The Future of Agricultural Land

Joop H. J. Schaminée and Nils M. van Rooijen

Abstract From the moment people started to settle, agriculture became a common and rapidly increasing form of land use, having a huge impact on nature and landscape on all continents. An impact much greater than even urbanisation and increasing infrastructure. Nowadays, agricultural activities directly influence more than 38% of the world's land surface. Two major practices must be distinguished: on the one hand the production of crops on arable land, and on the other hand livestock farming. The focus in this chapter is on the production of crops on arable land. An exception is made for two examples on the landscape level, which will be discussed here. These refer to traditional agricultural land use systems, one from the low mountain ranges of Central France and one taken from the Northwest European lowlands.

After a general introduction on the worldwide distribution of agricultural land and the focus on strong mechanisation in modern agriculture, a wide spectre of issues will be addressed. This includes issues like: how are world processes affected by agricultural land use in history and present times, what is the origin of species that are accommodated in agricultural ecosystems, and what is the relationship between agriculture and nature, regarding different levels of farming.

Keywords Agriculture · Arable crops · Living archives · Traditional land use · Co-evolution · Genetic manipulation · Organic farming

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1 Introduction

More than 13,000 years ago, mankind made a world-changing decision by settling down. The nomadic way of life by hunting and gathering, in which people were ruled by nature, transformed into a domestic lifestyle, in which people shaped and exploited their natural environment for the production of food: agriculture was born (Larson et al. 2014). Worldwide, at least eight centres of origin can be distinguished. In the Levant, grains, peas and flax were cultivated since 11,500 years ago. In China, rice was cultivated more or less around the same time, whereas a couple of thousand years later sugarcane became a crop in New Guinea. At the other side of the Pacific, potatoes, coca, cotton and maize were grown in Middle and Latin America, more precisely in Mexico, Peru, Chile and Brazil. Apart from these crops, a decisive development was also the domestication of animals. Wild aurochs were transformed into cattle about 10,500 years ago in Turkey and Pakistan, while over a large area in Europe and Asia, pigs were bred from wild boars. Sheep were domesticated in Mesopotamia, already two thousand years earlier (https://en.wikipedia.org/wiki/History_of_agriculture). Both the production of crops on arable land and the livestock farming on grazing grounds changed our landscapes worldwide.

From this early start, agriculture has spread enormously and become dominant in large parts of the world. Currently, agriculture covers more than 38% of the world's land surface. Permanent pastures account for more than two-third of this area; most of the rest is used for cultivating crops (FAOSTAT 2019; Ritchie and Roser 2019). Agricultural land is widespread worldwide, found on all continents, with the emphasis on temperate and tropical climate zones; in the circumboreal regions, the conditions are too restrictive as in the larger deserts.

The distribution of temporal arable land and land under permanent use for crops or pastures (with herbaceous forage crops, either cultivated or growing wild) is showing some clear contrasts. For most countries, the majority of agricultural land is used for livestock rearing in the form of pastureland. In Europe and South-Asia, however, the amount of land used for livestock is much lower than for arable farming, less than 20% (Fig. 1).

To sketch future scenarios with perspectives for sustainable agriculture and biodiversity conservation, it is necessary to have insight in driving forces that have constituted our present agricultural landscape. We will explore and illustrate the complexity of the topic by addressing various aspects of this agricultural tapestry.

In modern, heavily mechanized agriculture, specialisation is a dominant factor. Nowadays, two of the main agricultural activities (crop cultivation and grazing) are generally separated on the level of individual farmers and farming systems, and at the same time scaled up to a degree never seen before. In the US, as an example, the average farm size (in 2017) is 444 acres, and still increasing. Each year since 2012, the average size has been expanded approximately two acres per farm, whereas the number of farms is gradually decreasing (www.usfarmdata.com). In the US, the centre of agricultural activity has to be looked for in the Great Plains, a vast and generally flat area, west of the Great Lakes and east of the Rocky Mountains. The

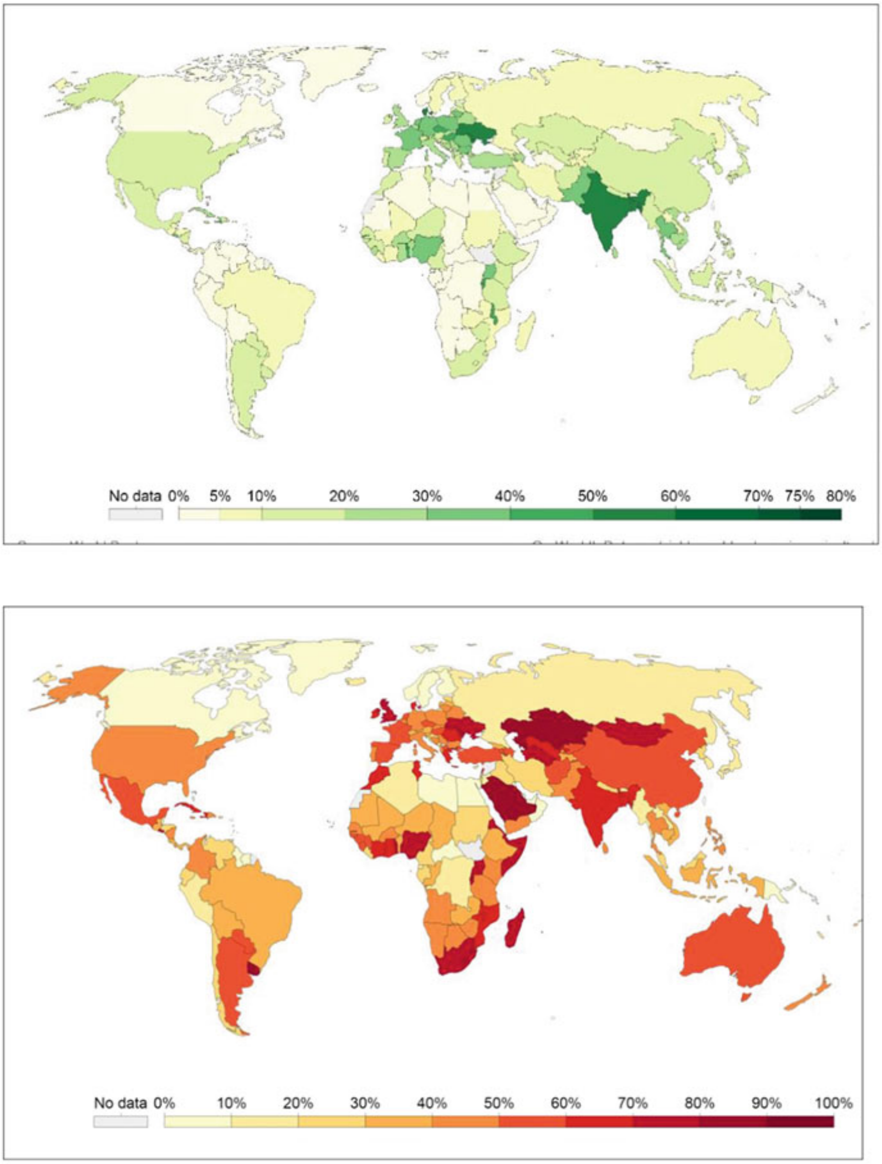

Fig. 1 Share of land area worldwide used for agriculture, measured as a percentage of total land area in 2015 (**a**). Agricultural refers to the share of land that is arable, under permanent crop or under permanent pastures. (**b**) Depicts the share of land area under arable use. Arable land in this context includes land defined by the FAO as land under temporary crops, temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow (Ritchie and Roser 2019)

Fig. 2 Wheat harvest in Idaho, US (ars.usda.gov, Image Number k1441-5)

relatively wet eastern half of these plains are a major corn and soybean producing region, known as the Corn Belt, whereas the drier western parts, known as the Wheat Belt, produce high rates of wheat. Currently, the yearly production of corn (maize) in the United States is more than 400 million tons, which counts for about one-third the worldwide production, more than the production of any other grain in the world (International Grains Council 2019). Approximately 40% of the crop is used for corn ethanol (*The New York Times*, 11-02-2011). The percentage of genetically modified corn (*Zea mays*) planted in the United States is increasing exponentially, from less than 10% in 1999 to more than 85% in 2009 (www.gmo-compass.org).

The annual US wheat production is about 80 million tons, of a worldwide total of more than 1000 tons. In the USA, currently most cropland is on farms with at least 1100 acres, and many farms are five to ten times that size (MacDonald et al. 2013; Fig. 2).

These figures are in strong contrast when looking at the worldwide distribution of farms and farm sizes. Based on agricultural census data from 167 countries, Lowder et al. (2016) calculated that there are more than 570 million farms worldwide. Of these, 72% of the farms are smaller than 1 ha, and only 6% of the world's farms are larger than 5 ha. The situation in the USA more or less reflects the situation in the European Union. Here, 50% of the farms are smaller than 2 ha, operating on less than 2% of the agricultural land.

Before discussing the complexity of the topic by addressing various aspects of agricultural land use, we will pay attention to some of the traditional agricultural systems that have been of great influences on the landscape development, in a time before specialisation became a dominant factor. We will describe two of such systems in Europe, one from the mountains of Central France and one from the lowlands in the Northwest of Europe (Germany and The Netherlands).

2 Traditional Land Use at the Hautes Chaumes in Low Mountain Ranges of Central France

Heathlands and grasslands still form a characteristic component of the subalpine landscape in European low mountain ranges, although the switch from traditional management practices put these systems nowadays under great pressure. For centuries, the highest parts of these mountain ranges (called *hautes chaumes* in France) were used for cattle grazing and the pastured land was held in common. During summer, the farmers lived in modest farmhouses, called *jasseries*. At springtime, the cattle was moved to grazing grounds at higher altitudes and moved back to lower elevations in fall (*transhumance*). At the beginning of the twentieth century, however, this system collapsed. The strong decline of the population density caused a strong decrease in grazing. Almost all *jasseries* became abandoned and fell into decay. In some parts of the subalpine zone, grazing stopped completely. In other parts, the way of grazing changed: the flock did not roam freely over the *hautes chaumes* anymore, but was kept in movable fences. Besides, farmers switched to sheep instead of cattle (Schaminée and Meertens 1992; Schaminée 1993).

This traditional system of pastural (cattle-lease, *bail à commande*) and mountain meadow land use developed during the late Middle Ages. It was a win-win situation for urban people and local farmers of the Massif Central. Urban capital was invested in cattle and the owners received agricultural products. The farmers produced meat, leather and other agricultural products, in particular cheese (fourme), and had little risk caused by unfavorable weather conditions. Like in other mountain regions used as summer pasture, the period of grazing lasted a couple of months until August. The number of domestic animals and the period of grazing was limited by strong regulations. Pastures were used on common ground, farmhouses and meadows were private property (Damon 1972; Schaminée 1993). Such grazing regimes supported high landscape heterogeneity in space and stabilized rich regional species pools.

Figure 3 shows a plan of the small farmhouses, called *jasseries* (Schaminée 1993, after Damon 1972). The largest part was composed by small stables for animals, the smaller part served as living room and place for cheese production. The concerted use, interplay and irrigation of water, dung as fertilizer for hay meadows and hay as fodder is described in Schaminée (1993). This agricultural system proved to be sustainable for many hundreds of years.

The importance of a constant management was already stressed by Josias Braun-Blanquet in 1926 in a study on mountain heathlands in the Monts du Cantal. The large-scale changes in land use during the twentieth century have strongly influenced the original diversity and vegetation pattern. An overall extensive grazing regime has

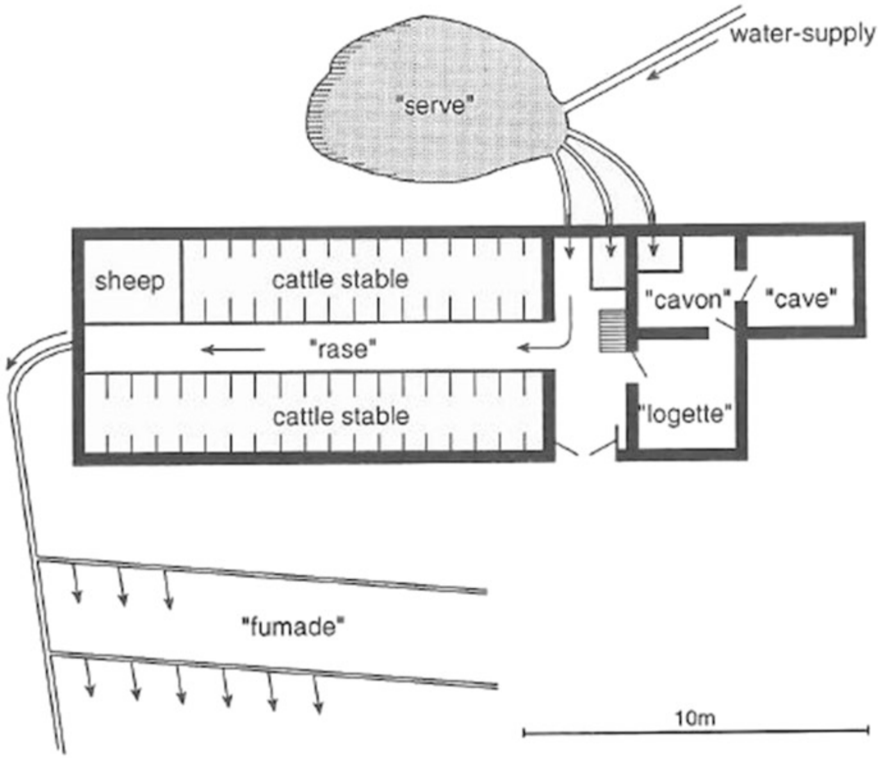

Fig. 3 Ground plan of a jasserie and its surrounding, at Garnier in the eastern part of the Monts du Forez (Schaminée 1993, after Damon 1972)

been converted into abandonment on the one hand and intensification on the other. Especially the mesotrophic mountain meadows near the jasseries, a unique feature within the oligotrophic and extensive heathland landscape of the subalpine zone of these mountain ranges, are showing a strong decline in floristic diversity. In this respect, these meadows, syntaxonomically to be assigned to the alliance *Polygono-Trisetion*, are no exception, as can be concluded from the voluminous documentation with regard to this subject (e.g. Klapp 1965; Dierschke 1991; Daniëls et al. 1987).

3 Eternal Rye Cropping in the Northwest European Lowlands

On the higher sandy soils in the northwest European lowlands, an age-old agricultural system was practiced for many centuries, the so-called *Potstal system*. An—also literally—central position hereby was taken by elevated field complexes,

Fig. 4 The Orange Lily, *Lilium bulbiferum* (photographed by J.HJ. Schaminée)

depending on the region called (in the Netherlands) *essen*, *enken* or *engen*. These were large complexes, located in the immediate vicinity of the farms, which were surrounded by vast heathlands. The heath had two important functions: first as grazing grounds for the flocks of sheep, who returned home in the evening and spent the night in the so-called *potstal* (potting stable), and furthermore as a supplier of raw plant material that was spread in the stable to be mixed with the sheep's faeces. The resulting fertilizer was then spread on the fields, where grains and other crops were grown. Due to the mineral components, these fields became higher and higher, and in this way they are still recognizable as elevations in the landscape today.

Rye (*Triticum secale*) was an excellent cereal to cultivate on these fields, as the species is able to grow on acidic sands that were too poor to grow other cereals. Cultivated Rye derived from the wild species *Secale montanum* and *Secale vavilovii*, which are endemic to forest clearings and field margins of South Asia, up to 2500 m above sea level (Schlegel 2014). The fields are known as eternal rye fields, but this image has been nuanced in recent years: the use was much more varied and in any case, they turned out not to be eternal. All sorts of annual herbals grew among the tall grain, many of which are now on the Red List of Vascular Plants in the Netherlands. Think of species such as *Arnoseris minima*, *Scleranthus annuus*, *Hypochaeris glabra* and *Anthoxanthum aristatum*. The latter species is called *slofhak* in Dutch, as the stalks of this grass contain a lot of silica, making the axes rapidly blunt (*hak* = ax, *slof* = blunt).

A rare and special plant species of these fields was the Rye Lily (*Lilium bulbiferum*; Fig. 4), which was well adapted to the original use. People used to plough the fields no deeper than about ten centimetres, while the main bulb of this species was growing at least 15 cm deep and thus spared during the process of ploughing. The fields are nowadays ploughed much deeper, and partly as a result of this, this beautiful lily has almost completely disappeared. At the initiative of a national initiative, called the *Living Archive*, an Action Plan is currently being worked out in collaboration with the province of Drenthe and a large number of organizations involved to preserve this characteristic plant for the Netherlands. Within this platform, programmes will be set up for both genetic rescuing and reintroduction of a wide range of priority species, a National Seed Bank will be established, and for each target species, a tailored plan will be set up. Among the target species there are many weeds from arable land. The *Living Archive* operates conform a stepwise approach, including: (1) analysing habitat characteristics of still-existing populations across the Netherlands, (2) assessing viability of these populations, (3) identifying new suitable sites by comparing them to habitat characteristics of viable populations, (4) collecting seeds from suitable source populations, (5) multiplying plant material through an *ex situ* breeding program, (6) using viable off-spring for reinforcing existing impoverished populations and/or reintroducing the species at former sites where the site conditions have been improved, and (7) monitoring the reintroduction success (Schaminée et al. 2019).

Because of the change in agricultural practice, the species has disappeared from the fields, but is still present in single places in gardens. For a long time, it was thought that the Rye Lily in our country was not native, but had managed to establish itself in the fields from gardens, but the story is exactly the other way round. The plants in the gardens originates from the fields; the plants were so beautiful that they were dug out in the wild and placed at home. The plant material that is still present is authentic and autochthonous and can serve as source material for the intended reintroduction. On the famous triptych of Hans Memling (from the fifteenth century), the Rye Lily is the last plant that the blissful can see at the foot of the stairs before entering heaven.

The two examples also demonstrated the major challenges nature conservation in rural areas is facing in the moment, at least in Europe but also in other parts of the world: on the one hand intensification, on the other hand abandoning. In European lowlands, especially in the densely populated northwest, intensification leads to a dramatic drop of biodiversity on the sites under management, whereas in European mountain ranges (as well as is in large parts of Eastern Europe, where traditional agricultural survived for many centuries but now (after the collapse of the communism) is rapidly replaced by modern techniques and the huge increase in applying artificial manure to increase the production. The dramatic changes in mountainous areas was perfectly predicted more than 25 years ago in a study on the landscape ecology of the Solano Basin in Tuscany, Italy, with the provocative title *Vanishing Tuscan Landscapes* (Vos and Stortelder 1992).

4 Agricultural Tapestry

Biodiversity and agriculture are entangled in an everchanging choreography. Some of the world's most remarkable species have evolved through agriculture, or found their habitat in man-made ecosystem; on the other hand, the ongoing development is turning now to be a growing threat for the same species. Local processes can have global consequences and vice versa. Questions arise such as: how are world processes affected by agricultural land use, what is the origin of species that are accommodated in agricultural ecosystems, what is the relationship between agriculture and nature, regarding different levels of farming.

4.1 Agriculture and Its Global Impact Over Time

Recently, the topic of deforestation has re-entered news headlines, also in the public debate. The clearing of rain forests in the Amazon area, as an example, on behalf of wood production and the construction of palm oil and soy fields has given rise to political conflicts. On the other hand, the call for reforestation or cultivating trees, to combat the growing CO_2-emmissions is also heard more often and more loudly. This entanglement of agricultural activity and climate can be recognized throughout history. Deforestation in order to increase hunting grounds in Northern America or (later) giving room for agricultural land use in Eurasia had its impact on local and global climate, which could be recognized in our common history.

At the same time, agriculture activity has always been driven by climate. As such, the climatic conditions and in line with the development of agriculture, have dictated history, as can be shown by a European example. In the pre-roman era, the central Italian area had a favourable climate for the cultivation of wheats, supporting the growth of the populations and the Roman society. However, a shift in climate conditions with increased drought in the central Mediterranean led to a decrease in yields and eventually in food shortages. This forced the roman people to expand their territory to the West and East, where conditions were more favourable. An empire was born. A few centuries later the coin flipped and a less favourable climate in Western and Eastern Europe forced the peoples living there to move. The Migration period started leading to the fall of the Western Roman empire (Harper 2017).

Climate, however, is not only a driver but can also be driven by man. In the middle ages, the European population flourished and the need for nutrition and building material peaked. The feudal system of land tenure, in which rights to farming were given in exchange for fealty, increased the deforestation in Europe. This is correlated with an increase in carbon dioxide in the atmosphere. The medieval warmth period is associated with a peak in CO_2 as was reconstructed from captured air in centuries-old ice cores taken from the ice caps. As the plague struck the European societies, leading to a decrease of 60% in population, spontaneous reforestation occurred. This is again associated with a decrease in atmospheric carbon. The Little Ice-age followed, resulting in a cooler climate throughout the seventeenth, eighteenth and nineteenth century, just until the industrial revolution gave rise to an unprecedented increase of carbon emissions (Soon and Baliunas 2003).

Current climate change will have an impact on agriculture in the near future. A growing world population increases the need for food, although area suitable for agriculture is in decline. In Asia and Africa, rice production, a crop feeding over 20% of the world's population, is threatened by an increasing number of climate extremes. Major production areas are found in low-lying lands and deltas in Bangladesh, Myanmar, Vietnam, Japan, and Egypt. Sea level rise and extremes in precipitation increase the risk of flooding plantations, leading to an estimated loss up to 20% in some countries before 2080 (Chen et al. 2012). The combination of a rising sea level together with the occurrence of more droughts leads to salinization of soils, decreasing the extent of rice yields. As it takes 2.000 l of water to produce 1 kg of rice, droughts in particular are forming a major threat. The same accounts for wheats, corn and potatoes. However, as the equatorial climate becomes more dry, a shift of these agricultural systems to higher latitudes is halted by other environmental conditions. For example, the dry and grassy plains of Siberia are not likely to support the growth of potatoes, rice or wheat, as the seasonal climate here becomes extreme. In addition, the vast areas of peaty soils of melting permafrost are no option for regular crop cultivation. As grasslands remain to dominate these areas, the area in which crops can be grown is diminishing. Still the need for nutrition grows. As the grassland systems in Eurasia are still able to support cattle and livestock breeding, the consumption of meat may become an increasingly inevitable alternative. An alternative that will further increase the pressure of climate change and environment change.

Let us return to the clearing of rain forests in the Amazon area for the construction of soy fields, to show the complexity of such global issues. Already in 2006, the Netherlands (one of the largest soy importers of the world) declared the Amazon to a no go area for commodity traders and processers. It was decided not to purchase products from areas in the Amazon that have been deforested after 2008. As a result, the soy production shifted to other areas in Brazil that were less protected, such as the savannah area of the Cerrado. Another escape was found in the likewise less protected forest areas of Paraguay, Bolivia and Argentina. In response to this, the Dutch government decided, in 2015, to restrict the import of the product to soy that meet the strict standards of the Round Table on Responsible Soy (RTRS), an international collaboration between governments, retailers and producers. Again, there is a snag in the grass. The strict rules only apply that the soy that is used for the production of meat, eggs and diary for the Dutch market, not for the products that will be exported. Within the context of this, it is a sad prospect that in Brazil, Paraguay and Argentina, still 110 million hectares of forest are registered to be cut legally, a staggering 20% of the entire amazon area (*De Volkskrant*, 31 August 2019).

4.2 The Origin of Species Living on Arable Land

An interesting question concerns the origin of weeds on arable land. Historical-geographic research has shown that the species in question all have their own story, as was already demonstrated by Tüxen in 1958. Charred seed residues from the German Rhineland showed that species such as White Goosefoot (*Chenopodium album*), Black Bindweed (*Fallopia convolvulus*), Redshank (*Persicaria maculosa*) and Hairy Vetch (*Vicia hirsuta*) were already present in cultivated fields from about 5000 years BC, in plant assemblages that were described as the *Bromo-Lapsanetum praehistoricum* (Knörzer 1971). A number of arable plants derive from nearby natural ecosystems, such as scree vegetation on mountain slopes, pioneer vegetation on riverbanks, and natural forest fringes. The name-giving Nipplewort (*Lapsana communis*) of the plant community mentioned is an example of the last group. Quite some species were present as local wild plants in human-affected environments before cultivation took place; with the establishment of systematic farming, they evolved into weeds or functioned as weeds without further evolution (Snir et al. 2015). Most species, however, originate from naturally appearances much further away. They mainly derive from a vast area from the Iberian Peninsula to West Asia, far more extensive than the 'fertile crescent moon' of Southwest Asia, where arable farming has its origins (Weeda et al. 2003).

Due to strong selective forces on agricultural land, crops and weeds may co-evolve a process that has been described and discussed in many scientific papers (Baker 1974; Radosevich et al. 1997; see Guglielmini et al. 2007 for a debate). A well-known example is the occurrence of specific weeds in flax fields, plant species that are hardly found outside these agro-ecosystems, making them vulnerable. In the Netherlands, for example, species like Flax Field Ryegrass (*Lolium remotum*), Flax Dodder (Fig. 5, *Cuscuta epilinum*) and False Flax (*Camelina sativa*) have all become extinct after the collapse of the flax cultivation in the fifties last centuries. The occurrence of coevolution is also demonstrated for crops and their rust fungi, and again flax provides a nice example, which already has been described by Flor in 1955. He discovered that genetically different strains of the fungus could only infect specific lines of flax, on which observation he concluded that the parasite and its host had complementary genetic systems as a result of coevolution (Kliman 2016.)

4.3 Industrial Agriculture

As the need for nutrition and convenience is growing worldwide, the efficiency for agriculture is increasing at an unprecedented pace. To counter effects of environmental change and responding to a growing demand, more land and new technologies are developed and applied worldwide. International development and agricultural land use are intertwined and particularly visible in East and South Asia and the Middle East. As an example, a consequence of a growing demand of

Fig. 5 *Cuscuta epilinum* (Universal History Archive/Shutterstock)

agricultural products is the use of artificial fertilizer (Fig. 6). Although it creates an increased fertility and more production on poor soils, the added nutrient cause a decrease in biodiversity as competitive species take over (Bobbink et al. 2010; Ceulemans et al. 2014). Where innovative techniques in Western society cause a decrease in artificial fertilizer consumption per hectares, developing countries are adding a growing amount of artificial fertilizer each year (FAOstat 2019).

Moreover, as most agricultural enterprises are embedded in a competitive and commercial system, where profits are driving the increase in efficiency and

Fig. 6 The global growing consumption of artificial fertilizer in kilogram per hectare of arable and permanent cropland (source: The Worldbank—IBRD-IDA 2019)

production on a global market, the technological advances in agriculture are continuously pushing the possibilities. Genetic manipulation is often inherent to selective breeding techniques. Genetic properties of species are recombined on a global scale to counter environmental threats, increase yields or to make the crops commercially more attractive. Having the lead in agricultural techniques improves the competitive position of farmers and pushes them to strengthen their position on a global market. Particularly in western society, the agricultural systems have been pushed over their environmental limits, which led to unsustainable farming that on itself has a demand of natural resources, which the land cannot provide. Resulting in pollution, hypertrophy and land depletion. At the same time, farmers that are outcompeted abandon their lands or are forced to use outdated and often polluting techniques and products.

As environmental problems are becoming more apparent, agricultural legislation in regards to pesticides, emissions, food quality and land use in western society are becoming more strict. This is not only leading to tensions between farmers and society (as farmers' competitive positions are threatened), but it also forces farmers to expand their activities abroad. Intensive and large-scale farming by western European farmers in Eastern Europe and Northern America strongly increased over the last decades often at the cost of local small-scale farming (Deininger and Byerlee 2011).

As agricultural products are sold worldwide, an increase in transportation (and its environmental consequences) have rapidly increased. As an example, the US state Iowa alone transports a yearly 152.6 million tons of agricultural products by train (a revenue of 6.1 billion US dollars). On a total, the United States export 33% of its agricultural products abroad for circa 190 billion dollars. Where to US has about 22.6 million hectares of agricultural area, the Netherlands is the runner-up in export of agricultural products (Figures of 2015). With a production area of 2.2 million hectares, the country exports for 115 billion dollars of agricultural products (a revenue that is six times higher per unit of surface area compared to US production), while the competition for export is growing internationally (CBS and WUR 2017; FAOstat 2019).

As small-scale agriculture has had positive effects on biodiversity. In Europe, biodiversity even showed a peak in species richness in the mid of the nineteenth century (Haveman et al. 2009), when a wide spectre of small crop-fields, forests, and meadows covered the countryside. Large-scale agriculture has opposite consequences. The lack of habitat diversity, environmental gradients and landscape connections are detrimental for biodiversity. The use of pesticides only strengthen this effect. A growing number of studies show a massive decline in insects over the last decades. Not only the number of species of insects decreased, also the total number of insects is in strong decline. Up to a 75% loss of insects was reported in heavily cultivated Netherlands and Western Germany within 30 years (Hallmann et al. 2017). The use of neonicotinoid pesticides, which is only part of its cause, has its legacy as the now-banned poisons were accumulated in the food web, probably led to a massive decline in insectivorous bird species in the same region in the same period. As insect populations disappear, also the services they provide for agriculture are under threat. Wild pollinators are essential for the production of 35% of our crops, of which amongst are 121 different bee species on a global scale (Klein et al. 2006).

As the world population is growing and the development of second and third world countries is gaining pace, the global intensification of agricultural lands is persistent.

5 Turning the Tide

The growing global demand for nutrition, space, natural resources, the threats of climate change, soil depletion, pollution and biodiversity decline underline the need for a different approach in our land use and agriculture. A tremendous amount of studies shows that biodiversity is a key factor in maintaining agricultural production. Climate resilience, crop health, pollination, soil stability and crop yields are all linked to local biodiversity. Therefore, to ensure food security in the future maintaining and supporting biodiversity should be a focus in the development.

5.1 Scaling Down

Large-scale intensified and internationally orientated agriculture, where an acre of land is forced to produce a yield, which demands many times more natural resources than an acre, can deliver, leads to land depletion and biodiversity loss. Added to that are the disadvantages of international transport (emissions) and the waste of products through this supply chain. Up to 75% of the fresh product are lost before consumption in the US. This loss is explained by a 7% loss during harvest, after which 33% is lost in transport or rejected upon arrival at processing facilities. During the production of end-products another 39% may be considered lost. About 10% of the products is rejected or marked as waste by retailers before the products reaches the consumers. And at that level, about 25% is not consumed in the end (Stroecken 2017). With a more efficient supply chain only a quarter of production is thus necessary to respond to the same demand. A large part of this supply chain is the transportation. Scaling down productions to local markets may increase efficiency, decreases production demands, decreases waste and decreases environmental impact.

5.2 Organic Farming

Organic farming is defined as a form of agriculture in which no synthetic inputs take place, such as artificial fertilizers, pesticides or hormones (Rehber et al. 2018). With over 69 million ha, almost three million farms and a revenue of more than 90 billion euro's worldwide, organic farming is one of the fastest growing agricultural disciplines in the world. Growing 5% per year globally, organic farming seems to be linked to an increase in general welfare. Switzerland and Denmark are spending most on organic products per capita. As more area is in need to produce equivalent yields, organic farming generally requires more space. To counter the absence of pesticides, other methods of crop cultivation are in need. Old traditions like crop rotation or newer methods such as strip cropping, to prevent depletion of soil nutrients, offers the chance to produce multiple crops and meanwhile increase the biodiversity on a farmland. Additionally crops are less prone to pests (Li et al. 2014).

Wild collection is often considered as part of organic farming. Over 440 products are known to be commercially picked or collected from their ecosystems. The area where wild organic farming is practised is estimated to be almost 40 million hectares in size, spread out over 71 countries. In this extreme form of organic farming, the ecosystem plays a central part and an ecosystem conservation approach is necessary to maintain yields over longer periods. A good example of this is Wild Rooibos tea. The leaves for this tea are picked from the Rooibos shrub (*Aspalathus linearis*) which only occurs in the Fynbos biome in the southwest of South Africa. Where cultivating outside of its natural distribution area is impossible, even small organic plantations are devastating for the vulnerable ecosystem. The indigenous Koi-San peoples, as an alternative, collect Rooibos leaves from the original vegetation, meanwhile protecting their environment and culture. However, the limited yields, the small market as well as the immense competition makes wild Rooibos farming hardly profitable until now (Sluiter and Schaminée 2012).

Organic farming is marketed around the world as a durable alternative to conventional farming, provided that farming methods are further developed. However, definitions, legislation and especially certification is often not clear and therefor often misused by large producers and retailers.

5.3 Paludiculture

An example of innovative agricultural practice is farming on peatlands. Historically, peatlands were considered unusable for crop farming, due to wet conditions and the low fertility. Large areas of peatland were therefore either exploited for their peat as a fuel or drained and transformed into still inefficient cropland, grazing areas or forest plantations. With the destruction of peatland, carbon emissions increased as oxygen caused large amounts of organic mass—accumulated through centuries under anoxic ad wet conditions—to decompose. As this led to an ongoing chain reaction, the loss of peatland led to more peat loss. This also leads to land subsidence in peatland around the world (Pronger et al. 2014), often with severe consequences for inhabitants of these areas, who need to coop with structural damage of buildings and increased impacts of weather extremes and sea level rise (Gambolati et al. 2005).

Paludiculture may offer a good alternative. Here well-adapted crops are grown on wet soils. By rewetting peatlands, both soil subsidence as well as carbon emission may be halted, even turning the system into an efficient carbon sink with a rising soil which may even counter problems caused by sea level rise, salinization and extreme drought events. Current research programs are focussing on the cultivation of crops as sources of biomass and building materials such as reeds, moor-grasses and peat mosses (*Sphagnum*) or even, through forestry, alders for application in cardboard, paper of isolation material. But also edible crops may be cultivated through paludiculture in the future, such as Wild rice in Northern America. In addition, due to climate change more peatland will become available. Peat, which is stored in permafrost, will start to melt and decompose under rising temperatures. Rewetting these systems may limit the effects of permafrost loss and may compensate losses of agricultural lands on a global scale.

6 Concluding Remarks

As the global population grows, the need for food security increases. However, the depletion of resources and the immense impact agriculture has on our world's landscapes, climate and biodiversity is beginning to reach its limits. Therefore, new ways of agricultural practice is necessary to ensure our future: a form of agriculture in which nature and farming are much more interlinked and where the resilience of food production relies on the capacity of our natural capital to coop with the increasing threats of climate change and urbanisation. Therefore, we need to protect our current biodiversity. New approaches such as multifunctional land use, where cropping and nature conservation go together, are interchangeable or even support natural ecosystem functions. Ecosystem functions, such as natural pollination of crops, need to be protected. The genetic capital that incorporates the adaptations to climate change is already present in our nature and should be protected. Production and food supply chains can become more efficient, so production does not need to increase further and also the natural capacity of cultivated soils should be taken more into account to ensure food production in the future.

Agriculture and climate dictated our societies' history. As our population and our need for products grows above our planet's capacity and the repercussions become more visible, we need to start to overthink our production systems. Agriculture can take the lead in a changing world. We need to stop focusing on quick wins and maximal productions, but change our perspectives to long-term food security and resilient nature-based food systems. In this way, agriculture can also lead us into the future.

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