat). Parts of the country have been reserved for specific crops, partly to maintain production, but also to take advantage of economies of scale. Policies are in place for specific crops and sub-sectors, obviously pigs but even wine as well. 'Production of grass-fed cattle and sheep will be encouraged. In an effort to revive the dairy industry, the government will support the development of family ranches and foster domestic dairy brands' (USDA, 2017).

  The USDA observed that, whilst food security remains a top priority in China, the focus seems to have shifted from quantity to quality, which is also the core of the so-called supply-side structural reform. In other words, the government encourages farmers to improve product quality or to produce commodities that meet the increased

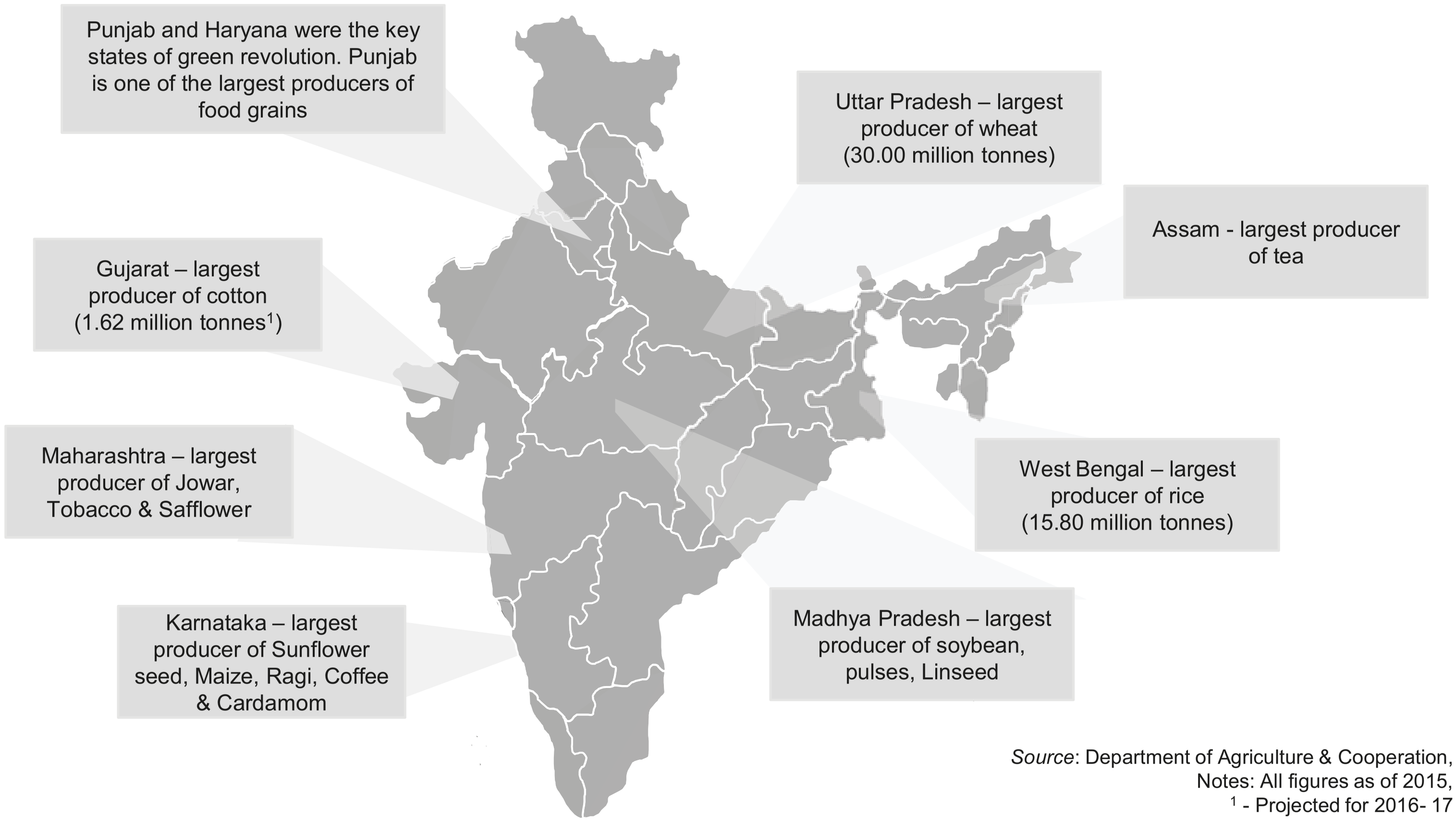


Figure 1.11 Agricultural production in India by state – key indicators

demand from local consumers for better and more varied agricultural products. For example, the government encourages farmers to plant premium rice varieties and wheat varieties with high/low gluten content. While the government guides farmers to reduce corn acreage, with millions of hectares fewer planted at the end of the 2010s than the outset, China also encourages farmers to expand areas for feed crops, such as silage corn and alfalfa in order to increase grass-fed cattle and sheep production. Farmers are also encouraged to increase production of food-grade soybeans, tuber crops and coarse grains.

Agriculture and the environment in a time of climate change

Climate is the primary determinant of agricultural productivity. Food and fibre production, in turn, are essential for sustaining and enhancing human welfare. Inevitably, therefore, agriculture has been a major focus in discussions about the effects of climate change. This has now been the case for decades: the United Nations Framework Convention on Climate Change (United Nations, 1992) viewed the sustainability of food production as paramount in the objectives for stabilising greenhouse gas (GHG) emissions, with the view that emissions should be stabilised at a level that 'ensures that food production is not threatened' (Muldowney *et al.*, 2013). Clearly, agronomic and economic impacts from climate change depend primarily on two factors:

(1) The rate and magnitude of change in climate variables and the biophysical effects of these changes; and
(2) The ability of agricultural systems to adapt to changing environmental conditions (Adams, 2009).

Environmentalists point out that expanding food production and economic growth have often come at a heavy cost to the Earth's natural environment. Croplands cover 12% of the available land and they have, no doubt, a massive environmental impact. Almost one-half of the forests are now gone. Groundwater sources are being depleted rapidly and sometimes irretrievably, for example in Australia, where feeble and largely competitive local government policy has entirely failed to prevent it. Biodiversity on Earth has been deeply eroded, with consequences that are not yet fully understood. Every year, the burning of fossil fuels produces billion of tonnes of greenhouse gases, which are responsible for global warming and climate change. Notably, deforestation, mainly for plantations and farming, produces a significant share of global GHG emissions. Natural resources are being depleted, as much in the Punjab in India (Singh, 2011) as in Africa, ecosystem services are being degraded and there may be pollution of groundwater with pesticide or fertiliser residues, or the atmosphere with nitrous oxide, a potent greenhouse gas. The presence of pesticides in the environment can contribute to adverse ecological effects ranging from fish and wildlife kills to more subtle effects on reproduction and fitness. Due to the toxic effects that pesticides have on pests and potentially to the environment and human health, national regulatory agencies regulate their use and exposure. For example, the EPA has set standards for pesticide residues in drinking water for approximately 200 organic chemicals. All of these negative trends are at least not diminishing, and agriculture is an important part of the problem (FAO, 2017:4).

Agriculture is also a significant direct contributor to climate change. This is because agribusiness uses significant quantities of energy, taking up somewhere between 10–20% of US energy production a decade ago (Ricketts & Ricketts, 2009:53), of which farms, which both produce and consume energy, took about one-third. Globally, estimates of energy use from international agencies are close. The FAO reported that the food sector (including input manufacturing, production, processing, transportation marketing and consumption) accounted for around 95 exajoules – approximately 30% of global output – and produces over 20% of GHG emissions (FAO, 2011), whilst the World Bank estimated 25%, including land use change for agriculture (World Bank, 2015:13).

Whilst the comparative energy efficiency of developed farming in the USA is noteworthy, future energy production will undoubtedly be more decentralised, so statistics of this kind may become obsolete, especially as the energy will be predominantly generated from renewables. But for the time being, there is still reason to be concerned on this score as well.

Moreover, not all agricultural production is created equal. The global shift to meat consumption currently entails far less efficient utilisation of energy than plant-based products. In the USA, though climates vary, one hectare would be enough to feed an individual if wheat, potatoes or another high-producing grain were used. For comparison, it takes an estimated 2–3 calories of fossil fuel to produce 1 calorie of protein from soybeans, corn or wheat. For beef it takes 54 calories of fuel to produce 1 calorie of protein. The result is that almost 50% of the world's harvest is fed to animals. Globally, 90% of the ever-increasing soybean harvest goes for animal feed. Online it is now possible to see real-time estimates of meat consumption, as part of the global concern with the environmental consequences of meat production and consumption (World Counts, 2019). Inevitably, as worldwide demand for animal protein rises, there will be increased derived demand on natural resources, disproportionate to the nutritional benefit.

Soil erosion is a natural geological phenomenon resulting from the removal of soil particles by water or wind. This natural process can be accelerated by human activities creating soil loss that exceeds the soil formation rate in a given area. Human activities that change land use from a comparatively higher form of permanent vegetation cover, to a state of lesser vegetation cover, have increased soil erosion. In developing countries in particular, for example Ethiopia, soil erosion has become an alarming problem over several decades, and it is now considered to be the major factor affecting the sustainability of agricultural production in the country. The leading factors causing erosion are the usual culprits: increased population pressure resulting in forest/woodland clearance for wood and smallholding agriculture, traditional agricultural practices, and declining land productivity – partly as a result of bringing marginal land into production and partly as a result of intensive use of the land (Wolka *et al.*, 2015). But the problem is by no means confined to developing countries: soil erosion is a major environmental problem on Prince Edward Island in Canada as well (PEI Department of Agriculture and Fisheries, 2018). The loss of topsoil has obvious implications for the loss of agricultural productivity, but there are also wider environmental concerns, e.g. for wildlife in wetlands.

Hence, although Brazilian agribusiness stands out globally for its competitiveness in exporting products such as sugar, coffee, orange juice, ethanol, soybean and derivatives, and beef, pork and chicken meat – which has been attributed mainly to three measures: the management of natural resources, the use of genetic engineering in the development of new varieties, and the adoption of new management practices (Oliveira & Alvim, 2017:46) – environmental criticisms have emerged. 'Soybeans have particularly impacted Brazil's agricultural landscape and environment. Since 1970, almost 20% of the Amazon rainforest has been cleared to make way for agriculture in Brazil' (Pullman & Wu, 2012:88). An even more dramatic, but much more longstanding, reduction in forestry has occurred in the Wheatbelt of Western Australia, but the politics appear very different when the destruction of the forests occurred over a century ago, and there is no NGO campaigning for *reforestation* although the rainfall effect is equally significant – the Amazon, similar to other forests, produces over half its rainfall via the moisture it releases into the atmosphere, so cutting its trees reduces rainfall, which in turn dries out the remaining trees, a vicious cycle that eventually leads to salinated soils, vegetation loss and a decline in agricultural production itself.

There are models aplenty of the interaction of all these issues and problems.

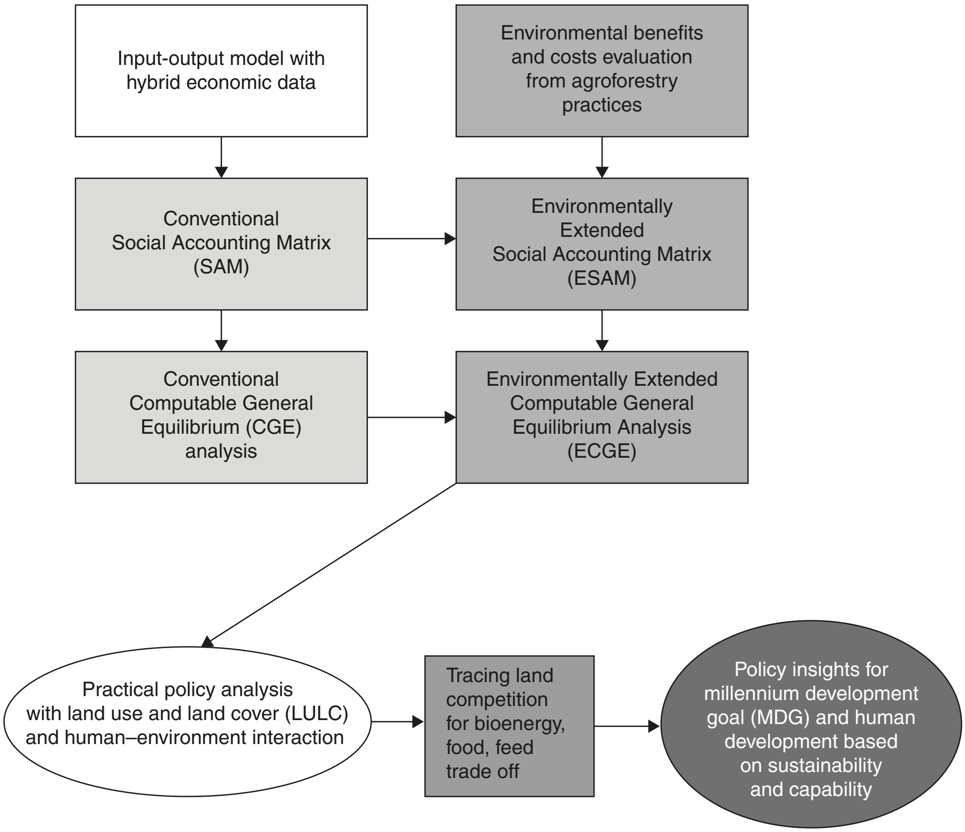


Figure 1.12 Millennium development goal (MDG) development
Source: Das (2014)

Perhaps even more significant going forward, however, is the fact that as arable land available for farming diminishes, substantial gains in production of higher value foods are most likely to come from intensive production systems in which animals are raised in confinement systems, and reared, to a large extent, on grains. This has a multiplier effect on grain consumption due to the increased demand for grains which are used as feed for livestock. To produce one gram of animal weight requires many grams of grains to be used as feed:

> For example, approximately 8.3 grams of grain are required to produce 1 gram of beef, while 3.1 grams of grain are required for 1 gram of pork. Further, the energy produced by one gram of beef is 2.78 kcal, which is much less than the energy produced by the 8.3 grams of grain required to produce it, which is approximately 25 kcal. This multiplier effect means that as dietary patterns shift to include a greater proportion of higher value foods a much greater volume of grains is required to maintain the amount of energy consumed (Macquarie, 2010:3).

Doubt has been expressed over the accuracy of these figures, on the grounds that they refer only to OECD animal husbandry and moreover overlook the price effects of switching away from animal production and the equally important question of land use for protein production (Flachowsky *et al.*, 2017).

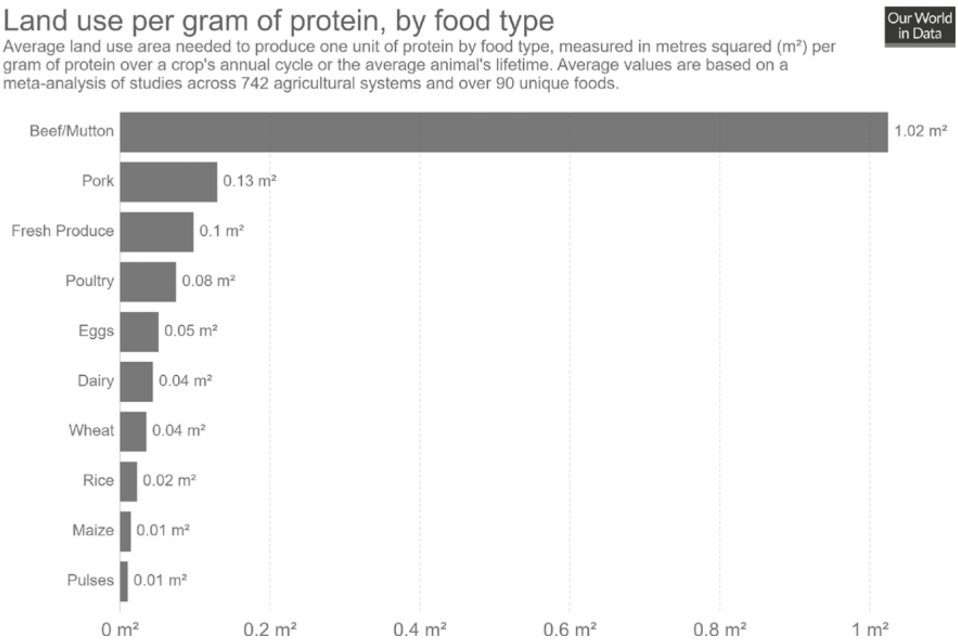


Figure 1.13 Grains required for animal production
Source: Ritchie (2017)

Serious consideration has already been given to grain diversion, even through regulation (Locke *et al.,* 2013).

The disparate nature of individual initiatives and the way in which some of them counteract each other should shine through these pages. Unfortunately, although a plethora of integrated assessment models (IAMs) have been constructed and used to estimate the social cost of carbon (SCC) and evaluate alternative abatement policies, it has been argued, at least, that these models have crucial flaws that make them close to useless as tools for policy analysis: certain inputs, e.g., the discount rate (the rate at which future values are reduced in value by comparison to present ones, see Harrison (2010) are arbitrary, but small changes in their values have huge effects on the SCC estimates the models produce; the models' descriptions of the impact of climate change are completely ad hoc, with no theoretical or empirical foundation; and the models can tell us nothing about the most important driver of the SCC, the possibility of a catastrophic climate outcome. IAM-based analyses of climate policy, and government policy papers on environmental assessment and the impact of agriculture, create a perception of knowledge and precision, but that perception is illusory and potentially even misleading.

Climate change and water use

Warnings from international organisations have continued over the decades. The World Economic Forum, regarding 2018, declared that:

> Rising temperatures and more frequent heatwaves will disrupt agricultural systems that are already strained. The prevalence of monoculture production heightens vulnerability to catastrophic breakdowns in the food system – more than 75% of the world's food comes from just 12 plants and five animal species, according to the FAO, and it is estimated that 'there is now a one-in-twenty chance per decade that heat, drought, and flood events will cause a simultaneous failure of maize production in the world's two main growers, China and the United States (Kent *et al.*, 2017).

Global water use doubled in the last four decades of the last century and is projected to grow at least twice as fast as oil consumption over the next two decades (United Nations, 2018). Maybe even more. Agriculture and land use change, construction and management of reservoirs, pollutant emissions and water and wastewater treatment have a critical influence on water resources in terms of both quantity and quality. None of this is new: the Intergovernmental Panel on Climate Change said decades ago that the principal drivers of these pressures are the result of demographics and the increasing consumption that comes with rising per capita incomes, and in fact rapid population growth had already led to a tripling of water withdrawals in the second five decades of the last century (IPCC, 2001). Agriculture takes 70% of all water withdrawal, whilst almost half the world's rural population lives in or around river basins that are water scarce. Countries are considered 'water-stressed' if they withdraw more than 25% of their renewable freshwater supplier, 'water scarce' at 60% and severely stressed after 75%. An alternative approach is to define 'water stress' as having less than 1,000 m^3 per capita per year (based on long-term average runoff), since this volume is usually more than is required in a basin for domestic, industrial and agricultural water uses. It was estimated a decade ago that the population living in water-stressed basins – from Africa through America and Asia – ranged from 1.4 billion to 2.1 billion, so this number will undoubtedly have risen since. Fast-forward a decade, and an estimated 3.6 billion people (nearly half the global population) live in areas that are potentially water-scarce at least one month per year, and this population could increase to some 4.8–5.7 billion by 2050 (United Nations, 2018). Drought, the next stage of water deprivation, is defined as a sustained and regionally extensive occurrence of below-average natural water availability, and both more intense and more widespread droughts affecting more people and linked to higher temperatures and decreased precipitation, have been observed in the 21st century. The problem is exacerbated by depletion of water tables beyond their – declining – renewable levels, sending water supplies into a downward spiral from which they cannot recover, e.g. in West Asia, North Africa and even in parts of Australia. This in turn reduces water quality, which is negatively impacted by chemical, microbiological and thermal pollution.

Eutrophication, defined as the excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life mainly due to high phosphorus and nitrogen loads in water, is the most prevalent water quality problem globally, substantially impairing the beneficial uses of water. Inorganic nitrogen and phosphorus within river systems have increased several-fold over the last two centuries. Moreover, chemical contamination is occurring as a result of excess nutrients, acidification, salinity, heavy metals and other trace elements, persistent organic pollutants and changes in sediment loads. Microbiological contaminants, bacteria, viruses and protozoa in water pose one of the leading global human health hazards, and when water heats, biological functions can be impaired. All these contaminants can operate together, reinforcing their collective impact.

The politics of environmental control at national level

Almost every country devolves environmental legislation to an agency. The USA has the Environmental Protection Agency (EPA), but a great deal of the responsibility is devolved to state level. Constraints on agricultural production to reduce pollution discharges typically arise at the state level in response to local concerns, and how to manage agricultural sources has been a prominent issue in several locations, such as the Chesapeake Bay and Florida. Most environmental regulations, in terms of permitting, inspection and enforcement, are implemented by state and local governments, often based on federal EPA regulatory guidance. In some cases, agriculture is the direct or primary focus of the regulatory actions. In other cases, agriculture is one of many affected sectors. Traditionally, farm and ranch operations have been exempted or excluded from many environmental regulations. Given the agricultural sector's size and its potential to affect its surrounding environment, there is interest in both managing potential impacts of agricultural actions on the environment and also maintaining an economically viable agricultural industry. Of particular interest to agriculture are a number of regulatory actions affecting air, water, energy and pesticides.

Agricultural production practices from both livestock and crop operations generate a variety of substances that enter the atmosphere, potentially creating health and environmental issues. Water quality issues also are of interest to the agricultural industry, as water is an input for production and can also be degraded as a result of production through the potential release of sediment, nutrients, pathogens and pesticides. But recent actions by the EPA to regulate emissions and pollutants have drawn criticism, including GHG emission reporting and permitting requirements, and National Ambient Air Quality Standards (NAAQS) related to dust. The criticism, however, is divided, reflecting a fundamental political division. On the one hand, some claim that the EPA is overreaching its regulatory authority and imposing costly and burdensome requirements on society. In general, the agriculture community, among others, has been vocal in its concerns, contending that the EPA appears to be focusing some of its recent regulatory efforts on agriculture. On the other hand, many public health and environmental advocates support many of the EPA's overall regulatory efforts, even suggesting that the EPA has not taken adequate action to control the impacts of certain agricultural activities.

The Nutrient Management Program (NMP) is directed by the Delaware Nutrient Management Commission (DNMC) and administered by the Delaware Department of Agriculture (DDA). Delaware's Nutrient Management Program is broad in coverage, requiring NMPs for all animal feeding operations (AFOs) with greater than eight animal units (AUs) and for any farmer who applies nutrients to more than 10 acres under their control. All NMPs must be developed by a certified nutrient consultant. In FY2013, the Nutrient Management Program had a total budget of $103,335 and approximately 1.625 full-time employees dedicated to it.

In 2015, there were approximately 1,072 AFOs and crop land farm operations in Delaware regulated by the Delaware Nutrient Management Law, representing approximately 57% to 68% of the farms that meet the USDA definition of a farm in Delaware over 10 acres or with more than $10,000 in sales, respectively. The DNMC reported that 100% of cropland and nutrient-applied acres were managed under a current NMP developed by a certified consultant.

Source: EPA (2015)

Another contrasting example: in Zambia, for instance, the Zambian Environmental Management Agency (ZEMA) has developed sector guidelines, including air and water quality guidelines, for Environmental Impact Assessments (EIAs) for major projects in fisheries and forestry, amongst others, examples of which are available (ZEMA, 2018).

So far as agriculture is concerned, there are six criteria for schemes requiring EIA: (a) Land clearance for large-scale agriculture; (b) introduction and use of agrochemicals new to Zambia; (c) Introduction of new crops and animals, especially exotic ones new to Zambia; (d) Irrigation schemes covering an area of 50 hectares or more; (e) Fish farms, of which production is more than 100 tonnes annually; and (f) Aerial and ground spraying on an industrial scale.

Similar organisations and procedures exist in virtually every country in the world.

There must, for example, be integration with water use. Water is now an especially important factor for agriculture and one of the keys to understanding agribusiness worldwide.

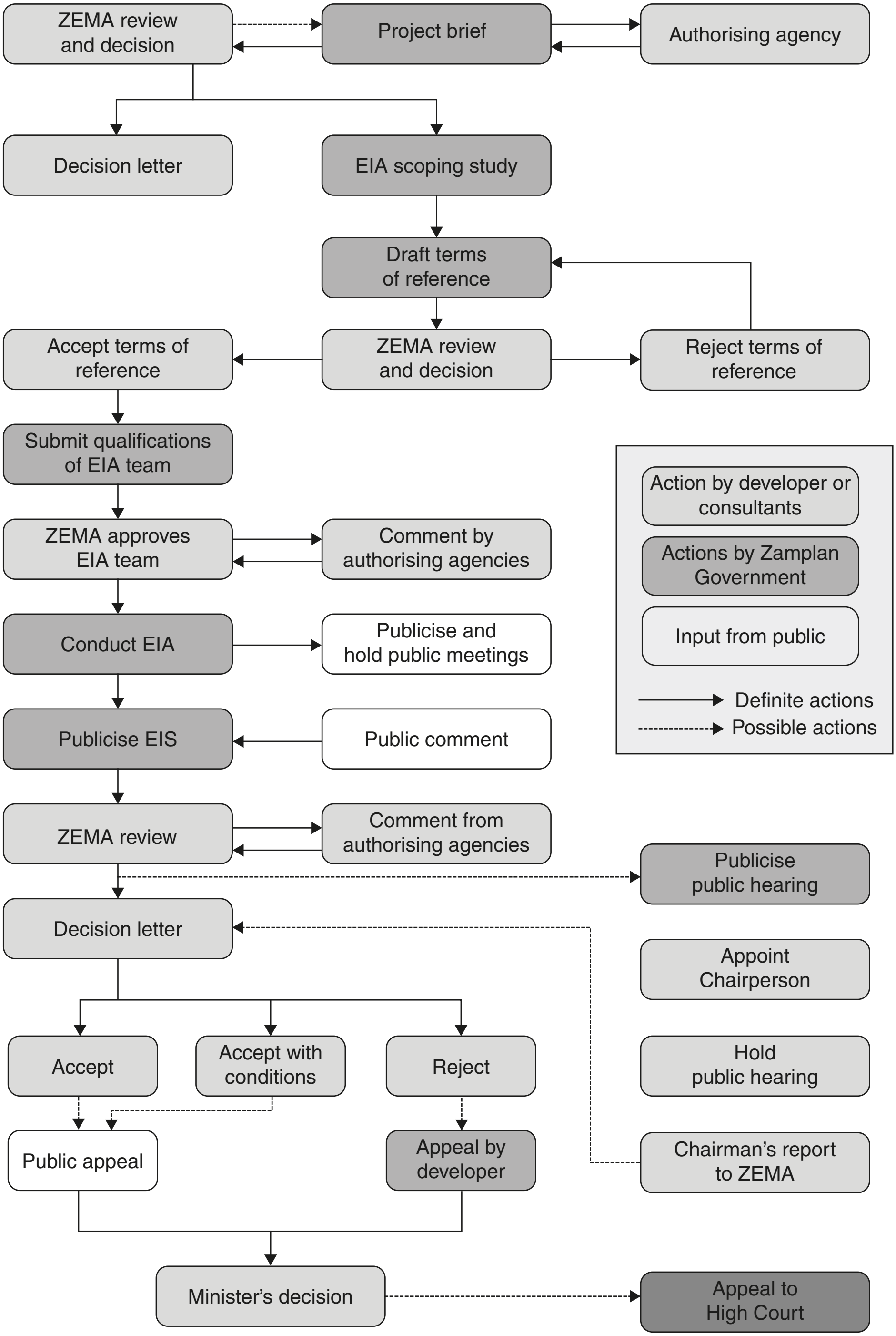


Figure 1.14 The EIA process in Zambia
Source: ZEMA (2018)

Irrigation is a good example of why, in the last 50 years, the worldwide area under irrigation has grown at approximately 1.6% annually, more in developing countries. But the growth in agricultural water use is decelerating, partly due to encouraging developments in the performance of irrigation systems themselves, but also because increased urbanisation is compressing water demand. There is now more competition for water, so for example the construction of dams and water diversion is affecting fish migration and inland fisheries. Urban settlement is dominating water use, and agriculture has been forced to adapt. Large levels of investment are needed to solve the problem.

Meteorology and climatology

This reinforces the need for accurate understanding of the weather. Demand is growing worldwide for forecasts of storms, floods and droughts in particular, as the risks and consequences of environmental change are rising. Modes of collecting and delivering weather and climate information are evolving. Businesses and non-profits are increasingly supplying weather services to farmers. And data now stem from a broader range of sources, such as for Android mobile-phone apps (e.g. Yahoo Weather) and other smart devices.

Typical publicly available snapshots of climate as it relates to agriculture are shown in Figure 1.15a–b.

To make the task of agribusiness that much more complex in coming decades, significant average crop yield declines are projected with higher temperatures. There are suggestions that this is already happening, for example stalled wheat yields in Australia (Hochman *et al*., 2017). Declines of 5–10% in the concentrations of iron, zinc and protein in crops such as wheat, rice, and soybeans with increased CO_2 concentrations, would certainly place people at greater health risks due to potential malnutrition as well as posing social risks, which are again arguably already happening (Fuller *et al*., 2018). Projected global shifts in consumption patterns to yet more livestock and dairy products, which are more emissions-intensive than cereals, will further increase the challenge of lowering the aggregate emissions intensity in the sector.

There are in many countries meteorological services provided to farmers to warn them of the dangers of climate to agricultural production.

Obviously, what is needed are innovative systems that protect and enhance the natural resource base, while increasing productivity – but this may be an impossible combination. Equally needed is a transformative process towards 'holistic' approaches, such as agroecology, agroforestry, climate-smart agriculture and conservation agriculture, which also build upon indigenous and traditional knowledge (FAO, 2017a:xi) – and equally obviously, if these approaches do not provide value for money, they will not be taken up. To be charitable, the FAO argument excludes research and development (R&D) improvements to seed and varieties. It does not even take a position on genetically modified (GM) crops. It mainly refers to environmental issues in developing countries, which are very real, such as the depletion of rainforests in Indonesia as a result of commercial palm oil, timber and rubber plantations.

> Palm oil is the most widely used vegetable oil in the world, appearing in the ingredients list of many consumer goods, from chocolate to soap. Indonesia, the world's largest

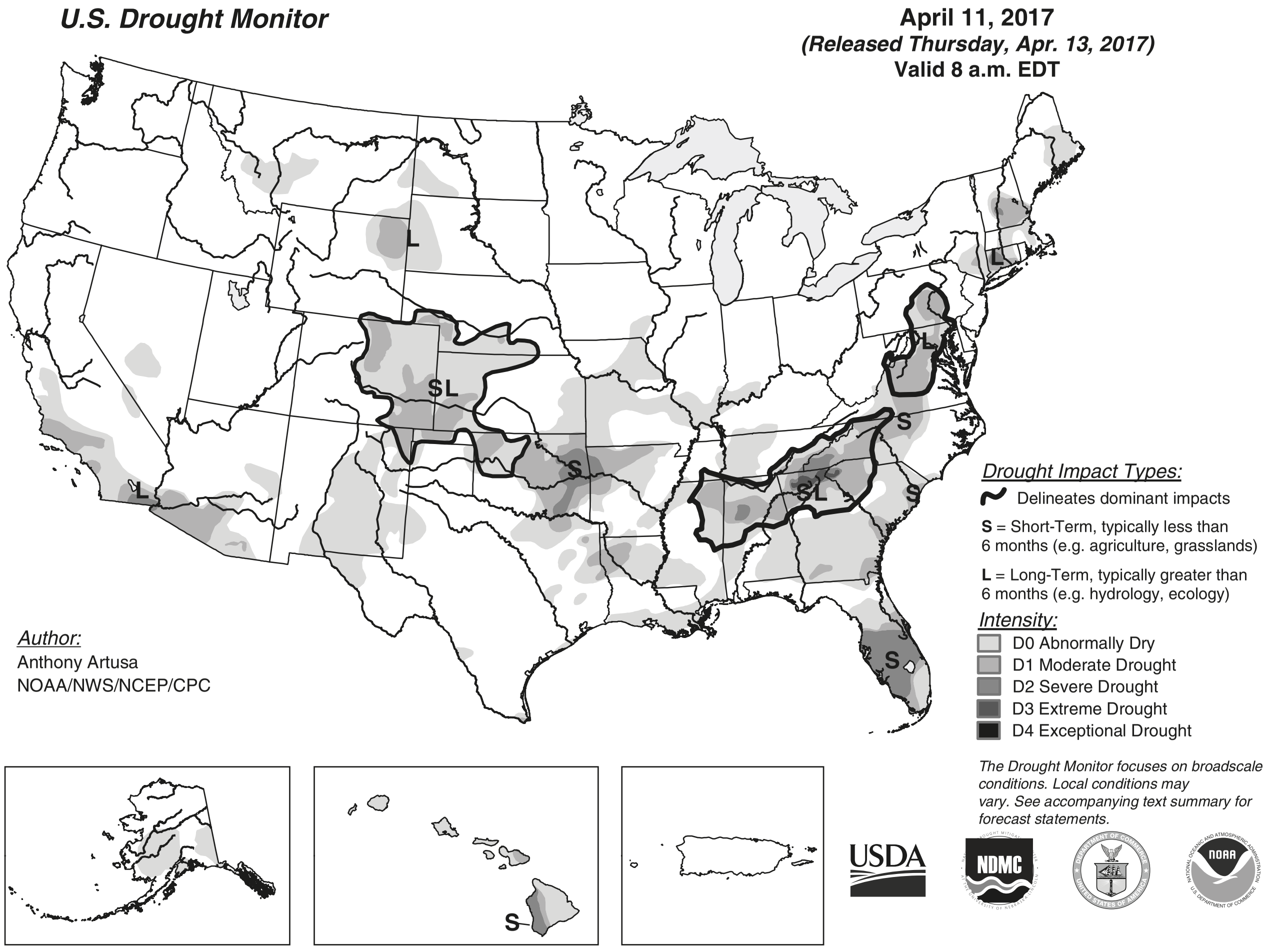


Figure 1.15a Weather map for the USA
Source: Rabobank (2017:5); Climate Prediction Center (2019)

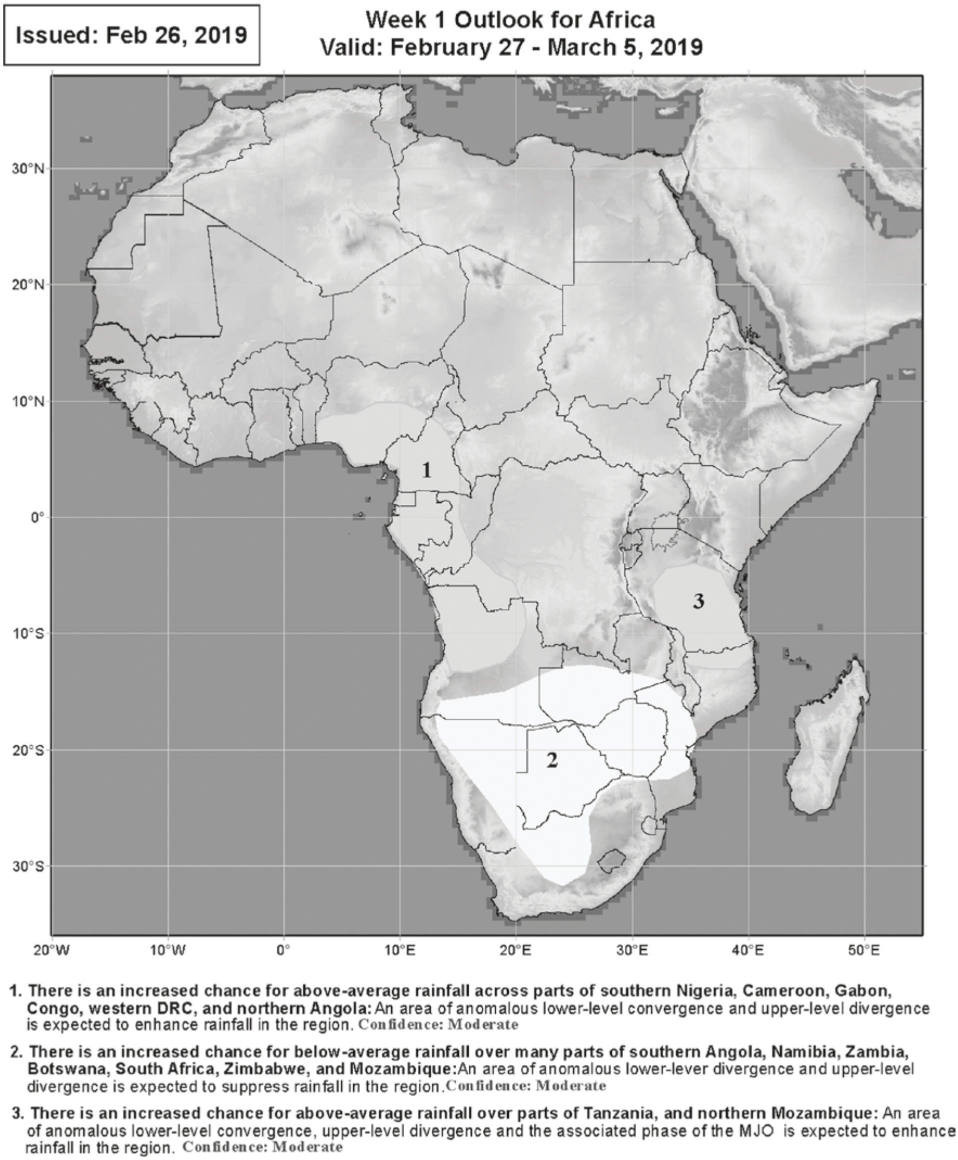


Figure 1.15b Weather map for Africa
Source: Rabobank (2017:5); Climate Prediction Center (2019)

producer of palm oil, has seen large swathes of rainforest cleared away and replaced by oil palm plantations at rates that exceed those of Brazil. On the island of Sumatra, which has had the highest loss of native rainforest in all of Indonesia, the changes in land use have meant a substantial loss of animal and plant diversity (Science Daily, 2017).

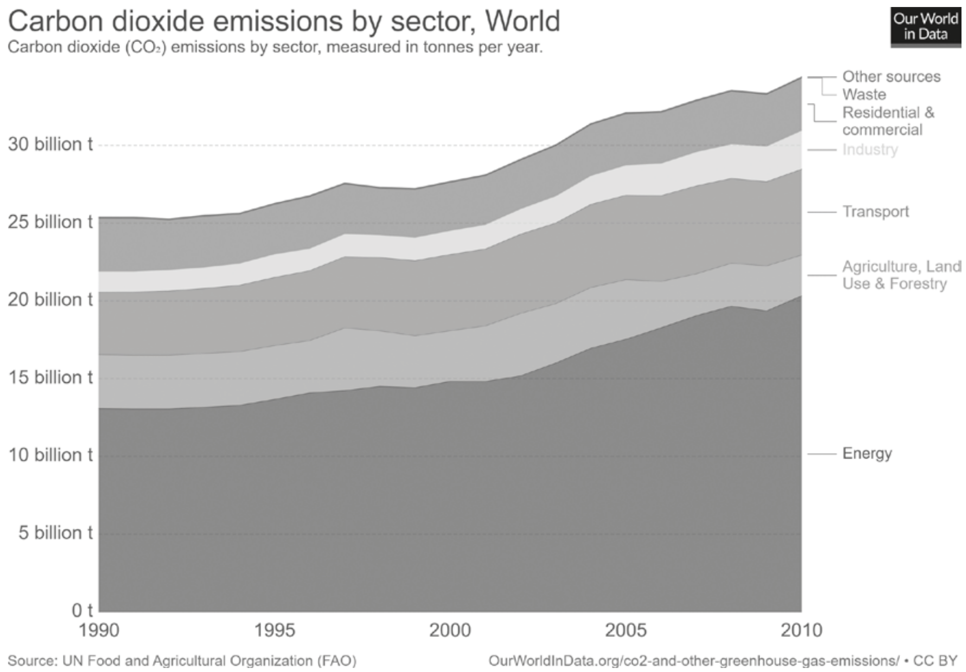


Figure 1.16 Summary of greenhouse gas effects of agriculture
Source: Ritchie & Roser (2017)

But it not just in Indonesia that commercial farming is replacing subsistence agriculture, or that farm sizes are rising: the average size of farms in developed countries is rising. And even in Indonesia, all is not lost: the rate of depletion of rainforests has declined, largely thanks to government action following NGO pressure. The large international trading companies (the largest known as the ABCD companies, discussed in Chapter 7 as well as other chapters) are now also active in the sustainability space: for example, January 2017 saw the major international trading firm Louis Dreyfus Company (LDC) join the World Business Council for Sustainable Development. They reported this example of collaboration, as shown in Figure 1.17.

Commercial farming and agribusiness operations

Agriculture is still one of the world's largest industries. More people work in agriculture than all other occupations combined. Based upon applying the definition of agribusiness to global data, the food and agribusiness system is the largest economic sector in the world economy, representing 50% of global assets, 50% of the global labour force and 50% of global consumer expenditures. The sheer scale of agriculture in countries such as the USA, Brazil and Russia should never blind us to the continued importance of agriculture elsewhere. For example, Tunisia is one of the world's biggest producers and exporters of olive oil and it exports dates and citrus fruits that are grown mostly in the northern parts of the country.

Working Alongside LDC – Partner Testimony

REA Kaltim

Global demand for segregated palm oil products has increased over the past few years as end consumers have become progressively more aware of the importance of whole supply chain sustainability. REA Kaltim is a grower and producer of crude palm oil in the East Kalimantan region of Borneo, Indonesia. The company currently produces crude palm oil and palm kernel oil under the mass balance supply chain model but is committed to moving towards producing segregated palm oil, notwithstanding certain challenges.

In 2016, 16% of the oil palm fruit processed by REA's three mills was sourced from independent smallholder farmers neighbouring the Group's own plantations. REA's relationship with these farmers was initially purely commercial, but over time REA has become more involved in the socio-economic welfare of neighbouring communities and now works closely with independent smallholders to improve their farming practices and make them more sustainable. Despite considerable efforts in this regard, the independent smallholders that supply oil palm fruit to REA's mills are not yet RSPO certified. To achieve the objective of producing segregated palm oil products, REA would therefore have to either refuse to accept palm fruits from non-certified smallholders or reconfigure the production and transport logistics of the operations to allow for the production of some segregated palm oil, while maintaining the current mass balance system so that fruit from non-certified farmers can still be accepted.

REA does not consider the rejection of fruit from neighbouring smallholders to be a desirable option given the negative economic impact on local communities that would ensue, inevitably harming the good relationships with these communities that have built up over recent years, and likely to lead to a gradual return to less sustainable farming practices by smallholders. Until local independent smallholders have achieved RSPO certification, REA's strategy for producing segregated crude palm oil products must therefore be the reconfiguration of its business logistics. This is a significant challenge for REA that is unlikely to be overcome in a reasonable timeframe without support. So how can other members of REA's supply chain help the Group to achieve its objectives, and as a grower, what does REA expect from its partners further down the supply chain?

REA sees its relationship with LDC as analogous to its relationship with independent smallholders. The partnership with LDC began as a commercial relationship, with each company solely responsible for the sustainability of its own operations. Now, however, REA and LDC have the opportunity to further develop this relationship and work more closely together in order to improve the sustainability of our shared supply chain and meet the market demands for palm oil that is produced according to stricter sustainability standards. LDC can assist REA in two ways. First, by providing logistical support as REA reconfigures its business to produce segregated oil and, secondly, by collaborating with us to help the independent smallholders that comprise part of the shared supply chain to achieve RSPO certification. In providing this support, LDC would not simply be benefitting REA's operations, but enhancing the sustainability of a product from the base of the supply chain through to the end consumer.

As a grower at the base of the palm oil supply chain, REA also expects downstream elements of its supply chain to maintain the sustainability of the palm oil products that began with us in order to uphold the international sustainability standards to which the group is committed through capital investment, biodiversity conservation and the socio-economic improvement of local communities.

Dr Ben Godsall
Sustainability Consultant
REA Holdings plc

Figure 1.17 Partner testimony between Louis Dreyfus Company and REA Kaltim
Source: Dreyfus (2017)

In the Lebanon, agriculture is the third most important sector after the tertiary and industrial sector. It contributes nearly 7% to the country's GDP and employs around 15% of the active population. The main crops are cereals (mainly wheat and barley), fruits and vegetables, olives, grapes, and tobacco (Agra ME, 2017:4).

In sub-Saharan Africa, the agribusiness sector is about half the economic size of farming; in Asia and Latin America, it is about two to three times the size; while in some industrial countries it is more than ten times as large. As economies grow, the agribusiness share of GDP relative to the farming share of GDP increases even as the overall share of agriculture in GDP declines. In agriculture-based economies (most of sub-Saharan Africa), this relative share is about 0.6; in transforming economies (most in Asia), it is 2; in urbanised countries (mostly in Latin America), it is 3.3; and in the USA, it is 13 (World Bank, 2013). The trajectories of developing countries are therefore readily apparent.

Hence the significance of the most important insight raised by Davis & Goldberg in *A Concept of Agribusiness* (1957), which was that what was happening *on* the farm in the USA, and in other developed countries, even by the mid-20th century, was utterly dependent on what was happening *off* the farm. A reviewer almost six decades later was surely right, though, that 'So many people seem to have missed this point, however, that even today when most people hear the term "agribusiness" they think not of food processors, fertilizer manufacturers, or supermarket chains but instead of large-scale commercial farms' (Hamilton, 2016:543) Farms produce output, but it is processed, marketed and distributed by agribusiness companies. A range of service companies is also part of agribusiness: transportation, storage, refrigeration, credit, finance and insurance, plus now agtech throughout the sector.

What is different, this century, is the globalisation of agribusiness. Already by 2013, agribusiness had taken hold in India, where there was a rising trend in *marketable surplus*. For major staple crops it had already risen to high levels: 81% for rice and 73% for wheat. Even for 'inferior' staples, it had reached high levels such as 62% for sorghum and 67% for pearl millet. This growth in marketed surplus brought substantial agribusinesses development – for handling it, including procurement/purchase, transport, storage, processing and marketing, as well as providing services such as finance, information and management. Just as important, commercialisation has also led to *diversification* in production, as farmers respond to market signals, needs and prices, and seek profits. Inevitably, there has been a shift to high value crops/products such as fibres, spices, vegetables, fruits, flowers and livestock products. This has stimulated the development of various agribusinesses which support and facilitate their production, undertake processing, and do the special supply chain management, marketing and trade arrangements they require (Gandhi, 2014).

A significant share of agricultural commodities is traded internationally (OECD-FAO, 2016). The larger this share, the more local production conditions are codetermined by global socio-economic and environmental conditions and political interventions mainly through price signals from world markets, although there are still significant price distortions at national and again at local level. The intensely political nature of agriculture explains why political decisions, e.g. on agricultural policies, as well as demographic and technological developments – and now environmental pressures as well – trigger feedback between global markets for agricultural commodities and local land use decisions which, in turn, eventually affect global prices, stocks, consumption and planting decisions. Virtually every individual producer, with very rare exceptions in highly regulated markets (Obasanjo Farms in Nigeria, perhaps (Ngex, 2018) are price-takers, and do not therefore control prices through their own investment and planning decisions. This is especially so for agricultural production

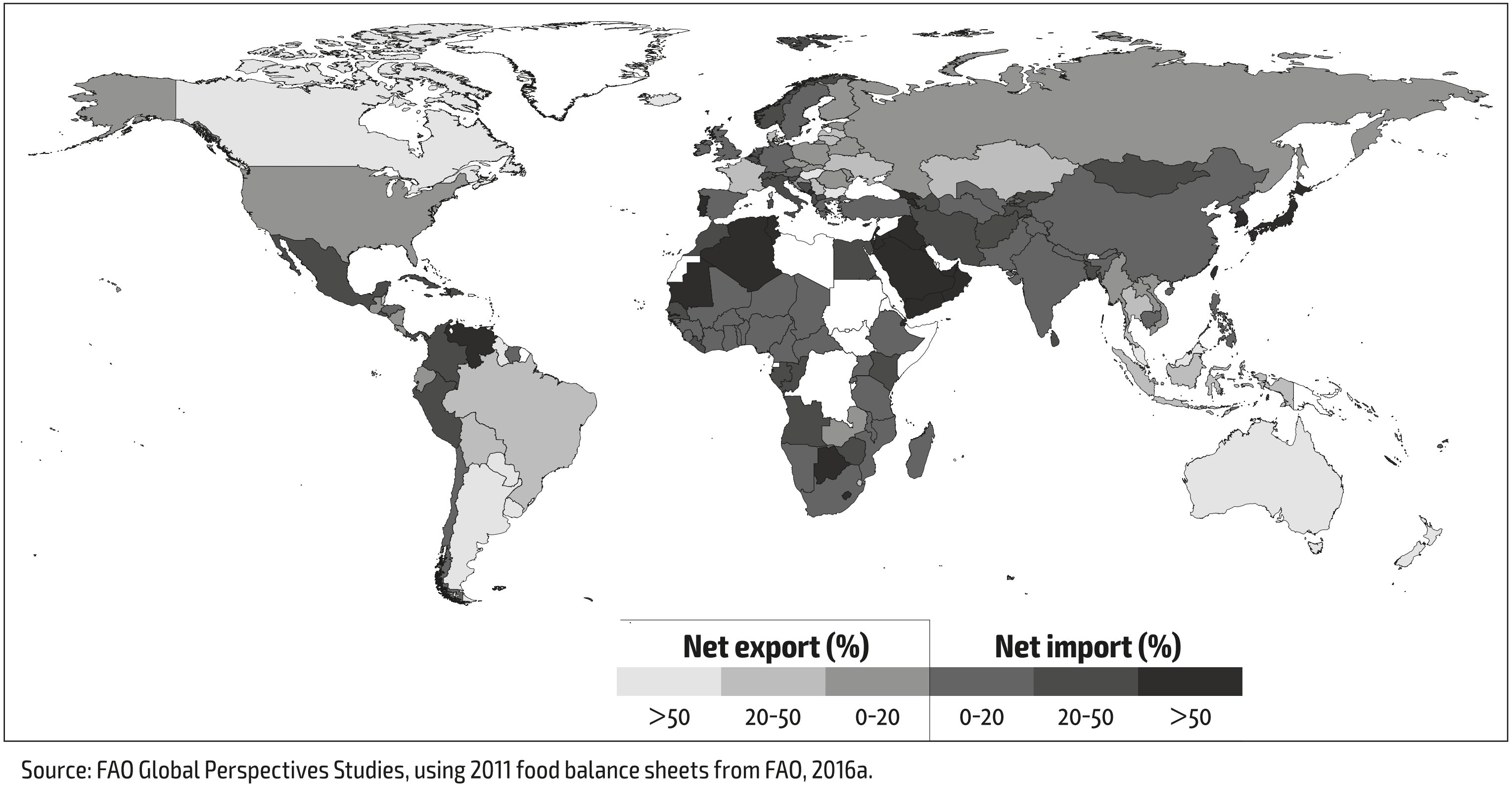


Figure 1.18 International agricultural trade patterns
Source: FAO (2015a)

for export. Although more than 90% of food consumed in the USA is produced there, for example, countries such as the USA, as well as Argentina and Australia, export more than 50% of their domestic food supply. At the opposite extreme, the Near East/North Africa region imports more than half of its food supply (FAO, 2017a:29).

The pattern of a world divided is very clear: the USA, Australia, Russia and the former CIS countries, and South America, are now feeding the world.

What drives commodity volatility?

The volatility of the price of an agricultural commodity can be associated with the standard deviation or error of price fluctuations of the commodity with respect to the mean value or to the trend. It is also possible to conceptualise volatility more straightforwardly as the rate at which asset prices change. Volatility affects prices, production and inventories in agricultural commodities by directly affecting the marginal value of storage (the marginal convenience yield), i.e. the flow of benefits from an extra unit of inventory. When prices – and hence production and demand – are more volatile, there is a greater demand for inventories, which are needed to smooth production and deliveries and reduce marketing costs. Thus, an increase in volatility can lead to inventory build-ups and raise prices in the short run (Pindyck, 2004). But note Pindyck's second process, that of the option premium, does not apply as agricultural commodities are a largely renewable resource, albeit with exceptions and bottlenecks. And with respect to the predictability of agricultural commodity market volatility, at least one study (Giot, 2003) suggested that the best way to predict volatility is to look at the price of options (see Chapter 8), although this work would require constant updating to be reliably used as the basis for any action.

International agribusiness organisations

Agriculture – not so much agribusiness in its widest sense, but certainly production agriculture – is also characterised by a number of international organizations that undertake much of the global research and co-ordination effort. Most of them would resist very strongly the suggestion that they were, or even could ever become, global trade associations for agribusiness. The most well-known, and important, is the Food and Agriculture Organisation of the United Nations, the FAO – a vast collection of expertise, data, policies and experience on global food and agriculture questions. Figure 1.19 shows how it was described in a report from 2013.

The FAO has come in for much criticism in recent decades. An independent review of its policies in 2007 said the agency had lost the confidence of donors, who had steadily reduced funding to the organisation and at least one director-general has been forced out as a result (Christoffersen *et al.*, 2008). Since then the FAO has attempted to pursue a middle line between the market advocacy of organisations such as the World Bank and the criticism of NGOs, for example of its attitude towards and plans to deal with agriculture and climate change (e.g. Oxfam, 2015). With the receding of the food crisis of that time, criticism has also become less vocal, although the internal struggle within the FAO between supporters and critics of market solutions continues to rumble on, with no sign of resolution any more than in the world at large.

The oldest of the Rome food agencies, the Food and Agriculture Organization of the United Nations (FAO) was born in 1945 in the post-World War II burst of international institution building. It is the only global intergovernmental organization today with a broad mandate in governing the world's food and agriculture system. FAO is charged with four goals: improving nutrition, increasing agricultural productivity, raising the standard of living in rural populations, and contributing to global economic growth.

Given this comprehensive mandate, FAO's work spans an array of activities, including gathering and analyzing statistics; providing policy assistance to countries; engaging in advocacy and capacity building; implementing field projects; contributing to international agreements and guidelines; and responding to emergencies. These activities fall into numerous areas—crops, livestock, fisheries, forestry, and water and land management.

FAO's notable historical achievements include:

- Adopting the International Plant Protection Convention (1951), the framework for rules to prevent the spread plant pests through international trade.
- Establishing the Codex Alimentarius Commission with the World Health Organization (1961), regulating international food safety standards.
- Creating the Global Information and Early Warning System for detecting food crises and enabling timely response (1975).
- Pioneering integrated pest management, which reduces losses to pests without exposure or reliance on excessive pesticides, and the farmers' field schools approach used to disseminate integr ated pest management through farmer participation (1980s).

More recently, FAO's achievements include:

- Leading successful campaigns to eradicate rinderpest (1998–2011) and to control avian flu (2004) and desert locust (2003–2005).
- Adopting the International Treaty on Plant Genetic Resources for Food and Agriculture.

Figure 1.19 About the FAO
Source: Center for Global Development (2013:xiii)

The FAO is not the only organisation active in the space: the Consultative Group on International Agricultural Research (CGIAR) states that its objective is a world free of poverty, hunger and environmental degradation. They say that they work to advance agricultural science and innovation to enable poor people, especially women, to better nourish their families, and improve productivity and resilience so they can share in economic growth and manage natural resources in the face of climate change and other challenges. Their claim is that, by 2030, the action of CGIAR and its partners will result in 150 million fewer hungry people, 100 million fewer poor people – at least 50% of whom are women – and 190 million hectares less degraded land. They aim to:

- Improve the rate of yield increase for major food staples from the current <2.0 to 2.5%/year;
- Ensure 150 million more people, 50% of them women, are meeting minimum dietary energy requirements;
- Enable 500 million more people, 50% of them women, to be without deficiencies of one or more of the following essential micronutrients: iron, zinc, iodine, vitamin A, folate and vitamin B12;
- Achieve a 33% reduction in women of reproductive age who are consuming less than the adequate number of food groups;
- Enable a 20% increase in water and nutrient (inorganic, biological) use efficiency in agro-ecosystems, including through recycling and reuse; and

- Reduce agriculture-related greenhouse gas emissions by 8 $GtCO_2$ eq per year (15%), compared with a business-as-usual scenario in 2030.

These are ambitious goals, for sure, and they may not all be mutually compatible, let alone achievable.

CGIAR and its member centres have led studies concerning the adoption of new technologies in agricultural production by farmers in emerging economies. A leading member is the International Food Policy Research Institute (IFPRI), which 'provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition in developing countries. Established in 1975, IFPRI currently has more than 600 employees working in over 50 countries' (IFPRI, 2018). Another member is the Technical Centre for Agricultural and Rural Cooperation (CTA), a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). A similar organisation for West Africa is the West and Central African Council for Agricultural Research and Development (CORAF) – for their programme, see CORAF (2018). The promotion of the maize sector through collaborative and innovative research is one of the primary areas of the work of CORAF. For this specific project, CORAF worked jointly with the National Institute of Agricultural Research of Benin (INRAB), the Institute of the Environment and Agricultural Research of Burkina Faso (INERA), the National Center for Agronomic Research of Cote d'Ivoire (CNRA) and the Institute of Rural Economy of Mali (IER).

In addition, the international development banks perceive themselves as having a role in agricultural development. The Asian Development Bank (ADB), for example, has a five-year plan in the agriculture and natural resources sector, which prioritises four areas:

- Increasing the productivity and reducing pre- and postharvest losses of food harvests;
- Improving market connectivity and value chain linkages;
- Enhancing food safety, quality and nutrition; and
- Enhancing management and climate resilience of natural resources (ADB, 2015).

Generally, the ADB has focused on asset creation and access to markets and inputs in the poorest regions. For example, it has looked to replicate small-scale planting innovations in forestry, bringing them into the mainstream of forestry practice.

Conclusion

The current position of the FAO, in a tightrope walk between increasing production and conserving the environment, is that high-input, resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production without huge alterations in practice.

Yet, the inefficiencies of small farm operation have been regularly reported, for example that small farm sizes and growing wheat in the mixed production zone in Punjab in Pakistan tend to have greater technical inefficiencies (Battese & Smale, 2017). Moreover, whilst in rich countries farms are consolidating, although the trend has slowed, the opposite is found elsewhere: the average size of an Indian farm keeps shrinking, falling by 50% over the last half of the 20th cCentury. If this continues any potential comparative advantage to Indian agriculture will be lost. Only large-scale investment and entirely commercial agribusiness stands any chance of reversing this trend.

The need for commercial agribusiness to feed a growing world is clear. One indication of rising interest by government and the private sector worldwide in the sector is the proliferation of conferences devoted to agribusiness. For example, Agra ME (www.agramiddleeast.com), delivered a conference in Dubai in April 2017 focusing on issues surrounding production and import of agricultural commodities in the MENA (Middle East and North Africa) region. The annual Global AgInvesting Conference for investors in New York has hundreds of participants, more every year. There are many other such events. Regulators and governments confronting agtech and international trade are similarly beset with problems and issues surrounding agriculture, food and livelihoods.

Agribusiness has a huge task ahead of it this century. *How it will achieve it is the subject of the rest of this book.*

Notes

1 The cattle inventory in India includes water buffalo.
1 There may soon be just three if one of the others merges with Bunge.
1 This text is drawn from the EU but the explanation is generic. Similar analysis is to be found in Kang & Mahajan (2006) and in numerous other sources, e.g. Madre & Devuyst (2016), many of which take divergent views on the usefulness or otherwise of these financial instruments for agriculture.

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