CHAPTER

7

Agriculture, forestry, and fisheries

OUTLINE

Food or more specifically agriculture in this sense is also responsible for a large proportion of global employment.

7.1 The agricultural landscape: a global structure

By 2010, there were approximately 525-570 million farms worldwide (Lowder et al., 2016). Collectively, these farms employed over 1 billion people, equivalent to just over one-third (35%) of the global employable population. Furthermore, on top of this, another 2.6 billion men, women, and children directly relied on such agricultural systems for their livelihoods (GHI, 2010).

Food and Society
https://doi.org/10.1016/B978-0-12-811808-5.00007-6

However, these figures can be misleading, for on the face of it these numbers might suggest a healthy and thriving global agricultural sector, yet the actual underlying trend is one of consolidation and industrialization. And this is having a downward impact on the employment numbers and a concomitant increase in the number of larger farm sizes. Moreover, the debate is not clear-cut; for instance, mechanization allows fewer people to achieve greater production which is not necessarily a bad thing in and of itself. However, on the flipside, this industrialization often results in benefits from economies of scale and labor-saving costs, which often combine to undermine their smallholder competitors.

What we end up with is a global agricultural production system on a two-track footing: the global and local. The global track can be considered as comprising an agricultural market driven and catered for on an industrial scale; the local track on the other hand can be considered as comprising predominantly small-scale or subsistence farming catering to the individuals or limited local markets. This is perhaps an unforgivable generalization, yet it suffices to highlight the inherent dichotomy within the system.

7.1.1 A global track

In terms of the local track, of the previously mentioned 525 million farms, there are between 400 and 450 million strong smallholder farms comprising 2 hectares or less. These collectively employ about 1 billion people, approximately one-third (35%) of the entire global population. Furthermore, the 525 million farm lands are equivalent to about 60% of worldwide arable land and provide the bulk of many developing countries food requirements, or from another perspective about half the world's total food supplies (Hartmannshenn, 2004; Båge, 2008; IAASTD, 2009). The global track is increasingly characterized by larger farm sizes and the ever-growing mechanization and industrialization of the industry. While in the developed world this trend has been ongoing for the last 60 years plus, it was the advent of the Uruguay GATT trade rounds in 1992, with the inclusion of agriculture in the barrier reducing targets that really defined the beginning of the complex global food chain that is familiar to us today. In fact, in the last 20 years or so, global agricultural trade has increased more than threefold, although having said that this still only represents a small part of total overall global production. This industrialization of the agricultural product has its focus on both the domestic and international markets. This is increasingly reflected in the intensification of farming and the overall increase in farm sizes particularly in the industrialized world (Table 7.1). As a result, today's complex global food system remains

TABLE 7.1 Approximate farm size by region.

Region	Average farm size (ha)
Africa	1.6
Asia	1.6
Latin America and Caribbean	67.0
Western Europe	27.0
North America	121.0

Source: Compiled from UNCTAD report, Technology and Innovation for Sustainable Agriculture. (Geneva, Switzerland, UNCTAD: Commission on Science and Technology for Development, 2010).

populated with larger farm sizes, which are increasingly owned by or under the management of multinational corporations who continue to combine both sovereignty and leverage over unwitting end users such as consumers and agricultural producers alike.

7.1.2 The local track

The size of the small-scale farm holdings identified previously, the local track comprises numerous other pastoralists or herders; hunters and gatherers; forest dwellers; fisherfolk; gardeners; and the landless and other rural workers. While the benefits of local and smallholder farming have seen a renaissance of late, there is, however, one obvious disadvantage. That having such a large proportion of a country's domestic agricultural production supply in the hands of such small-scale farmers and the like, then this predominantly, subsistence-oriented approach becomes extremely vulnerable particularly from direct drivers of change such as climate change, pests, disease, natural disasters and economic instability, etc.

Moreover, particularly within developing countries with little political or economic power, the small farmers have not readily benefited from the globalization and increased traffic within the sector. Barriers such as international protectionism coupled with the high capital entry deterrents exclude any real democratic participation of smallholders. Sadly, changes are not on the near horizon either, not until that is, trade reforms aiming to reduce protectionism in the form of subsidies and import tariffs are lowered or removed completely, will a more level playing field be created. In fact, until the negotiating position of small-holders is strengthened in the developing countries, the status quo is likely to remain.

So, it can be seen that agriculture can be viewed as a critical point of economic growth for the poorest countries; however, their exclusion from the global platform ensures the exclusion of many, potentially strong, players. Crucially, there are several economic and agricultural development paradigms with as many believers in each camp. Thus, back-and-forth posturing does little to progress the situation for all parties.

7.2 Increased food production?

By 2050, the population of the Earth is anticipated to tip over the 9 billion mark. Between now, then, and beyond, agriculture will be required to not only provide food, feed fodder, and fiber to meet our existing populations' needs but also over and above that it would have to meet the needs of the projected increase. This equates to an increase of 0.35% year-on-year food production if one is to generate the 70% extra food essential to meet the expected population numbers. Achieving this though is only a small part of the challenge, the problem or challenge is one of balance. Are we collectively able to produce this amount of extra food without seriously affecting the environment or unduly raising the price of food remains to be determined (GHI, 2010). This challenge also comes during a period which sees agriculture sector continue to decline in popularity. In the United States and Western Europe, for example, the past two generations or so have collectively seen their share of global agricultural output fall to around 1%–2% of GDP. This is in comparison to fewer developing countries whereby the agricultural sector still represents (albeit declining) an average of 20%–40% of overall GDP and which continues to employ 60% or so of the labor force.

This is a very real challenge, food chain waste savings, economies of scale, and eating lower on the food chain as well as other initiatives aside, one can legitimately ask where is this 70% increase in production supposed to come from? Ignoring for now any off-farm food generation, the core challenge of increasing the quantity of food must come about one of the two ways; the first is increasing yields and the second is increasing land under production (possibly from the regeneration of depleted land). Yet the Earth's budgeted land is a finite resource. Furthermore, when it comes to yields, there is also a natural limit which is proportional to the quantity and even the quality of any agricultural inputs. Once again, the outcomes are financially driven whereby economic trade-off is one of the inputs versus outputs. This creates what is known as a yield gap, i.e., the difference pertaining to a crop's maximum potential yield and to what is actually grown. This in turn depends to a large extent on the prevailing economic or policy environment of the day. Consequently, the future needs of the next generations rely to a large extent on conducive political and economic agendas (DFID, 2004).

These agendas might promote policy changes including the direction, for instance, of agricultural development paradigms with possible changes inter alia market-oriented over subsistence farming, smallholdings versus large farms, and self-sufficiency among others. However, these policy changes need to be considered carefully. Improving the lot of smallholder farms might increase rural employment, productivity, which on a national level improves overall agricultural output and which in turn can effectively lower food commodity prices. Having said that, an all-too-familiar response from farms in these circumstances is to increase production, further depressing prices creating a seesaw effect of over and under production (Zhang et al., 2007). There are indeed ways to account for these kinds of ups and downs and it becomes necessary to find a suitable balanced solution or trade-off to maximize potential food output while satisfying as many stakeholders as possible.

Such considerations are predicated on sustainable agricultural models. More on this is discussed in the next section.

7.3 Modern agricultural practices

Boserup (1965) in his study specifically targeted lesser developed nations in which he identified five unique agricultural systems based on the time and length of fallow between periods of productivity. These included (1) multicropping where no fallow was given, (2) annual cropping where fallow only lasted a few short months, (3) short fallow, which allow periods of fallow to last between 1 and 2 years, (4) bush fallow, which lasted a little longer at between 6 and 10 years, and (5) slash and burn forest fallow lasting between 15 and 20 years (Boserup, 1965).

This is neither a definitive list nor does it take into account the various other farming practices such as fisheries and livestock production. Interestingly too, while all of the above methods are still practiced to some extent in various parts of the world, today there is a growing propensity (driven by need and profit) for shorter or no-fallow periods of agriculture. Of course, this trend aside, the underlying consideration over which farming method is chosen still remains to a large extent dependent on available resources and constraints such as government policy, climate change, and numerous other economic and social or political pressures. The essential thing to take from this is that different practices have different impacts vis-à-vis soil quality, sustainability, and ultimately future productivity. Take for instance fallow-based farming—this method allows sufficient time between cropping to allow the soil to naturally replenish its stock of nutrients. The trend for shorter or no-fallow period farming asks much more of the land and requires the land to be micromanaged. Nutrients, given time to naturally replenish in the fallow farming process, now, had to be added manually. This intensification also requires that every aspect or every process is now considered at the micromanagement level; these include biodiversity, land degradation, irrigation, pest control, fertilizer, and even agricultural effluent. Farming at this level is as much a science as it is an art, and getting the right balance between productivity and sustainability is as much a political hot potato as it is a way of life.

In summary, it can be seen that while both monocultures[1] and polycultures[2] (multiple cropping and intercropping) are in common use, monocropping has undoubtedly become the dominant form of agriculture these days.

Some of these will be looked at in the following text.

7.3.1 Slash and burn

Slash and burn, or more commonly shifting cultivation, is a term used to describe land that is temporarily cultivated and then left to fallow for certain periods of time. If the slash and burn practice takes place in the forest or woodland, then it usually involves the burning of the shrub land or trees releasing much needed nutrients back into the soil. After cultivating the prepared nutrient-rich land crops are resown until such time as yields are no longer productive. The area is then abandoned or left to fallow while surrounding trees and shrubland as well as the forests natural flora can regrow and become fertile again. A process which could take years to achieve, although this is not necessarily a bad thing as the land, is still used for firewood, fetching, timber, berries, and other cultivatables, after which the process is repeated again and again. Slash and burn farming requires large amounts of land at any one point, most of which are out of use. In terms of sustainability of the slash and burn method, the skill lies in understanding how long to cultivate and how long to fallow each piece of land: the aim of course is to not allow the net nutrient loss or degradation of a particular parcel of land. Other questions of sustainability are determined by many factors such as time, availability of land, the intensity of cultivation, and the cultural appropriateness of the slash and burn practice (Brush, 1987).

7.3.2 Annual, monocultivation, and polycultivation

Annual cultivation drastically reduces periods of fallow or time when the land is allowed to rest between cropping seasons. This method of farming is used a lot in the intensification of

[1]**Monoculture** – is the practice of growing a single crop over a wide area. It is widely used in modern agriculture and its characterized by its large harvests with minimal labor UOR (2009). "University of Reading: Agriculture, Policy and Development, History of Agriculture." Retrieved 4 June 2019, from http://www.ecifm.rdg.ac.uk/history.htm.

[2]**Polyculture** includes multi-cropping - the practice of planting several crops sequentially in any 1 year is known as multiple cropping; and intercropping - is when several crops are grown at the same time on the same land.

modern agriculture. Consequently, the land has to be managed properly to ensure that nutrients are not leached from the soil and that pests are kept under control. This usually means greater financial cost and issues of sustainability, biodiversity, and soil degradation (Boserup, 1965).

It's difficult to say what came first, whether industrial advances or agricultural paradigms; however, one of the other led to the practices known as mono- and polyculture. Although both are in use today, monocropping is without doubt the most predominant type of agricultural practice today.

Monoculture is the growing of a single crop. It is in wide use around the world and is considered the modern method of agricultural cropping. It is characterized by the minimal labor input and large agricultural output (UOR, 2009).

Polyculture is the planting of multiple crops consecutively in a single year called as multiple cropping; on the other hand, intercropping is the term used when several crops are sown together within the same area.

Inherent advantages exist for each method whether monocultures or polycultures practice. Monoculture, for instance, largely benefits from lack of competition for certain nutrients; furthermore, advantageous cost savings can be made to large-scale industrial output. Lastly, although it receives a lot of bad press, monoculture is not by itself a bad agricultural practice; in other words, it is not inherently unsound when it comes to the environment. More and more studies show that the problems attributed to monocultural practices are due in large part to poor management and then to the practice itself. Polycultures tend to benefit from year-round production and provide diversity for the ecosystem, as well as reach less nutrients from the ecosystem.

7.3.3 Pastoralism or pastoral farming (animal husbandry)

Pastoralism, or animal husbandry, is that part of agriculture that deals with animal livestock such as goats, chickens, yaks, camels, sheep, and bovine, etc. Not only are they great sources of proteinaceous meat, but also many provide milk, eggs, leather, and fiber too. There are several types of pastoralism—the first is nomadic whereby humans move along with their herds in search of grasslands to grade; then there are the herders who migrate seasonally also in search of pastures new; and lastly there is the branch of pastoralism called transhumance, which is similar to the herders in which they move seasonally between higher and lower pastures. Being an important part of the agricultural sector, pastoralism faces challenges and is especially vulnerable to natural and man-made risks/disasters. One such risk involves the decreasing availability of pastures. Moreover, apart from inclement weather, other challenges encountered in pastoral communities may include competition for land in such things as expansion of sedentary agriculture or the expansion of other agricultural projects like the conversion of lands to things such as animal sanctuaries, game reserves, and wildlife parks, thus creating competition for valuable natural resources. One aspect of which type of pastoralism is considered over another depends partly by the climatic conditions. Tropical areas, for instance, allow for all types of pastoral practices, while subtropical and arid environs are limiting because of sunshine, rainfall, and temperature.

7.3.4 Permaculture

Permaculture is a relative newcomer to the more traditional farming models. It is a holistic approach to farming that attempts to mimic relationships found in nature. By mimicking nature, permaculture establishes relationships and aims to sit side by side with the natural ecosystem. It embodies a set of goals and values that is almost a way of life rather than a way of agriculture. In these values, permaculture espouses an environmentally beneficial paradigm of education, population numbers, and a light touch when it comes to the utilization of Earth's natural resources.

Some of the more central principles laid out in this method includes the following:

- interacting with nature for the more efficient use of resources;
- utilizing better the abundant natural energy provided by the sun, wind, and water;
- encouraging self-reliance through the incorporation of marginal lands, urban gardening such as window boxes, and even replacing ornamental gardens with dual-purpose multifunctioning esthetic and edible plants;
- producing little or no waste by connecting input and output elements so that they meet each other's needs.

All in all permaculture aims to be fruitful by integrating agricultural systems within the ecosystem rather than outside of it (Permaculture Ass, 2011).

7.3.5 Agroforestry

In terms of agriculture, forests provide both produce and employment either through wood and wood products or specialist food commodities. Agroforestry or forest farming is the practice of combining trees and shrubs with crops and/or livestock. These can either be integrated in a spatial sense or temporally (over time) but it is not uncommon to find agroforestry specializing in high-value crops. By mixing forestry and agriculture—in this way biodiversity and ecological systems remain healthy and varied as well as being an added environmental benefit which also allows for valuable water retention in the soil while further protection is offered against wind and rain erosion. In general, the successful practice of agroforestry relies on knowledgeable and careful selection of trees and crops to optimize production and minimize negative competitive effects. Several categories of crops are particularly suited to this type of farming, including mushrooms; nuts; vegetables such as radish and beetroot; honey; herbs; fruits such as blueberries; elderberries; blackberries; raspberries, and so on; edible flowers; and sap products such as maple syrup, birch sap wine, etc.

7.4 Fisheries and aquaculture

Fish is a highly nutritious animal protein that contributes significantly to the diet of around 1 billion people worldwide—in fact, it has been suggested that globally as much as 15%–20% of all animal proteins. It is also understood that much of the world's oceans, rivers, and lakes are overwhelmingly fished by small-scale artisanal fishers contributing vital food sources to the overall dietary makeup of many poor localized communities. Not surprising then that in

1996 fish and fisheries accounted for the income of an estimated 30 million people worldwide of which 95% reside in the developing countries (FAO, 2011).

Of note too is the growing tendency for traditional small fisheries to divert traditional foods away from the local community, instead choosing to supply the international market in exchange for valuable incomes and alternative food sources. This comes about largely through the growing demand of industrialized nations. This is coupled with advances in processing, packing, and transporting perishable goods over the last two to three decades. While this decreases the available fish for local consumption, there are those that argue that the increased processing and fisheries employment opportunities create more jobs and income. Moreover, some argue that by selling premium fish products on the international market, cheaper imported food substitutes effectively create a net inflow of foreign earnings. With regard to traditional capture fishing, it can also be seen that the industry is receiving competition from a growing aquaculture[3] (or aquafarming) industry. This according to the Food and Agriculture Organization (FAO) is the fastest growing food-producing sector now accounting for nearly 50% of the world's food fish (FAO, 2011). Systems like these and the more efficient processing entailing less spoilage and wastage together with a reduction of discards at sea have the potential to considerably increase the productivity of the sector. However, poor fishery resource management has been seen to have an adverse impact on the aquatic environment and resources, which in turn create enormous pressures in terms of wastage and the sustainability of the sector (Kurien, 2004).

Another important characteristic of the modern agricultural landscape is the industrialization or more specifically the intensification, extensification, concentration, and specialization of agriculture.

7.4.1 The green and evergreen revolutions

When people talk of the green revolution, they generally focus around the 1960s, as new technologies became widely available and were taken by many farmers across the world. However, in point of fact, foundations for the green revolution were actually sown long before when agricultural yields really began to take off. This so happened around the agricultural industrial and chemical revolutions of the 18th century. New advances in science and technology are all about the industrialization of the agricultural sector. However, this was fairly short-lived as yields once again began to stagnate around the 1850s (Johnson, 1997, 2000; Borlaug, 2000; McCalla and Revoredo, 2001; Webb et al., 2008). However, all that changed once again from the 1940s onward, which is characterized by scientific and technical progress in terms of genetic breeding, creating hybrid crops and the industrialization and increasing mechanization of agriculture (Brewster, 1945; Barton and Cooper, 1948; Borlaug, 2000; Gardner, 2002; UOR, 2009). Of course, as mentioned previously, much of the progress of increasing food yields and the mechanization of agriculture came about toward the end of the war as the allies needed to maximize food production and do so quickly. Such urgency necessitated the multilateral pooling of resources through technical assistance programs led by the likes of the FAO, the United States, and also through the dissemination of information

[3]The cultivation of aquatic organisms whether fresh or saltwater under controlled or farm conditions.

by the Cooperative Mexican Government-Rockefeller Foundation agricultural program of 1943.

Such resources were developed in no small measure by Nobel Laureate Norman Borlaug and others which brought about hybrid crop varieties, crops more resistant to disease and more pest-resistant plants and crops. On top of this, the now widely available synthetic fertilizers brought about increasing yields per hectare (Sharma and Gill, 1983; Perkins, 1990; Herdt, 1998; Borlaug, 2000; Troyer, 2004; Wu and Butz, 2004; USAID, 2009). The problem with the notion of the green revolution was that these technologies and advances in science were not particularly widely used or disseminated outside of the industrial nations. Instead this happened around the 1960s and hence the reason why people believed that the green revolution began about this time. Indeed, the phrase "green revolution" was kneeling coined until 1968 in an address to the Society for International Development by the then United States Administrator of the Agency for International Development (USAID) William S. Gaud, who offered

> These and other developments in the field of agriculture contain the makings of a new revolution. It is not a Violet Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution. *Gaud (1968)*.

By the 1980s, the so-called green revolution had been adopted by many developing countries excluding sub-Saharan Africa. The results were tangible with large 70% plus crop yield averages between 1961 and 1999. This led to the conclusion by many that research and development would play a pivotal role in securing future global needs (Nellemann, 2009).

Nowadays, however, there is much blame aimed at the green revolution especially in connection with the industrialized nations. This is due in no small part to criticisms about the heavy use of fossil fuels, inorganic fertilizers, and the environmental consequences of both the scientific and industrialization practices in general (Muir, 2010). One of the more frequently repeated issues in modern agriculture is the use of the inorganic or mineral fertilizers as they are sometimes called. As both can be made from natural and synthetic sources in recent years, close to 97% is now regularly produced from synthetically created ammonia. The major problem is to do with the huge amount of energy required to produce this ammonia and some have suggested that the process consumes up to on average 5% of global natural gas supplies, which equates to just over 1.5% of the entire global energy production (McLaughlin et al., 2000; GEO, 2007). To place this in perspective to produce one ton of nitrogen (chemically fixed) in the form of it takes around 30 to 40,000 ft^3 of feedstock in the form of natural gas and a further one ton of oil to drive the process. Furthermore, to produce this one ton it produces on average 1.8 tons of CO_2 (Sundquist and Broecker, 1985).

This is not the end—every year between 30% and 40% of global food production is damaged due to birds, mammals, insects, viruses, bacteria, weeds, and fungus. Indeed, insects alone are responsible for 14% of such losses. Therefore, the need for pesticides cannot be underestimated. This is not a problem it in and of itself; however, the term pesticides incorporate insecticides, herbicides, fungicides affecting any chemical, biological, or physical agent that has the ability to destroy or control such pests (Muir, 2010). While we have recently learned a lot about the use of such agents, first- and second-generation compounds including dichlorodiphenyltrichloroethane, cyanide, and arsenic were found to be highly toxic.

By contrast, modern-day pesticides are rigorously tested for potential damage to the soil, the crops, and the potential for toxicity in humans through excessive use, so lessons have been learned yet the fear among many doubters remains (Muir, 2010).

The second important charge delivered at the feet of the green revolution is those of environmental consequences. For instance, unsuitable use of fertilizers, pesticides, and any number of persistent organic pollutants has been linked to the long-term degradation of the soil itself. Most damage comes from poor farming practices where buildup of excessive nitrate, heavy fertilizer run-off, eutrophication, salinization, and the chemical "burning" of the soil affecting much needed trace elements and microbial species has taken place (Eifert et al., 2002). People are also aware and offer considerable concern about how the green revolution affected the biodiversity of the plants and crops we grow. Many crop hybrids have been harvested over the years that it has resulted in some cases to 90% reduction in crop varieties grown. Such reliance on so fewer crops brings with it its own set of problems to deal with increased vulnerability, fragility, and effect of unknown influences, not to mention a loss of dietary diversity and related nutritional concerns (Darmawan et al., 2006).

Finally, the green revolution was party to the huge structural changes within the industry. Essentially, farming now encouraged larger, more industrial-focused farms at the cost of their smallholder brethren. The larger farms meant ever-increasing agricultural inputs due to continual depletion of base soil fertility. This resulted, according to Pimentel et al. (1998), in a cost–benefit trade-off between productivity and the local ecosystems so as to avoid damaging our future generation's environmental habitat. This message took on increasing potency as the world observed a not so slow and steady decline in the quality of local ecosystems. This view quickly became mainstream affecting policies of energy, environmental protection, and agriculture, etc.

7.4.2 Evergreen revolution

There is no doubting the effect the green revolution had on the world and on global production. Indeed, it can be seen that over a comparatively short period of time, 8% growth came from increasing cultivatable land, whereas a whopping 92% increase was a direct result of the green revolution technologies. Furthermore, despite a continuing shocking number of people who remain hungry and malnourished, there are still more people in the world, to date, who have achieved increased nutrition at less cost than any other time in history. Increased yields further developed peoples and countries' economies, population levels, and a further distribution of equity. As an aside, the specter of the Malthusian prophecy was indeed kept at bay (Brown, 1981).

Moreover, the question of sustainability in the face of intensive agricultural productivity cannot be brushed aside although the yield gap is decreasing, and as the revolution continues, more and more people are looking for another more fully sustainable "evergreen" revolution devoid of expensive monetary and environmentally costly practices. More favorably, one can see that research spending governed by a more knowledgeable political and social awareness has emerged fully supportive of the postgreen or evergreen technologies. By fully maintaining a balance of equilibrium, modern-day evolution within the field is sympathetically maintained with the resultant sustainable, natural resource base.

Indeed, more focus on the environment, from a holistic perspective, ensures the overall efficiency of inputs while effectively controlling for pests through a sweeping array of complimentary practices. Through the introduction of conservation tillage and other environmentally friendly practices of drip irrigation and multiple cropping practices among others, it is hoped the adoption of a new agricultural, economic, and social paradigm is a snug fit for the modern ideology of developmental and economic and social growth (GHI, 2010).

7.5 The intensification, concentration, and specialization of agriculture

By the middle of the 20th century, fears over population growth spurred a dramatic acceleration in global food production. This has been achieved through improved technologies including agrochemicals, mechanization, and plant breeding, "progress," which has ultimately been responsible for the intensification, extensification, concentration, and specialization of agriculture.

In intensive agricultural systems, large amounts of capital relative to the area of land cultivated as well as large quantities of fertilizer, insecticides, fungicides, and herbicides are employed to improve crop yields and manage pests. Furthermore, intensification also sees farming becoming increasingly mechanized with capital intensive high-efficiency machinery being used for planting, irrigation, cultivating, and harvesting. This kind of agriculture is often employed where population densities are high and/or where land values are also high; such situations also often occur near primary markets.

Unlike the large inputs of intensive agriculture, extensive agricultural practices rely heavily on the natural fertility and productivity of the soil. As this type of agriculture usually provides lower yields, large tracts of land are needed. This type of farming can usually be seen in areas of low population density where land is plentiful and cheap in relation to labor and capital. It also means this sort of practice is oftentimes far from primary markets (Britannica, 2009; UOR, 2009).

This above gives a brief snapshot of the many styles of farming and whether working the land, with livestock, farming the seas or the forests, each has its benefits and each faces a myriad of challenges. All are important too when it comes to the challenges of food waste. One concept closely associated with the current drive to reduce food wastage is that of sustainability; it is a concept that runs parallel to both the idea of efficiency within the food supply chain and the good stewardship required to successfully manage the natural resource base. As with food wastage, sustainability seeks to ensure the ongoing viability of a supply stream hitherto seen as limitless.

7.6 The impact of food consumption on the agroecological resource base

Presently, global agriculture production is already an extremely resource-intensive sector. On top of this, pressure on worldwide resources is being further compounded by unrelenting demand from growing populations with ever greater food production needs (UNEP, 2012).

Currently, global food production sector utilizes about one quarter of all habitable land on Earth and uses more than 70% of total freshwater consumption. As a result, the world's food production sector has become the largest single cause of biodiversity loss in the world; it produces over 30% of global greenhouse gas emissions; it is responsible for as much as 80% of total annual deforestation contributing to its roles as the single greatest cause of land-use change throughout the world. The following gives a small glimpse of the effects our food production sector is having on our planet's land and water resources.

Only one quarter of the Earth's land surface is suitable for cultivation and within these confines' cattle occupy about 25% of this land with feed required to sustain these and other livestock requiring another 25%, also recalling that livestock is an inefficient use of resources. In US style feedlots, animals are reared intensively and fed almost exclusively on grain. Furthermore, as a result of this, the conversion factor of meat versus wheat varies from animal to animal and from the intensity and frequency with which they are fed, as well as efficiency in which various animals convert grain into protein. All this varies widely. And by way of example, we take approximately 7 kg of grain (once again in American style feedlots) to produce 1 kg of live weight beef. In other animals, pork, for instance, it takes 4 kg to make just 1 kg of live weight pork. And for poultry the ratio is 2:1, and lastly for farmed fish it takes less than 2 kg of wheat to produce approximately 1 kg of fish protein (Worstall, 2012).

With this in mind it comes as no surprise that 35% of the total global grain harvest is ultimately used in the production of animal protein. Indeed, in many regions around the world, the majority of new agricultural land brought into play is employed simply for this purpose of supplying the growing market for animal protein, whether directly in the production of animals or for animal feed. This is perhaps not more evident than in the high-profile deforestation patterns as seen in Brazil's national treasure—the Amazon. In 2007, for instance, ranches in the Amazon covered about 8.4 million ha[4], which, according to Nellemann, is suggestive of simple market responses to global demand (Nellemann, 2009). Furthermore, if consumption trends continue as predicted, animal protein consumption is set to increase by a factor of 4 by 2050, placing further pressure on existing land resources with this in mind (UNEP, 2012).

Available land is only one part of the equation; maintaining adequate food production, whether land- or water-based, relies on well-functioning ecosystems, which in turn rely on healthy and sustainable practices with the long term in mind. Unfortunately, continued misuse and abuse of the land has led to widespread degradation the full scale of which is only recently coming to light.

By way of example, intensive agricultural practices during the second half of the 20th century directly led to the degradation of 2 billion hectares of arable land (about a quarter of all arable land). And it does not stop there, it is estimated a further 2–5 million hectares are added to this figure annually (Nellemann, 2009). Overall, this has lead to very real losses; according to the International Food Policy Research Institute (IFPRI), such degraded lands lead to nonoptimized yields amounting to the loss of about 20 million tons of grain or 1% of global annual grain production each year (IFPRI, 2012).

In terms of freshwater resources, agriculture, as mentioned, utilizes about 70% of global annual supply. Continued agricultural pollution from intensification is threatening the

[4]In Brazil in 2007 ranches alone accounted for an estimated 70% of deforestation in that year.

current sustainability of the system, resulting in unnecessary acidification and dead zones within our river and aquifer ecosystems, etc. Apart from implications of land-based production, this also comes at a time when fish consumption is at an all-time high with fish contributing to 15% of animal protein intake for over 3 billion people (or equivalent to about 17 kg per global capita) (UNEP, 2012). Yet amid these figures, the industry is in perilous condition as approximately 75% of the world's major marine fish stocks are either depleted or overexploited.

Furthermore, while aquaculture supplies a good proportion of global fish protein needs—growing in excess of 60% between 2000 and 2008 (from 32.4 million tons to 52.5 million tons), it is not always the panacea that it is sometimes portrayed. For example, each 1 kg of farmed tuna requires 20 kg of wild-caught fish feed during the course of its life.

References

Båge, L., July 7, 2008. G8 Summit Special Report: Supporting Smallholders is Crucial to Food Security. Financial Times, London.

Barton, G.T., Cooper, M.R., 1948. Relation of agricultural production to inputs. Rev. Econ. Stat. 30 (2), 117–126.

Borlaug, N.E., 2000. The green revolution revisited and the road ahead. In: 30th Anniversary. Lecture. The Norwegian Nobel Institute, Oslo.

Boserup, E., 1965. The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure. G. Allen and Unwin, London.

Brewster, J.M., 1945. Farm technological advance and total population growth. J. Farm Econ. 27 (3), 509–525.

Britannica, 2009. Encyclopædia Britannica Online.

Brown, L.R., 1981. World population growth, soil erosion, and food security. Science 214, 995–1002.

Brush, S.B., 1987. Comparative Farming Systems. Guilford Press, New York.

Darmawan, et al., 2006. Effect of green revolution technology from 1970 to 2003 on sawah soil properties in Java, Indonesia: I. Carbon and nitrogen distribution under different land management and soil types. Soil Sci. Plant Nutr. 52 (5), 634–644.

DFID, 2004. Agriculture, Hunger and Food Security. Department for International Development (DFID), UK.

Dyer, G., 2006. Feeding the World: How long can the world feed itself? Retrieved 6 July 2019. http://gwynnedyer.com/2006/feeding-the-world/.

Eifert, B., et al., 2002. The World Grain Economy to 2050: A Dynamic General Equilibrium, Two Sector Approach to Long-Term World-Level Macroeconomic Forecasting. University Avenue Undergraduate Journal of Economics (Online).

FAO, 2011. Fisheries and Food Security. Retrieved 5 Jan 2019, from http://www.fao.org/FOCUS/E/fisheries/intro.htm.

Gardner, B.L., 2002. American Agriculture in the Twentieth Century: How it Flourished and What it Cost. Harvard University Press, Cambridge, Massachusetts.

Gaud, W.S., 1968. The Green Revolution: Accomplishments and Apprehensions. The Society for International Development, Shorehan Hotel, Washington, DC. US Agency for International Development.

GEO, 2007. Planet's Tougher Problems Persist, UN Report Warns. Global Environment Outlook 4.

GHI, 2010. GAP Report: The Global Harvest Initiative: Measuring Global Agricultural Productivity. The Global Harvest Initiative, Washington, D.C.

Hartmannshenn, T., 2004. Food Security: Guidelines for the Promotion and Execution of Food Security Projects by German Agro Action. German Agro Action, Bonn,.

Herdt, R.W., 1998. The Rockefeller Foundation: The Life and Work of Norman Borlaug, Nobel Laureate. The Rockefeller Foundation, New York.

IAASTD, 2009. IAASTD Global Report: Agriculture at a Crossroads. IAASTD Synthesis Report. Johannesburg, South Africa, International Assessment of Agricultural Knowledge. Science and Technology for Development (IAASTD), p. 6.

IFPRI, 2012. IFPRI books, International Food Policy Research Institute (IFPRI), number 2011 Global Food Policy report. Washington, D.C.

Johnson, D.G., 1997. Agriculture and the wealth of. Nations. Am. Econ. Rev. 87 (2), 1–12.

Johnson, D.G., 2000. Population, food, and knowledge. Am. Econ. Rev. 90 (1), 1–14.

Kurien, J., 2004. Responsible Fish Trade. Towards Understanding the Relationship Between International Fish Trade and Food Security. FAO and the Ministry of Foreign Affairs of Norway (MFA), Rome.

Lowder, S.K., Skoet, J., Raney, T., 2016. World Development: The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide, 87. FAO, Rome, Italy, pp. 16–29.

McCalla, A.F., Revoredo, C.L., 2001. Prospects for Global Food Security: A Critical Appraisal of Past Projections and Predictions. International Food Policy Research Institute, Washington, DC.

McLaughlin, A., et al., 2000. Comparison of energy inputs for inorganic fertilizer and manure based corn production. Can. Agric. Eng. 42 (1).

Muir, P., 2010. BI301: Human Impacts on Ecosystems. Oregon State University.

Nellemann, C., 2009. The Environmental Food Crisis: The Environment's Role in Averting Future Food Crises. United Nations Environment Programme (UNEP) GRID-Arendal, Geneva.

Perkins, J.H., 1990. The Rockefeller Foundation and the green revolution, 1941–1956. Agric. Hum. Val. 7 (3/4), 6–18.

Permaculture Ass, 2011. Website of the Permaculture Organisation. Retrieved 12th Feb 2019, from http://www.permaculture.org.uk/.

Pimentel, D., et al., 1998. Energy use in agriculture: an overview. Agric. Eng. Int. CIGR J. 1.

Sharma, H.C., Gill, B.S., 1983. Current status of wide hybridization in wheat. Euphytica 32 (1), 17–31.

Sundquist, E., Broecker, W., 1985. The Carbon Cycle and Atmospheric CO_2: Natural Variations Archean to Present. American Geophysical Union, Washington.

Troyer, A.F., 2004. Breeding widely adapted, popular maize hybrids. Euphytica 92 (1–2), 163–174.

UNEP, 2012. The Critical Role of Global Food Consumption Patterns in Achieving Sustainable Food Systems and Food for All. UNEP Discussion Paper, Nairobi, Kenya. United Nations Environment Programme: 43.

UOR, 2009. University of Reading: Agriculture, Policy and Development, History of Agriculture. Retrieved 4 June 2019, from http://www.ecifm.rdg.ac.uk/history.htm.

USAID, 2009. FrontLines: Borlaug, Father of Green Revolution, Dies. Retrieved 5th March 2019, from https://pdf.usaid.gov/pdf_docs/PNADQ606.pdf.

Webb, P., et al., 2008. More Food, but Not yet Enough: 20th Century Successes in Agriculture Growth and 21st Century Challenges. Food Policy and Applied Nutrition Program. School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts.

Worstall, T., 2012. It Does Not Take 7 kg of Grain to Make 1 kg of Beef: Be Very Careful with Your Statistics. Forbes, Jersey City, USA, New York.

Wu, F., Butz, W.P., 2004. The Future of Genetically Modified Crops: Lessons from the Green Revolution. US, Rand Corporation.

Zhang, X., et al., 2007. A Typology for Vulnerability and Agriculture in Sub-saharan Africa. IFPRI, Washington, DC, 2010.