1 Agricultural Landscapes: History, Status and Challenges

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Abstract

Agricultural landscapes (rural landscapes, agrolandscapes) are territories shaped by agricultural production. They have enabled the development of human civilizations and are a cultural achievement. Peasants, farmers and agricultural enterprises feed society. They have created agricultural landscapes for their business and habitats for their life. To understand transformation processes in agricultural landscapes, we analyse the history of

Abdulla Saparov died of COVID-19 in 2020. The team of editors and authors mourns the loss of a highly esteemed scientist and will preserve his scientific legacy.

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agriculture with a special focus on Europe and Eurasia. Current agricultural landscapes in a crowded, globalized world are multifunctional, highly complex systems. They not only serve to produce food commodities and energy for the increasing and expanding urban population but also provide diverse ecosystem services and need to cater for the demands of the rural population. Current agriculture is highly productive in wealthy countries, but due to high inputs it is also responsible for environmental problems such as water pollution and loss of biodiversity. Industrial-style agriculture in large fields has resulted in increased productivity but simplified the structure of landscapes and eliminated elements of nature and rural culture. Major problems that urgently need to be addressed include trends towards disrupting natural cycles in agricultural production, soil and water degradation, ageing populations in villages and the breakdown of rural infrastruc-

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ture. Agricultural landscape research provides analyses to understand these processes and helps elaborate sustainable scientific, technical and cultural solutions.

Keywords

Agriculture · Landscape · History · Transformations · Research · Food security · Land productivity · Intensification · Degradation · Agro-environmental monitoring · Europe · Russia · China

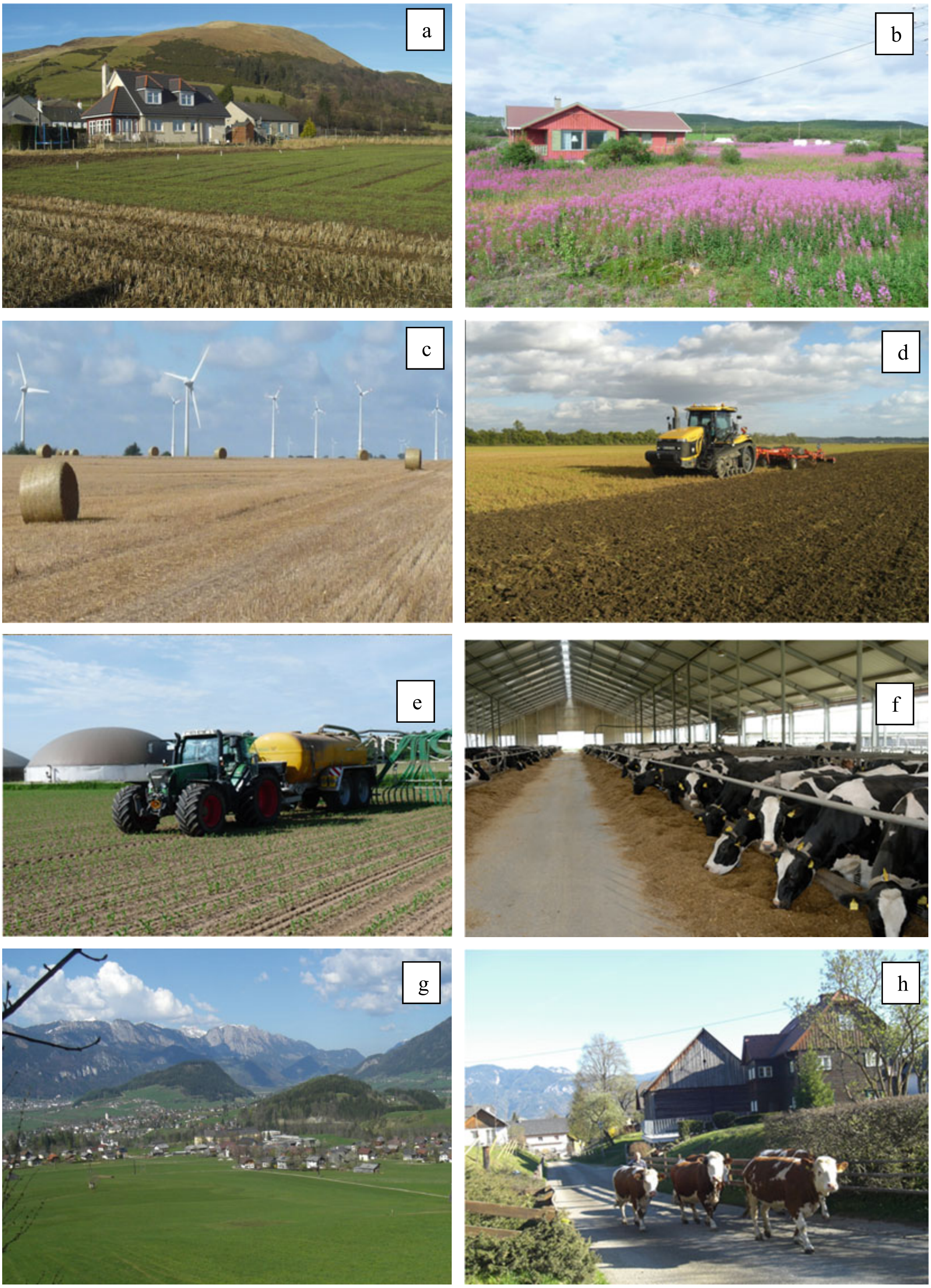
1.1 Introduction: Essence of Agricultural Landscapes and a Research Agenda

Agriculture is one of humankind's oldest economic activities. It has developed since the Neolithic Revolution, when humans became more settled. Humans' production of food crops for themselves and their offspring required the cultivation and transformation of originally natural landscapes. Before the beginning of the industrial age, rural cultures and societies and multifunctional landscapes were typical. Agricultural productivity is increased through the further social division of labour, innovations and knowledge transfer in cropping technology and livestock breeding. Farmers and peasants created food surpluses that enabled people to live in cities. Agricultural production is based on human intervention in biological cycles. Agricultural landscapes require interaction between anthropogenic and natural processes in order to be productive in the long run. Agriculture is the largest land use sector on earth. It influences all major global cycles and operates in close interaction with other spheres of society.

Agricultural landscape (rural landscape, agrolandscape) means land (territory) shaped by agricultural production. An agricultural landscape constitutes a spatio-temporal structure in which many complex processes occur continuously and in parallel. The temporal dynamics of these complex processes result in complex interactions between nature and human society (Mirschel et al. 2020). In geographical terms, agricultural landscapes form a mosaic of ecotopes and, functionally, an ensemble of ecosystems with varying degrees of anthropogenic influence (Haase et al. 1991). Agricultural landscapes have diverse functions for society and natural cycles. They convert solar energy into food and fibre; they supply water and air and guarantee their quality; they provide a suitable meso- and micro-climate; they recycle waste; they provide biodiversity; they have aesthetic value; and they are the basis for rural communities and their culture (Olson 1999). Agricultural landscapes over the globe are highly diverse due to geosystem characteristics and cultural history (Figs. 1.1, 1.2 and 1.3). Landscapes are "cultural" in a double sense. One is the cultivation of crops. The other is rural culture with its value in terms of settlements, the layout and maintenance of the land, the architecture of its buildings, its social life and natural life in rural landscapes (Vroom 1990).

Agricultural landscapes are not only a source of food, fibre, timber and other materials but are also important secondary landscapes for the leisure activities of the urban population. Agricultural land and associated forested, aquatic and other landscape elements are ecosystems that provide ecosystem services (DeClerck et al. 2016; Köppke and Schnug 2017; Kienast et al. 2019; Loos et al. 2019). Besides being agricultural producers, farmers become landscape stewards (Raymond et al. 2016), providing ecosystem services by managing agricultural landscapes.

As human civilisations developed, the pursuit of power and wealth increased, but also a sense of the beautiful and the sublime. Ever since landowners, peasants and farmers have lived in their agricultural environment, they have created useful and attractive landscapes and infrastructure. Under socio-economic conditions that were favourable locally, and over time, it became possible to revalue agriculture as an economic activity with elements of spirituality, art and science. Manor houses, religious places and buildings, farm buildings, schools, roads and other rural infrastructure developed. Ancient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◀ **Fig. 1.1** Visual impressions of agricultural landscapes in Europe. **a** Late Glacial landscape near Edinburgh, Scotland. Temperate humid climate. Bottomlands provide productive cropping. Deforested hills carry heather vegetation for sheep grazing. **b** Late Glacial landscape in Finnmark, Norway. Subarctic humid climate. Badly drained soils. Grasslands for cow grazing and silage as winter feed in the background and overgrown land in the foreground. Potato cropping possible. **c** Late Glacial landscape in north-east Germany. Temperate sub-humid climate. Intensive cereal cropping on big farms and fields in simplified rotations. Wind generators. **d** Holocene river lowland landscape in east Germany. Dry sub-humid climate. Cereal cropping on large fields. Farming by managers of an investment company. **e**, **f** Bio-energy farming in Germany. Dairy farm. Semi-indoor housing of milking cows in open stalls. Highly mechanized and sensor-controlled feeding and milking systems, purchase of high-energy feed. High indoor livestock density. Biogas plants. Maize-dominated rotations for digestate fertilization. High nutrient loads to soil and groundwater. **g**, **h** Agriculture in a mountainous landscape in Austria. Family farming with milking cows and other livestock, winter ski tourism and agri-tourism

terraces for the irrigated cultivation of rice, grapes or other crops are examples of useful and attractive agricultural heritage (Tarolli et al. 2014; Martin 2017; Agnoletti et al. 2019).

Understanding landscapes of the past is of crucial importance for managing landscapes of the future (Antrop 2005; Agnoletti 2014). Agricultural landscapes are a cultural achievement. The term "agricultural" includes current industrial-style farming (Printsmann et al. 2012). Like other landscapes, agricultural landscapes undergo continuous transformation due to natural processes as well as the development of human society (Antrop 1998; Lipský 1995; Plit and Myga-Piatek 2014; Jepsen et al. 2015; Mueller et al. 2019). Consequently, the most stable feature of an agricultural landscape is continuous change (Mirschel et al. 2020).

Agricultural landscape research. Society needs in-depth understanding and actionable knowledge for the sustainable development of agricultural landscapes. Agricultural landscape research contributes to this cognitive and innovative process. It can be understood as an essential pillar of landscape research (Mueller et al. 2019). This results from the special status of agriculture in securing the basic needs of human existence and preserving global ecosystem cycles. Thus, agricultural landscape research involves a potentially very broad field of scientific activity. It ranges from the analysis of processes in all parts of the agricultural landscape and its adjoining regions and spheres (e.g. natural landscapes, the hydrosphere and atmosphere), the evaluation of resources (e.g. soil, water and genetic resources), the sustainable management of landscapes, the conservation of biodiversity and agricultural heritage, and landscape governance and policies. Current agricultural landscape research, like most landscape research, has had a strong focus on Western Europe. In the context of modern landscape research, landscape transformations in Central and Eastern Europe should be better monitored and understood (Palang et al. 2006; Elbakidze and Angelstam 2007). This is also true for agricultural systems and landscapes in developing countries, which are not a main topic of this chapter. A great challenge is to understand landscape transformations in different contexts and to seek to generate landscape sustainability (Antrop and van Eetvelde 2019; Mueller et al. 2019).

The mission of agricultural landscape research is conveyed by the United Nations' sustainable development goals. These goals provide a vision for the living conditions and behaviour of the global population to be achieved by 2030. The principal goals are ending poverty and hunger, and ensuring healthy lives. Environmental issues such as water pollution, soil degradation and climate change are also explicitly addressed (United Nations 2015). Climate change and loss of biodiversity at the landscape scale combine to give alarming signs of planet-altering activity.

To improve the population's living conditions, and to stop soil, water and air pollution and degradation, better cycling of energy and matter fluxes in agricultural landscapes is needed. Novel methods and technologies for understanding, monitoring and managing landscape processes must be developed and set into operation. Landscapes are becoming more multifunctional and, because of the multitude of issues to be addressed when planning and managing agricultural

Fig. 1.2 Agricultural landscapes in southwest Siberia and north Kazakhstan. Landscapes belong to the Eurasian Loess belt. Climate zones range from forest steppe to dry steppe. Soils range from leached Chernozems to Solonetz-Solonchak complexes. Land is used for extensive grazing (**a**, **b**) and cropping of spring wheat (**c**, **d**) on fields up to 200 ha in size, sometimes separated by windbreaks. Countering the extreme risk of wind erosion would require conservation agriculture. International agroholdings may provide such investments

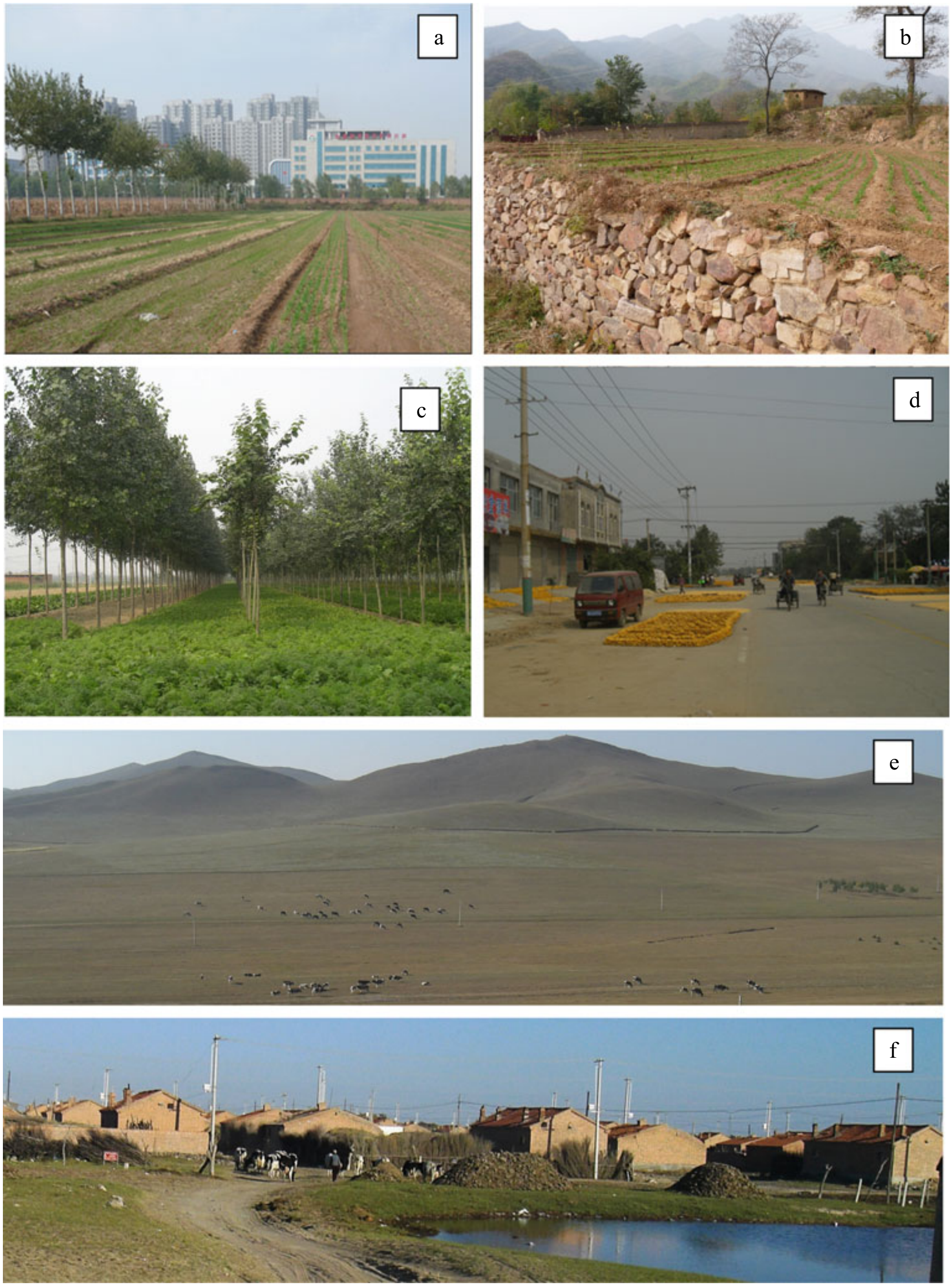

Fig. 1.3 Agricultural landscapes in north China. Landscapes belong to the northern part of the Eurasian Loess belt. Loess deposition from the Taklamakan desert and local soil translocation are still intact. The climate ranges from dry continental to subtropic monsoon. **a** Intensive maize-wheat and vegetable double cropping systems under surface irrigation at the fringe of the town of Shanxi. Land is under urbanization pressure. **b** Intensive maize-wheat double cropping on small irrigated terraces in the Tai Han mountains of Hebei province. **c** Vegetable and tree cropping, Shanxi. Row of medium trees for landscaping measures. **d** Drying of harvested maize in a village of Hebei province. **e** Bovine grazing on deforested mountainous landscape in the Gu Yan region of Hebei province. Reforestation programmes have limited success. **f** Village in the steppe landscape of inner Mongolia. The mounds behind the pond are cattle dung collected for heating purposes

landscapes, interdisciplinary and transdisciplinary approaches and decision tools are needed alongside disciplinary innovations (Naveh 1999; Buttimer 2001; Brandt and Vejre 2004).

Information provided in this chapter. In the following, we aim to review:

- the pivotal role of agriculture for the development of humankind
- the importance of agricultural landscapes and their components (soil, land, water and biota) as a basis for delivering multiple ecosystem services
- the importance of agricultural landscapes as a habitat for the rural population
- the challenges for agriculture in the 21st century and their implications for rural landscapes.

As global landscapes and agricultural practices are extremely diverse due to the characteristics of geosystems, climate and local cultures, we focus on developments in Europe, although Russia and China are also addressed as post-Communist regions in Eurasia. Agricultural development in these countries has huge implications for the status of the globe.

1.2 Land Cropping and Livestock Husbandry as a Basis for Cultural Development

1.2.1 Agriculture and Peasants in Human History

1.2.1.1 Beginnings of Agriculture in Prehistory

All high civilisations of the past, such as the empires of the Egyptians, the Assyrians, the Sumerians, the Chinese and the Romans, were based on highly productive agricultural activity and the storage, distribution and processing of basic food. The breakdown of agricultural systems, rural infrastructure and food webs due to climate change, with soil exhaustion, wars and epidemics, was responsible for or contributed to their fall (Moeller 2005; Giosan et al. 2018; Montgomery 2007; Norrie 2016).

The Neolithic Revolution, which began in the geological epoch of the Holocene around 12,000 years ago, created settlements, agricultural fields, domesticated plants and animals, private property and rural cultural landscapes (Pregill and Volkman 1999; Zeder 2008; Bowles and Choi 2019). Soil tillage and irrigation converted land around settlements to agricultural land. Human construction activities, food preferences and livestock-keeping changed the vegetation and soils of the rural environment. The “cradle of civilisation” has been identified as the Levant, a region on the east coast of the Mediterranean Sea in today’s Turkey, Syria, Lebanon, Palestine and Israel, with its hinterland in the fertile crescent of Ancient Egypt and Mesopotamia (Pinhasi et al. 2005).

There is a hypothesis that the cradle of civilisation, the dawn of the Neolithic revolution, could also have occurred in the northern part of the fertile crescent (southeastern Turkey), where pre-pottery cultures brewed beer and celebrated religious feasting (Dietrich et al. 2012; 2017). However, terms such as the “cradle of civilisation” or the “Neolithic Revolution” are popular but misleading. Processes and innovations stretched over hundreds to several thousands of years and kilometres. Processes were evolutionary rather than revolutionary. In contrast, current developments and those of the recent past, such as the introduction of modern machinery and molecular genetic technologies into agriculture, are truly revolutionary.

From around 9,500 BC, crops such as emmer wheat (*Triticum dicoccum*), einkorn wheat (*Triticum monococcum*), hulled barley (*Hordeum vulgare*), peas (*Pisum sativum*), lentils (*Lens culinaris*), bitter vetch (*Vicia ervilia*), chickpeas (*Cicer arietinum*), and flax (*Linum usitatissimum*) were cultivated (Heun et al. 2012; Abbo et al. 2016). In around 9,400 BC, parthenocarpic figs (*Ficus carica*) (Kislev et al. 2006) and livestock such as goats, sheep and pigs were domesticated in the Levant (Ensminger and Parker 1986; Larson et al. 2007; Zeder 2011). Cattle were domesticated in areas of modern Turkey and Pakistan around 8,500 BC (McTavish et al. 2013). Later, cattle were used as draught animals for wagons and ploughs as well as to produce milk and hides. Evidence of the domestication of the horse around 5,500 years ago is found in the Botai culture in northern Kazakhstan, a Copper Age culture of the 4th millennium BC (Outram et al. 2009; Gaunitz et al. 2018). The horse revolutionized the history of mankind through rapid mobility, warfare, trade and the cultural development of the Eurasian continent.

1.2.1.2 Bronze and Iron Ages in Europe

In Central Europe, early farmers were directly descended from Neolithic Aegeans (Hofmanová et al. 2015). The development of settled farming structures was interrupted by invasions of equestrian nomads who migrated from Central Asia and Southeast Europe to Central Europe. The Yamnaya culture (Mathieson et al. 2015) brought domesticated horses to Central Europe and promoted Bronze Age cultures. The use and breeding of domestic horses improved communication and transportation. The combination of settled arable farming with horse-based mobility became a successful basis for food production, trade and military activities (McNeill 1987).

Dryland cropping in prehistory was first based on shifting cultivation in former woodland that had been subject to slash-and-burn and turned over with primitive ploughs. In the Bronze Age, two-field rotations (alternating cropping and fallow) became common. Agriculture provided most food, but was still largely subsistence farming (Falkenstein 2009). Sheep, goats, cattle, pigs and horses grazed in the woods near the settlements. Grazing changed the structure of the forests, which were thinned while trees such as oaks and beech were promoted, as they provided particularly nutritious nuts for the livestock. Advances in metallurgy improved work in agriculture.

The Bronze Age brought significant progress in agriculture and settlement in Northern Europe. Burial mounds in which the remains of ancestors were interred were often found near settlements (Fokkens 2009). Sandy soils were improved by manuring. New species such as spelt (*Triticum spelta*), proso millet (*Panicum milleaceum*), broad beans (*Vicia faba*) and oats (*Avena sativa*) were introduced (Behre 1998) and the cultivation of barley (*Hordeum vulgare*) continued to expand. Cattle sheds for sheltering dairy cows over the winter were combined with dwellings (Behre 1998). A landscape structure consisting of fertile arable lands, elevated places for settlement, open waters, wetlands and forests for secondary food and as shelter, pastures, and interconnecting transport routes at community or regional levels was advantageous for the development of local rural Bronze Age cultures in Central Europe (Meller and Michel 2018).

During the Iron Age, ploughs and harvesting devices such as sickles were improved. Part of the pastures could be converted into meadows where hay could be produced as winter fodder for livestock. Soil erosion developed as a serious problem on cropland. Agricultural land became degraded in Greece and Carthage, northern Africa, the breadbasket of the Roman Empire (Hughes and Thirgood 1982; Montgomery 2007).

In the Roman Empire, bread wheat, mainly emmer wheat (*Triticum dicoccum*) and barley, were the most important cereals. Oats had been grown in Europe since the Bronze Age, but gained importance in the Iron Age, and were important to sustain the Roman cavalry (Moore-Colyer 1995). Rye (*Secale cereale*) became common in the early Iron Age (Behre 1992). Both crops are better adapted to lower-quality soils in Central Europe: oats on wet soils and soils of alternating wetness and drought, and rye on sandy soils. The Romans cultivated grapes (*Vitis vinifera*) and olive trees (*Olea europaea*) in regions with Mediterranean climates. Viticulture was introduced in more northerly areas of today's France (Bouby et al. 2013) and in the Moselle and Rhine river valleys. Landscapes east of the Rhine river remained generally less cultivated than landscapes to the west. During the period of the Roman Empire at its largest extent, about 117 AD (Kelly 2007), the Limes Germanicus (German frontier) divided two very differently cultivated regions in Central Europe along a line from Castra Regina (Regensburg) to Colonia (Cologne) and further north along the Rhine river. Landscapes located to the south and west were characterized by Roman high culture: cities and villages, urban and rural infrastructure, sophisticated arable plant cropping, horticulture and viticulture. The areas ruled by the Romans gained a specific agricultural landscape with a dominating road infrastructure. This was not the case in the non-Roman world elsewhere in Europe.

In Northern and Eastern Europe, sparsely populated, largely natural forest landscapes were typical during this time. Religions and religious conflicts led in the long term to changes in populations, cultures and landscapes. In Southern Europe, Christianization had been largely completed by the end of Antiquity. Climate changes led to food insecurity and the resulting movement of people, contributing to the fall of the West Roman Empire in the transition from Antiquity to the European Middle Ages. Mazoyer and Roudart (2006) comprehensively describe agricultural development in relation to the history of other parts of the world.

1.2.1.3 European Agriculture in Medieval Times

After the fall of Rome in 476 AD and the Justinian plague in 541/542 AD (Little 2006), much cultivated land in Europe became forest again, and agriculture declined. In the 9th century AD, the climate began to improve, and the Medieval Warm Period began (Easterbrook 2011). Agriculture received a significant upswing in the formerly cool Central, Eastern and Northern Europe. The population slowly increased again. The increase in agricultural production was due to new implements, the development of new land and the colonization of new areas. Forests were cleared and wetlands were drained. In the 11th century, agriculture began to boom (Abel 1962). Slavery had disappeared in Western Europe by this time (Fynn-Paul 2009), and was replaced by the feudal manorial system. The rural population benefited from progress in agricultural technology during what has been termed the "Agricultural Revolution of the Middle Ages in Northwestern Europe" (Mazoyer and Roudart 2006).

The wheeled iron mouldboard plough replaced the hook plough (Rösener 1985). It was drawn by oxen, cattle or horses. Improved methods of harnessing, such as the use of collars instead of yokes, enabled better power transmission and deeper tillage. The use of iron harrows improved tillage quality. New cropping systems were introduced, for example regulated three-field rotation in Western Europe. On one part of the acreage, winter crops were grown, on the second a spring crop, and the third was fallow. Later, when crop rotations containing legumes were introduced, fallow could be omitted. The housing of cattle improved. Straw could be used as litter. Manure, liquid manure and other fertilizers such as peat, ash and lime improved soil fertility. For harvesting, scythes were more productive than sickles. The harvested grain could be processed into flour faster and more efficiently because windmills and water mills had been constructed.

New centres of trade and commerce emerged, especially in the region of today's Netherlands and Belgium. The population grew. Towns and cities developed from villages. The increasing demand for wood decimated the forest. New farmland was created in unfavourable locations, such as on slopes and on sandy, boggy and clayey soils. Schreg (2020) argues that the intensive anthropogenic landscape change in the High Middle Ages was a main factor for the 14th-century crisis in Western Central Europe. Possible causal paths are shown in Fig. 1.4.

The European Middle Ages saw the expansion of the Roman Catholic Church. Monasteries of Christian orders were founded east of the Elbe river. Agriculture and horticulture ensured that the monasteries were supplied with food and developed as centres of religion, culture and science. Armies of knights supported the expansion by the forceful conquest of land. After the reconquest of Christianity's holy places in the Orient had failed, armies led by the German Order turned to the Baltic region and conquered it, except for Lithuania which converted to Christianity of its own accord to avoid conflict (Plakans 2011). This was associated with the development of new land for agricultural production. The strengthening of local secular forces in the Baltic region ended further expansion in 1410. Though the area possessed the superstructure of all medieval states, i.e. cities, towns, castles, courts and churches, the Baltic states remained 90% rural in terms of population and agricultural activities (Plakans 2011). However, during this period, the

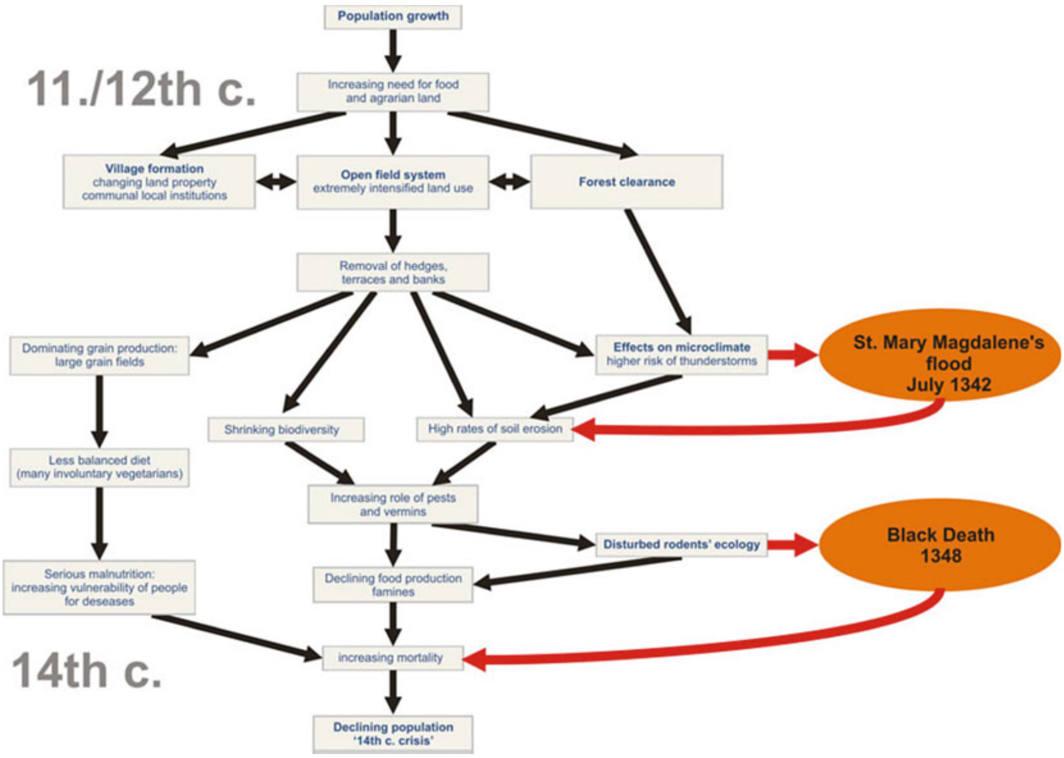

Fig. 1.4 Possible causal paths between intensive landscape change in the 11th/12th centuries and the later decline of rural regions in southern Germany (*Source* Schreg 2020)

Hansa city of Riga maintained strict control over its population to avoid unsustainable growth and rural depopulation.

The Late Middle Ages in Europe from the 14th century on were unstable in terms of the development of agriculture, economy, knowledge and culture. Depending on population dynamics resulting from wars, weather and climate fluctuations, the Black Death and other epidemics, land was either brought into cultivation or agricultural land was abandoned (Dyer et al. 2018; Rohr et al. 2018). Crop failures in the cold and wet summer of 1315 marked the beginning of the Great Famine in Northern and Central Europe which lasted up to eight years and claimed millions of victims (Geens 2018). Low agricultural productivity (Alfani and Gráda 2018) and limited property rights (Geens 2018) made the poor rural population particularly vulnerable. Extreme soil erosion damaged agricultural land in the first half of the 14th century (Bork and Bork 1987; Dotterweich 2012, 2013). In Northern Europe, much cropland that had been cultivated in the Late Iron Age or during the Agricultural Revolution of the Middle Ages reverted to forest. Population decline undermined monetary, feudal and manorial relationships (North and Thomas 1973). Up to then, monasteries had played an important role in the collection and preservation of knowledge about horticulture, agriculture, forestry and food processing.

Outside Europe, the late medieval times were not a "dark age" in terms of knowledge, science and technology. In the Arab world and in China, productivity rose in some periods corresponding to the European Middle Ages (Watson 1974, 1981; Broadberry et al. 2017). Along the Silk Road, trade and commerce flourished between the Far East, China, Central Asia, India, Persia, Arabia, East Africa and Southern Europe, cultivating economic, cultural, political and religious relations between the civilizations. Productive agricultural systems provided prosperity and power in Islamic regions (Idrisi 2005). The transformation of agriculture from the 8th to the 13th centuries is known as the "Arab Agricultural Revolution" (Watson 1981).

1.2.1.4 East Slavic Medieval World

Kievan Rus (Kievskaya Rus'), the cultural ancestors of the modern nations of Belarus, Russia and Ukraine, was a loose federation of East Slavic and Finnic peoples in Europe from the late 9th to the mid-13th centuries under the reign of the Varangian Rurik dynasty. The Kievskaya Rus' population is estimated to have reached about 1.9 million in 1000 AD and 3.3 million by 1300 AD—much less densely populated compared with medieval France and Germany (Vernadsky 1999). The urban population reached 13% on the eve of the Mongol invasion (1236 AD), indicating that a large proportion of the people did not depend on subsistence farming. This level of urbanization was only reached again in Russia at the end of the 19th century (Revi et al. 2003). Kievskaya Rus' was situated in two geographical zones: forest steppes and forest (temperate and boreal). The natural division between the steppe and the forest reflected the country's clear division into grain-producing and grain-consuming zones. Hence, exchange between the two zones was essential. The steppe lands in the south were fertile and widespread, allowing farming over large areas. In the forested north, where good agricultural lands were scarce, Russians developed more intensive farming. They ploughed only part of their lands and the remainder was left fallow. The Dnieper Basin, the main trade artery with rich fertile black soil (chernozem), was the major cultural landscape of Kievskaya Rus'. However, the Kievan economy mostly depended on trade in furs: sable, black fox, ermine, beaver and squirrel. The furs were sent to the Byzantine Empire down the Dnieper River. After the first Crusade (1096–1099 AD) was launched to invade the Byzantine Empire, Kiev's position as the major trade centre weakened. The Baltic region emerged as the most important trading area under the German Hansa merchants—about three-quarters of their trade was in fur. From the 12th century, the Novgorodian Rus' emerged as an East Slavic state, stretching from the Baltic Sea in the west to the Urals in the east. In the southern taiga, Novgorodians adopted two- and three-field crop rotation systems (Vernadsky 1999). The fur trade was a basis of Russian economic life. Novgorod became a major supplier of squirrel fur. Until the 14th century, all taxes, land rents and purchases were paid for in fur. Novgorod exported 400,000–500,000 pelts a year. By 1240 AD, populations of animals prized for their fur were depleted in the Dnieper Basin, and Novgorod merchants had to travel to and beyond the Urals to barter fur from nomadic tribes. By the 1460s, fur exports from Novgorod had fallen by about half (Ponting 1991). This economic decline was followed by the rise of Muscovy Russia (14th–17th centuries) with its rapid territorial expansion, primarily to the southeast (Kazan and Astrakhan khanates) and east (Siberia).

1.2.1.5 Examples of Ancient and Medieval Land Cultivation in Europe

Many rural landscapes in Europe have evolved "organically" and are open cultural landscapes dominated by arable land. Thus, typical elements and features of current landscapes are the result of past agricultural activity and associated animal husbandry. Where they have survived periods of recession and destruction, such features are pillars of cultural identity. Some examples of medieval land cultivation are terraces, Plaggenesch soils, ridge-and-furrow fields, hedge-banks and manor houses. Population increases about one thousand years ago led to the enlargement of village formation (Schreg 2006) and the foundation of small towns, and led to high food demand and investments in agriculture.

Meeus et al. (1990) define 13 types of European agricultural landscapes. "Open field" is one of them, the most widely distributed in Europe. These open fields, e.g. grain-growing landscapes, became the backbone of medieval European agriculture (Renes 2010). The farm buildings on open fields are concentrated in villages (Meeus et al. 1990). There is a strong connection between village and building types and territory

Fig. 1.5 Successful soil cultivation in Europe over many centuries. **a** Plaggenesch soils (Plaggic Anthrosols) are the result of humus-accumulating soil cultivation of formerly infertile Podsols from the Middle Ages onwards. **b** Mouldboard ploughs (here a modern variant), incorporating animal dung or green manure into soils, have created deep fertile A horizons on most soils in Europe. Problems with tillage erosion have occurred in undulating relief. European settlers using ploughs in dry continental steppe regions, insufficient dung availability and monoculture cropping have caused severe erosion and land degradation problems in the Americas and other parts of the globe. This example demonstrates the need for landscape-adapted land management systems

(Ruggiero et al. 2019). Local stone and timber characterize masonry and roofs.

In Mediterranean regions, Roman agriculture generated landscapes of high cultural and environmental value, permitting the cultivation of a wide variety of crops with sustained production (Ruiz Perez 1990). Terraces with drystone walls became part of many Mediterranean rural settlements. Many of them need revitalization and reconstruction today (Čurovic et al. 2019).

Plaggenesch soils and ridge-and-furrow fields are the result of medieval land cultivation in Northern Europe. In North-Central and North Europe in the period between 500 and 1,000 AD, after the great West Slavic migration, land cultivation and settlement became more fixed, as changes in settlement location and fields became less common (Schreg 2006; Widgren and Pedersen 2011). In this zone of natural forests, slash-and-burn agriculture was common (Rösch et al. 2017). Silvo-pastoral practices remained important in livestock farming (Vera 2000; Emanuelsson 2009).

Many soils were sandy, with a low water-holding capacity and poor in nutrients. Reclaimed agricultural soils suffered leaching, depletion of nutrients and low productivity. Land management required stepwise measures of soil improvement by organic fertilization (Baum et al. 2016). Special technologies such as plaggen cultivation became common (Giani et al. 2013; Kern et al. 2019). Plaggen cultivation created a typical fertile soil type, called "Plaggenesch" (Blume and Leinweber 2004). These fertile Anthrosols are the result of humus-accumulating soil cultivation from the Middle Ages onwards. Animal husbandry provided dung, liquid manure and nutrient-enriched grass sods (plaggen) for the improvement of soils (Fig. 1.5).

Other soils in marshy regions were clayey or peaty, often excessively wet and difficult to manage. Ridge-and-furrow fields (German: *Wölbäcker*, raised bed farming) resulted from mechanical soil ploughs with ploughshares and mouldboards becoming available (Küster 1997). A similar surface structure could also result from hand digging. This provided land drainage and increased the stability of crop yields in humid landscapes. These often-hidden structures of medieval fields—if not afforested—still influence pathways of runoff and soil erosion in agricultural landscapes (Deumlich 2012).

Thorny hedgerows protected villagers and their livestock from hostile neighbours (Küntzel 2009). Historical hedge-banks are typical in Northern Europe (Roßkamp 1999). Hedge-banks served as shelter against enemies attacking the rural population, as field boundaries, as protection for livestock against larger wild animals, as windbreaks, and to supply firewood. In other regions, stone walls or stone-faced hedges were common.

The process of differentiating land ownership accelerated from the late Middle Ages, although it varied from region to region in Europe (Zückert 2003). Large landowners gained a stronger position in society and with the authorities. The landed gentry developed and pushed the further redistribution of land. Common land declined and was limited to some pastureland in most regions. The gentry and rulers in Europe suffered less than the peasantry and landless during periods of recession. Rural spaces were important for agricultural production, as hunting grounds, parks and landscape gardens, and as unreclaimed wild land (Classen 2012). Many stone buildings from the Middle Ages or earlier, such as castles, manor houses and monasteries, survived into later periods or were reconstructed. They are now highlights of the cultural heritage in rural landscapes (Finch and Dyrmann 2019; Yılmaz and Yılmaz 2019).

1.2.1.6 Soils and Sediments as Archives of Rural History

Most information about landscape transformations of the past comes from soils and sediments (LABO 2011; Lucke et al. 2016; Fredh et al. 2019). For times and locations without written data, soils are often the prevailing source of information. Archaeologists have provided new insights into rural history and landscape transformations by analysing burial places and using advanced methods of laboratory analysis and multivariate statistical modelling of complex data sets (Van Mourik and van der Meer 2019). Remote sensing methods (especially high-resolution air-borne LiDAR) and data processing for pattern analyses help to detect places of past human activity (Melesse and Abtew 2016; Turner 2018). A broad array of dating and spatial allocation methods ranging from traditional pollen analyses to the latest molecular-biological methods (Giguet-Covex et al. 2014) have provided new insights into rural life and landscape history. Soil scientists have detected traces of past crop cultivation and fertilization practices using the same advanced analytical methods (Bogaard et al. 2007; Kögel-Knabner and Rumpel 2018). Past human activity has altered all soils irreversibly (Howard 2017). Phases of arable land use interrupt natural processes of organic carbon accumulation in soils. On this basis Lisetskii (2000) reconstructed soil formation processes in steppe regions north of the Black Sea as influenced by natural processes and anthropogenic evolution over the past 7,000 years.

Land use change from natural vegetation to agricultural land and vice versa, along with alterations to agricultural tillage practices, result in different rates of soil erosion (Lisetskii 2000; Vanwalleghem et al. 2017; Nearing et al. 2017). Sediment from agricultural land contains increased phosphorus loads. The dating of sediment layers in lakes or soils in floodplains and terrain depressions is thus a proven method for detecting those activities of the past (Giguet-Covex et al. 2014; Vanwalleghem et al. 2017; Kappler et al. 2018). Microbiomorphic assemblages (phytoliths, pollen and microbial genes) have been used to reconstruct the environment of the Early Iron Age at the southern fringe of the forest zone of the Russian plain (Makeev et al. 2019). Geomorphology and pollen records have enabled the scientists to reconstruct the effects of ancient Maya wetland management on soils, water and palaeoenvironmental change (Krause et al. 2019).

1.2.1.7 Status of Peasants in Pre-industrial Times

Peasants and rural populations have formed the foundation of the social system since ancient times. Their life was characterized by hard work and their attempts to understand their existence and destiny through religion, celebrated by religious leaders, and their own spiritual celebrations and rituals (Bradley 2005; Brink 2019). In slavery and feudalism, peasants had a low rank in society. Agriculture was subject to the manorial system, and was peasants' main activity, their second concern being to produce male descendants and serve as soldiers. Their low social status, poor living conditions and bondage ties to rulers led to peasants' revolts. In the feudal societies of medieval Europe, serfdom led to several peasants' revolts between the 14th and 18th centuries (Dunn 2004; Blickle 2004; Classen 2012).

Most peasants had no or very poor education. They were not free, as they were tied to their rural location and to their manor. This was especially true for the female population. Even at the beginning of the industrial age and the capitalist free market economy, peasants lived in feudal or semi-feudal conditions. Peasants in the German kingdom of Prussia gained personal freedom as a result of agrarian reforms in the early 19th century (Hubatsch 1989).

In the USA and in European colonies, farm labour was the work of slaves. Britain abolished slavery throughout its empire (except for India) by the Slavery Abolition Act 1833, the French colonies re-abolished it in 1848 and the USA abolished slavery in 1865 with the 13th Amendment to the constitution (Bader-Zaar 2010).

In Russia and China, feudal structures in agriculture were not removed until the Communist revolutions of the first half of the 20th century (Trotsky 1932; Pregill and Volkman 1999). Feudal structures in agriculture still exist today in some poor and underdeveloped countries.

1.2.1.8 Landscape Transformation in the Industrial Era

Key issues such as population growth, a rising demand for food, urbanization, monetary economy, the Renaissance, European discoveries of the world, long-distance trade, colonial systems and technical inventions characterize the transition from pre-capitalist forms of social development to capitalist industrial society. These developments began in Europe around 500 years ago and ushered in the accelerated development of agriculture and rural areas (Mueller et al. 2019).

The Renaissance initiated a spiritual, cultural and economic upswing in Europe. In the age of discoveries, new cropping plants were brought to Europe and led to change in crop rotations on large fields. New World crops such as maize (*Zea mays*), potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*) and manioc (*Manihot esculenta*) came to Europe, and Old World crops such as wheat, barley, rice and turnips, or livestock including horses, cattle, sheep and goats were brought to the Americas. This innovative period of agricultural development is known as the Columbian exchange (Crosby 1972).

Landscapes became increasingly multifunctional but maintained a rural character. The need for buffers against famines and national food insecurity were reasons for those in power to support agriculture and develop rural landscapes. To improve both land productivity and management, land reforms and large-scale land reclamation and land consolidation were conducted. Nevertheless, poverty and famines in the 18th and 19th centuries, in Ireland in particular (Mokyr 1983), caused the mass migration of Europeans to the New World.

Beginning in the 18th century, many peatlands and wetlands in Central and Eastern Europe were drained, dug for fuel, or converted into fertile pasture and croplands. Newly reclaimed lands were settled, such as in the Oderbruch landscape, located about 70 km east of Berlin, where the Oder river had been straightened and re-located (Mengel 1930, 1934). Mechanization allowed agricultural intensification and higher yields. Forestry has been reformed and intensified to meet the growing need for timber and other wood products in the industry (Hölzl 2012; Oosthoek and Hölzl 2018).

To improve both land productivity and management, land consolidation was initiated in some regions in the 18th and 19th centuries. Fields were re-arranged and grouped around single peasant homesteads and villages. This significantly altered the landscape structure in the poldered Oderbruch lowland and turned this region into the main food supplier for Berlin and other cities (Frielinghaus and Mueller 2003). River floods were diminished by the construction of dykes, and wetlands were drained by ditches. About 90% of the land became cropland. In other parts of Europe, cropland was reclaimed from forests.

In the Industrial Age, energy from burning fossil energy sources was the basis for the strong development of industries. Agricultural intensification through mechanization was typical. The availability of steam engines enabled deep soil tillage. More efficient transportation of agricultural goods was enabled by railways and steamboats. The introduction of power lines enabled easier but longer workdays for the rural population and a better quality of life in villages.

Many new animal and plant species, especially synanthropic species (i.e. those animal and plant species that benefit from changes made by man), and a large proportion of field margins led to an increase in biodiversity in agricultural landscapes in Europe in the 19th and 20th centuries (Küster 1997; Frielinghaus and Mueller 2003). This was documented by Baude et al. (2019) in a Loess landscape in the vicinity of Leipzig, Germany.

1.2.1.9 Russia at the Beginning of Modern Times

In retrospect, the most important change to East European landscapes was caused by the expansion of the Russian state from forest to forest-steppe and steppe zones. Russia expanded to include western, central and eastern Siberia by 1689 and Kamchatka in 1707, and Russian settlements were established in Alaska in the 1730 s. At the same time, European Russia remained confined to the forest zone because of a continuous struggle against the Crimean Khanate. Towards the end of the 17th century, the "Belgorod line" was established for defence near the present Russian-Ukrainian border. The vast Eurasian steppe was conquered only after the decisive defeat of the Crimean Khanate in 1774–1783. In the late 17th and the 18th centuries, more than two million Russian peasants moved south (as compared with 0.4 million people who went east to Siberia). The number of Slavs in the "New South" reached 14.5 million by the mid-19th century (Revi et al. 2003). This was accompanied by dramatic changes in land use (Dronin and Francis 2019). Pastoral and nomadic landscapes were ploughed up at a high rate and transformed into cereal fields (Moon 2013).

1.2.1.10 Beginnings of Agricultural Science

At the beginning of the 19th century, agricultural science became an acknowledged scientific discipline in Europe. R.W. Dickson (1759–1824) edited the book *Practical agriculture, or, a complete system of modern husbandry, with the methods of planting and the management of livestock* in England (Dickson 1805). In Germany, A.D. Thaer (1752–1828) published the journal *Annalen des Ackerbaues* from 1805, and the first volume of *Grundsätze der rationellen Landwirthschaft* in 1809 (Thaer 1809; Körte 1839). Pioneers of agricultural science such as A. D. Thaer and J. H. v. Thünen (1783–1850) developed the basics of land evaluation, land taxation, crop rotations, agricultural systems, and the rural economy in Prussia and Europe. "Thünen's Circles" denoted zones of resource demand emanating from economic centres (Thünen 1826), and are still frequently cited in the literature on agricultural economics.

Theories of plant nutrition and fertilization began to play a pivotal role in agriculture (van der Ploeg et al. 1999; Roberts 2009). In Germany, C. Sprengel (1787–1859) and J. von Liebig (1803–1873) made major contributions to agricultural chemistry (Pross 1973; van der Ploeg et al. 1999), as did J. B. Boussingault (1802–1887) in France (Boussingault 1845). In England, J. B. Lawes (1814–1900) began in 1843 the scientific investigation of fertilization at his home farm at Rothamsted Manor, later Rothamsted Experimental Station, and now Rothamsted Research. He had patented superphosphate fertilizer in 1842 and, together with J. H. Gilbert, investigated the impact of inorganic and organic fertilizers on crop yield. Some of the experiments started by Lawes and Gilbert in the middle of the 19th century still continue; they are the oldest agricultural experiments in the world (Holden 1972; Poulton and Johnston 2020). In Russia, the geographer and founder of soil science, V.V. Dokuchaev (1846–1903), created the basis for sustainable land management methods in steppes to ensure the productive longevity of agro-ecosystems and to obtain higher crop yields. He conducted landscape experiments for long-term studies of soil fertility in the Voronezh Region, Kamennaya Steppe (Chendev et al. 2015; Trofimov et al. 2020).

In the United States, the "Hatch Act" of 1887 used the term "agricultural science" for the first

Fig. 1.6 Pioneers of research in plant nutrition as a main pillar of agricultural science in the 20th century: **a** E. A. Mitscherlich and **b** D. N. Pryanishnikov. The international dialogue in science and practice was a constant concern to these outstanding scientists. The following data includes information from Wikipedia 2019 and Encyclopedia 2019. ***Eilhard Alfred Mitscherlich*** (1874–1956) was one of the most innovative and internationally best known German agricultural scientists of his time. He revolutionized research on soil fertility, plant nutrition and the yield performance of agricultural crops. Mitscherlich elaborated rules for the employment of field trials and soil analyses. He introduced fertilizer advice to agricultural practice. The plant culture containers he developed (Mitscherlich Vessels) are still used worldwide today. The Mitscherlich Curve, describing crop yield dependence on fertilization, and the Mitscherlich method for measuring the hygroscopicity of soils, became established in scientific literature and are still in use. From 1950 to 1956, E. A. Mitscherlich built up and headed the Institute for the Increase of Plant Yields in Paulinenaue, an Institute of the German Academy of Sciences. The Mitscherlich Academy for Soil Fertility in Paulinenaue, Germany, preserves his scientific legacy and works on its basis. ***Dmitry Nikolaevich Pryanishnikov (Дми́трий Никола́евич Пря́нишников***, 1865–1948) was a Russian agrochemist, biochemist and plant physiologist. Pryanishnikov discovered the general features of the exchange of nitrogen substances in plants and animals. His research provided a scientific basis for the use of ammonia salts in agriculture and for their extensive production. He founded the Soviet scientific school of agricultural chemistry. His book *Nitrogen in the Life of Plants and in the Agriculture of the USSR,* edited in 1945, became well-known. Pryanishnikov became an Academician of the Academy of Sciences of the USSR (in 1929) and the Academy of Agricultural Sciences (in 1936), a corresponding member of the French Academy of Sciences, and was the founder and director of the Russian Scientific Institute for Fertilizers. Pryanishnikov also analysed the influence of other mineral and organic fertilizers on plant growth in novel experiments. His work was a basis for more specific fertilizer application in agricultural practices of Russia and the USSR. The All-Russian Scientific Institute for Agrochemistry in Moscow bears his name and continues his scientific legacy

time. It provided information for farmers about the application of mineral fertilizer (Hillison 1996).

Agricultural research continued to progress in the 20th century. Processes of plant nutrition and soil fertility became better understood as a basis for fertilization, a crucial agricultural management measure. The work of leading scientists such as E. A. Mitscherlich in Germany and D. N. Pryanishnikov in Soviet Russia (Fig. 1.6) should be mentioned by way of example.

1.2.1.11 Agricultural Transformations in Russia and China

In Russia and China, agriculture was transformed from feudal to Communist structures. Peasants became acknowledged members of society, seen as feeding the nation. Agricultural transformations followed revolutions and wars; in Russia during and after World War I, and in China after World War II.

Russia. Agricultural science was given greater priority by the government. Agricultural

Fig. 1.7 Transformation of the Kuban region in southern Russia within a few decades. Introduction of rice cropping in Russia. **a** Semi-natural water courses with wetland vegetation before water regulation. **b** Landscape after water regulation and land clearing. **c**, **d** Land levelling and rice seeding in the 1930s. **e** Current soil tillage for wheat cropping within the rotation rice-lucerne-winter wheat. **f** Experimental rice plots of the All-Russian Research Institute for Rice in Krasnodar, founded in 1931. **g** Rice threshing in the 1930s. **h** Harvesters in 2000. **a** and **b** are paintings by P. G. Kalyagin at the Kalinin art gallery in the state farm of Krasnoarmeysk, Krasnodar region. Photos from the archive of the All-Russian Research Institute for Rice in Krasnodar

experimental stations were founded or enlarged. A typical example was the reclamation of the Kuban region in the south of European Russia. The region was developed for the cropping of rice, oilseeds, tea, vegetables and fruits. The landscape transformation to rice cropping is shown in Fig. 1.7. Economically, it was a success. Sophisticated water, soil and crop management systems were developed. The region supplies Russia with high-quality rice. Rice is grown on about 190,000 hectares in Russia, of which about 70% are in the Krasnodar region. The All-Russian Scientific Research Institute for Rice in Krasnodar is an internationally acknowledged breeder of high-yielding (potential of 7–10 t/ha rice grain) and robust rice and vegetable cultivars (VNIIrice 2019).

However, the introduction of innovations into agriculture was difficult during periods of economic disruption and political and cultural turmoil. All approaches were top-down, directed by the political leaders of the Communist parties.

Agricultural collectivization was introduced in Soviet Russia, in the 1920s (Hildermeier 1998; Segert 2019). Agriculture was organized in large collective farms (kolkhozes) and state farms (sovkhozes). Personal initiatives by the rural population were suppressed. Those who resisted were deported. Millions of people were sent to labour camps (gulags). In the still unexploited regions of the Soviet Union, labour camps were used to build up the mining industries and expand transport routes. Denunciation and mistrust shaped public life, including life in the villages. Human-induced famines such as that in 1932/33 (known in the Ukraine as *holodomor*) took millions of lives, not just in fertile steppe regions of the Ukraine and Kazakhstan but also in the Pre-Caucasus (Hildermeier 1998; Graziosi 2004). There were setbacks in agriculture and agricultural science. The president of the Agricultural Academy, Trofim Lysenko, denied Mendel's laws of genetics (Leone 1952; Caspari and Marshak 1965) and was responsible for the liquidation of the brightest heads of agricultural science as "bourgeois collaborators" and state enemies; many were deported to labour camps. Animal and plant breeding were thrown back decades. This process culminated in 1948 and ended only with the death of Stalin and Khrushchev's famous speech in 1956 (Khrushchev 1956).

During the Stalin era, private subsistence farming, even small-scale subsistence farming, gardening and livestock-keeping, was banned from rural areas. Even in the 1970 s, when private allotment gardens (dachas) became common in the Soviet Union, it was typical that no poultry, sheep, goats or cattle were to be seen or heard in the villages of many regions, such as in the Ukraine. Traditional rural culture seemed to be almost extinguished until the breakdown of the Soviet Union.

State-mandated and managed campaigns remained the typical instrument for agricultural development in the Soviet Union. The Virgin Lands Campaign was a huge land reclamation campaign in the steppes of Russia and Kazakhstan starting in 1954 (Pohl 1999; Meinel et al. 2014; Frühauf et al. 2020). Land was ploughed and spring wheat was grown. The impact on this region was beneficial for the rural population but at the cost of the environment (Frühauf et al. 2020).

Large rural centres were constructed in formerly remote and underdeveloped rural areas. This improved the living conditions markedly by providing better services to the rural population without interfering with the efficiency of farm operations (Valov 1963). Food security was a state doctrine in Soviet Russia and remains so in today's Russia (Dronin and Francis 2019).

China. The basis of modern China started with the creation of the People's Republic of China by Mao Zedong in 1949. The process of transformation from a backward feudal agrarian state into an industrial state began with the first land reform in 1950–52. Landless peasants received some land for subsistence farming. Manors and large farms were expropriated; their owners were publicly condemned and many of them killed. Subsequently, moderate collectivization began from 1957 on a more rapid basis. It was largely completed by 1958. People's communes were formed, embracing some villages. Communist Party-controlled communes were responsible for all areas of rural life, combining economic and local administrative functions. This dramatically reshaped social relationships and created new forms of political hierarchy and political teachings that brought rural households firmly under the influence of the state (Unger 2002). The Great Chinese Famine of 1959–1961 was a consequence of the politics of the Great Leap Forward (Ashton et al. 1984; Thaxton 2008), when people's communes were urged to become industrial enterprises. The large investments of funds and labour in heavy industry and in the energy and transport sectors seriously weakened the agricultural sector. Later, despite other campaigns such as the Cultural Revolution, when red brigades destroyed cultural heritage monuments, the situation in rural areas improved and stabilized. China moved away from collective agriculture in 1978. Today, the productivity and efficiency of agriculture is improving, with central government policies strongly supporting modernization and transformation (Shen et al. 2018; Cui et al. 2018; Robinson and Song 2018). China's grain yield increased from 1 t/ha in 1961 to 6 t/ha in 2015 (Jiao et al. 2018). However, environmental problems have arisen (Sun et al. 2018). Industry has developed faster than agriculture, and the gap in living standards between the urban and rural population, and between regions and villages has become greater over time (Unger 2002).

1.2.1.12 Agriculture in the Post-world War II Period: Progress and Concerns

In the second half of the 20^{th} century (post-World War II period, the beginning of the Great Acceleration of the Anthropocene according to Steffen et al. 2015), agriculture took high priority in Europe in order to overcome the damage of World War II. Developed countries profited from sustained economic growth, rural landscapes included. Stimulated by national and European agricultural policies, land consolidation, agricultural soil and water management, the implementation of modern crop management technologies, and the broad application of agrochemicals became common. A lack of food is no longer an issue in Western Europe and other leading industrial nations.

The USA was the engine of scientific and economic developments in the post-war period. Agriculture developed there with a strong scientific base, establishing an efficient system of research and development as well as partnership with industries (Busch and Lacy 1986).

The Green Revolution, starting in the 1960 s, furthered and stabilized agriculture in many developing countries such as Mexico, Pakistan, India and the Philippines, thanks to high-performing seeds and modern technologies (Evenson and Gollin 2003; Zeigler and Mohanty 2010). This process was scientifically planned and coordinated. The World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) supported the creation of the International Maize and Wheat Improvement Center (CIMMYT), the Consultative Group on International Agricultural Research (CGIAR) and other international research centres. The Green Revolution has prevented famine in many countries despite often only benefiting those regions with the most favourable physical conditions and good infrastructure. On the other hand, it can be argued that it has caused environmental pollution through the heavy use of agrochemicals and has promoted the process of agricultural industrialization and rural depopulation in developing countries (Evenson and Gollin 2003; Zeigler and Mohanty 2010). Its impact in some countries has been limited—in the Sahel zone of Africa in particular—and, despite significant efforts and improvements (McIntire 1981; FAO 2015), food insecurity and famines have remained a serious issue.

In highly developed, wealthy countries, the overproduction of agricultural products has required market regulation. The member states of the European Community and the European Union developed a comprehensive system of agrarian policy, the Common Agricultural Policy (CAP).

The use of agrochemicals has become excessive in Western Europe. Awareness of their possible negative impacts on water, soil and biodiversity has grown (Carson 1964; van der Ploeg et al. 2001). New environmental threats to soils, waters and landscapes have emerged. Examples include land loss and soil sealing through urbanization and highway construction; compaction of soils by agricultural machinery;

pollution of groundwater by nitrate and phosphorus, and of streams by phosphates; acceleration of soil erosion through elimination of terraces, hedges and buffer strips during land consolidation for industrial-style agriculture; loss of wetland habitats through land drainage; and damaged forests and bogs due to air pollution (Mueller et al. 2019).

Rural areas in wealthy countries have begun to change in new ways and landscapes have altered dramatically. More than half of the land in Europe was affected by these changes between 1900 and 2010 (Fuchs et al. 2015). New farm buildings were constructed, and existing ones were modernized. New infrastructure enabled a higher quality of life. Competition to boost the productivity and efficiency of agricultural work led to an increase in farm sizes and a reduction in the number of farm workers. Many villagers were no longer associated and familiar with local agriculture. Farmers remained acknowledged members of society, but their image was tarnished as they were blamed for damage to the environment.

In the Soviet Union and the countries under its hegemony, agricultural production reached a higher, more stable level compared with the previous situation. Limited resources in agrotechnology and agrochemistry, poor management and a drier agroclimate meant that production remained lower than in Western Europe, and there were differences between individual countries (Wong 1986). Collective farms were built and largely subsidized by states. Food prices for the population were kept low. Collective farms provided full employment and were responsible for the infrastructure in villages and for rural cultural life. Living standards in the countryside improved, approximating those in cities.

1.2.1.13 The Agricultural Recession in Russia and Central Asia, Beginning in the 1990S

The post-Soviet transformation of society and economics in Russia has brought significant changes in land use, especially in the forest zone. Between 1990 and 2007, about 48 million ha of agricultural lands in Russia, including 13.5 million ha in Asian Russia, were taken out of production (Lyuri et al. 2010; Saraykin et al. 2017). This was more than that gained during the huge land reclamation campaign in the 1950 s. Land abandonment was associated with a loss of rural population, which decreased by about 30% in most regions of sparsely populated Siberia. The cropped area has decreased for all food crops except for potatoes and vegetables, which are mostly grown on lands in individual ownership. The sharp decline in livestock production has reduced the area under fodder, especially in the areas traditionally specializing in dairy farming. The land cover and land use of the forest-steppe and steppe vegetation zones are still driven by extensive farming (e.g. up to 90% of lands in some areas have been converted to crop production). The area under sunflowers has been increased, with sunflowers replacing sugar beet and cereals (Uzun 2005).

Russian agriculture has operated at a low average level of input intensity. Agricultural management activities, such as soil tillage, fertilization, drainage and irrigation, have been seriously ignored since the 1990 s. The recession has not yet been completely overcome and management intensity is low. According to FAO data, nutrient applications in Russia in 2011 were very low: 10 kg N, 3 kg P_2O_5 and 2 kg K_2O per hectare of cultivated land (Mueller et al. 2016a). In the cereal cropping regions of Siberia, mineral fertilization was clearly below the already low Russian average (Bezuglov and Gogmachadze 2008). The application of NPK fertilizer in Siberia amounted to less than 10% of the application rates in the 1990 s (Gamzikov and Nozov 2010). Due to insufficient fertilization and diminishing soil fertility, the annual balance deficit of the main nutrients was 27 kg/ha N, 8.6 kg/ha P_2O_5 und 22.4 kg/ha K_2O in 2006–2009 (Gamzikov and Nozov 2010). Other measures for maintaining or improving soil fertility were also disregarded. Organic fertilization, the liming of acid soils and the amelioration of Solonetz soils were at levels of 12, 7 and 4%, respectively, compared with levels in the 1980 s (Gordeev and Romanenko 2008).

From FAO data, 29–74 million ha of land in Russia requires irrigation. In fact, the proportion of irrigated land has declined to a level of 2% of the total cultivated land area, and the proportion of drained land to 4% (Mueller et al. 2016a). The agricultural land located in the forest steppe and steppe zones requires irrigation. There is a great need for the reconstruction of irrigation and drainage systems which have undergone severe decay. Due to these deficits, cropland has become more prone to frequent droughts and floods; on irrigated soils, salinization is widespread. Important economic indices of the agronomic sector have declined. The share of agricultural production in the gross domestic product (GDP) decreased from 17% in 1990 to 3.5% in 2015. During the same period, agricultural land diminished from 213.8 million ha to 191.8 million ha, the rural population fell from 39.5 to 38 million and the share of agricultural employment dropped from 13.2 to 7% (Erokhin 2019).

In the Central Asian countries of the former USSR (Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, and Turkmenistan), agricultural production has declined, and food security concerns have increased (Swinnen and Vranken 2010). While countries which could export oil, gas or minerals recovered economically in the 1990 s, the poor, water-exporting countries of Tajikistan and Kyrgyzstan had problems with their state economy and with food security. In Tajikistan, insufficient purchasing power, limited production and very high population growth rates caused deficits in food security (Dukhovny and Stulina 2011). Food prices for many agricultural products increased by 10–120% in 2010 due to inflation. Kyrgyzstan had been self-sufficient and exported food in the 1980 s. After independence, more than half of all food commodities needed to be imported; among them were basic products such as bread, meat, sugar and oils. In 2009, about one-third of the population, the vast majority in rural areas, lived below the poverty line (Kulmyrzaev 2012). During the first years of independence, all the Central Asian countries focused their agrarian policies on maximizing wheat production. Due to dryland cropping possibilities on fertile Loess soils in the North, Kazakhstan became a grain exporter within a few years (Suleimenov 2014). In all the Central Asian countries, crop diversification and livestock production suffered from low productivity and limited sustainability. Grasslands have been degraded and desertified by overgrazing (Mueller et al. 2014a, b). Agricultural production in hot, dry Central Asia is extremely vulnerable to irregularities in water availability. All the great rivers and their main tributaries are transboundary. Permanent threats to water security exist for the downstream countries of Kazakhstan, Uzbekistan and Turkmenistan. Water conflicts have emerged between upstream and downstream countries and different resource users (Giese et al. 2004; Sehring and Giese 2011; Ibrayev et al. 2014).

1.3 Agriculture in the 21st Century: Implications for Rural Landscapes

1.3.1 The Anthropocene: Challenging Nexus Problems

Earth and humankind together form the Anthropocene, a new geological epoch. This epoch is characterized by increasing greenhouse gas concentrations in the atmosphere and by other irreversible signs of anthropogenic origin in current and future sediments. After World War II, at the beginning of what has been termed the Great Acceleration of the Anthropocene (Steffen et al. 2015), sedimentation of human origin increased dramatically. These sediments include plastic particles, waste products from the chemical industry and radioactive substances from nuclear processes. Agriculture contributes significantly to the changed global sedimentation conditions with increased phosphorus and nitrogen concentrations.

The Anthropocene is further characterized by climate change, rising sea levels (IPPC Special Report 2018) and resource scarcity. The current world economic order is based on economic growth, which has increasing influence on all natural processes. Greed for power and the possession and wasteful use of products, food included, are accelerating this process and leading to greater social differentiation. Capital and assets, land and fresh water included, are becoming concentrated in the hands of fewer people (van der Ploeg et al. 2015). Socio-economic phenomena include local overpopulation, social, political and religious tensions and conflicts, mass migration of people and over-exploitation of nature.

Accelerating interactions between humans, and between humans and their environment, have implications for all spheres of life, regions and landscapes (Millennium Ecosystem Assessment 2005; United Nations 2015). Further growth in world population, climate change and other factors will exacerbate the challenges to maintaining the capacity of ecosystems and livelihoods for future generations.

Multifunctional landscapes (Van Huylenbroeck et al. 2007) and multifunctional agriculture (MFA) are a promising innovation path for the evolution of rural areas (Madureira and Costa 2018; Far and Rezaei-Moghaddam 2019).

1.3.1.1 Food Security

The focus of current agriculture must be on food security (Mueller et al. 2010; Lal and Stewart 2011; Dronin and Kirilenko 2011; Gu et al. 2019). Food security is a human right and goal to be attained for the global population (United Nations 2015). The United Nations' Sustainable Development Goal 2 formulates this as follows: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" (United Nations 2015). Food security is formally secured by law in many countries but has not yet been achieved in many parts of the world.

The Economist Intelligence Unit (EIU 2019) publishes an annual country index based on a ranking model. As a general tendency, wealthy countries of Europe, countries of the Organisation for Economic Cooperation and Development (OECD) and other countries which rank high on the UN's human development index (HDI) (UNDP 2018) have high degrees of food security. The availability, access, utilization and stability of the food supply over time are important aspects of food security (Calicioglu et al. 2019). Producing enough fresh food and staples based on productive soils and well-performing agriculture is a crucial aspect of food security. Other aspects such as consumer preferences and mentality have also gained importance over the past years.

"Earth provides enough to satisfy every man's need but not every man's greed" is a saying widely attributed to Mahatma Gandhi (1869–1948), as quoted in D'Odorico et al. (2018). Regardless of whether Gandhi said that literally, it is a wise description of a crucial problem of human overpopulation, the exploitation of nature and providing food security in an inequitable world order.

The increasing demand for meat is a challenge for agricultural systems as it pushes the demand for fodder in the form of grain and pulses. This enlarges the human water and carbon footprints (Borsato et al. 2018). The meat consumption of wealthy groups in many countries is already excessively high, causing health problems for the population and environmental damage in production areas globally. The future expansion of pork production is expected to be largely concentrated in China, which will account for 42% of global growth by 2028, mainly occurring in large pig factories (OECD/FAO 2019).

According to the latest OECD/FAO outlook (OECD/FAO 2019), about two billion people will depend directly on agriculture for employment, and many of the world's poorest people will continue to live in rural areas. About 820 million people worldwide remain undernourished, while millions suffer from malnutrition or obesity (OECD/FAO 2019).

Paradoxically, increasing wastage of food is a common phenomenon that needs to be understood from sociodemographic and behavioural perspectives and tackled by policies aiming to create a sustainable food system (Abeliotis et al.

2019). Globally, about one-third of human food produced annually is lost or wasted (FAO 2016).

About one-fifth of global cropland area, with its associated water use, produces agricultural commodities that are exported (UNCCD 2017). The environmental burdens of food production are hence shifted to export-producing regions, posing a risk to their long-term food security, while importing nations become progressively dependent on foreign land resources, such as soil and water, for their food security (UNCCD 2017).

The challenge is to feed more people with less environmental damage by constructing healthy food chains (Singh et al. 2019; Fan et al. 2019). This will require the adoption of agricultural practices that are technologically sound, take into account traditional knowledge, and are socio-economically sensible in order to meet future dietary demands (Singh et al. 2019).

1.3.1.2 Global Status of Agriculture: Intensification

Global agriculture is characterized by constant growth due to technical innovations and specialization. The number of farms is decreasing and the average farm size increasing. OECD/FAO statistics and scenarios indicate that global agricultural production will grow faster than the population in the coming decade (OECD/FAO 2019). Agricultural production is expected to grow by 15% due to higher production intensity and yield improvements. The growth in livestock production will be based on the expansion of herds, and greater and more efficient use of feed (OECD/FAO 2019).

The globalization of all spheres of the economy has created a global food market and increased the flow of agricultural capital into profitable regions and centres outside the traditional rural areas (Robinson 2018 a, b). Production-oriented, specialized, industrial-style farming can have both positive and negative consequences for the development of rural areas (Robinson 2018b). Agro-industries and large agricultural enterprises are characterized by the separation of capital and labour (Cochet 2018). Decisions about adding value to the product are made outside rural regions, diminishing local investments and the purchasing power of the rural population. This makes agricultural landscapes vulnerable to global financial and economic crises (Tarolli et al. 2014; Pinto-Correia et al. 2018).

Scientific innovations such as information technologies, mechanization, application of new agrochemicals, and biotechnologies promote the intensification of agriculture (Fig. 1.8). Work processes have become more complex and faster in the agriculture of developed countries. Measures are geared towards high yields and efficient production with low human input. One good example is the production of grain. The technological chain in the production of grain is GPS controlled, highly precise and efficient (Lowenberg-DeBoer and Erickson 2019; Yost et al. 2019). Fertilizer spreaders and spraying machines with working widths of 20 m or more provide soil and plants with nutrients and treat them chemically with growth inhibitors, fungicides and herbicides. Nanofertilizer, nanoherbicides and nanopesticides release their agents in a controlled manner, enabling them to perform efficiently (Mitter and Hussey 2019; Joshi et al. 2019, Kremer 2019).

Crops can be harvested with GPS-based fully automated harvesters with a working width of 12 m or more, an engine power of 400 KW or more and grain bunker volume of 15 m^3 or more. Harvesting capacities of 5 ha/h are possible. Completely autonomous field machinery in grain crop production is expected to be developed in the near future (Shockley et al. 2019). Digital agriculture opens up great opportunities but has raised new questions about the wise application of what is technologically available, as well as data security (Rotz et al. 2019). These technological solutions are particularly effective in the large fields of large companies. Crop rotations, as well as field sizes and structures, have become simplified to adapt to the new types of machinery.

Animal production has also been rapidly intensified. In some countries, dairy cows, pigs and poultry are kept indoors and fed with imported high-energy food. Most protein-rich

Fig. 1.8 Intensification of agriculture. **a** Mechanized application of liquid manure in a bioenergy farm in Germany. **b** Automated milking carousel. **c** Modern pivot-centre field irrigation technology

feed is produced from genetically modified soybeans. Processes of feeding, manure disposal, milking etc. are fully automatic.

Agricultural intensification has its price for the environment and for society. Agriculture is the world's second largest producer of greenhouse gases (GHGs) due to the use of fossil-fuel-based fertilizers, agricultural machinery, and the burning of biomass (Qiao et al. 2019). In France, the intensification of agriculture in the second half of the 20th century has doubled GHG emissions compared with previous traditional systems (Garnier et al. 2019). Less and less labour is required for agricultural production. Intensification is leading to the shrinkage of the rural population.

Agriculture plays only a minor role in the national income of OECD countries. The agricultural gross domestic product (GDP) as a percentage of total GDP ranged from 0.6% (UK) and 0.7% (Belgium, Germany and Switzerland) to 6% (New Zealand) and 6.3% (Iceland) in the period 2010–2014 (Heisey and Fuglie 2018). This shrinkage has consequences for national expenditure as well as for research on and the stabilization of rural landscapes.

In developing countries, agricultural intensification still has an important role in economic growth and structural change (McArthur and McCord 2017; Christiaensen and Martin 2018). China's agriculture is a special case. The overuse of agrochemicals is particularly high on very small farms. Agriculture is largely based on smallholdings, and almost all farms are less than 2 ha (Cui et al. 2018; Wu et al. 2018).

1.3.1.3 Agricultural Land

Land, the basic resource of agriculture and rural life, is undervalued in the philosophical sense (Hetherington 2019). Agriculture uses about 40% of the earth's land surface, and of these agricultural areas, about 70% are pasture (OECD/FAO 2019).

Climate change has always influenced the availability and suitability of land for agriculture. Cool periods during the past 2000 years reduced land availability. This was associated with famines, civil unrest, migrations and changing political systems. Since the Neolithic Revolution, agricultural cropping zones in the Northern Hemisphere have moved northwards from the moderate sub-tropics adjoining the

Mediterranean Sea to steppes, forest steppes and forest zones. This process is accelerating. The current climatic warming is creating cropping potentials in the boreal zone of the Eurasian continent (Tchebakova et al. 2016). This potential will initially remain largely unused, as Podsol soils of the boreal zone have low inherent fertility and will need reclamation and improvement. The soils of the highly fertile Eurasian forest steppe and steppe region have become an important target for investment by international agro-holdings for wheat production (Petrick et al. 2013). Russia has the largest land resource potential for agriculture on the globe. The area of potential cropland in Russia amounts to 39–40 million hectares (Lambin et al. 2013). The Russian Federation's exports of wheat have become competitive in global markets (OECD/FAO 2019; Heigermoser and Götz 2019). In Europe, the proportion of agricultural land is shrinking for various reasons, e.g. transformation to urban land and to infrastructure (EEA 2019).

Currently, land clearing and reclamation in Latin America and the Caribbean account for most land expansion globally (OECD/FAO 2019). Large-scale land acquisitions by large enterprises (land grabbing), a highly controversial and widely debated issue (Dell'Angelo 2017; Zoomers et al. 2017, Robinson 2018a, De Maria 2019), are not limited to developing countries and transitional economies. Land grabbing is not only a growing phenomenon in Central and South America, Africa and Southeast Asia (UNCCD 2017), but is also common in West and Central Europe (Bunkus and Theesfeld 2018).

Very productive agricultural lands located in the broad-leaf forest zone and in the forest steppe zone are attractive for cropping. Planted forests are part of the agricultural landscape in many regions. The conversion of untouched forests to cropland is profitable in many parts of the world. Hence, forest stocks are declining in Africa and South America (Köhl et al. 2018). Forest land is being acquired on a large scale in Africa (Conigliani et al. 2018), Southeast Asia and South America, as well as in Europe.

Land grabbing also requires the acquisition of water for additional crop growth. How to plan the sustainable development of resource use and rural development in landscapes that are in the possession of foreign companies or countries is a very challenging question.

1.3.1.4 Breeding Progress, Molecular-Genetic Technologies

Plant breeding has experienced significant innovations over recent decades, leading to higher crop yields. Hybridizations have been developed for many crop species. Global action by multinational breeding companies enables shorter breeding times through laboratory and field experiments. Experiments with maize, for example, can be conducted twice a year, bringing seeds and genetic materials from breeding stations in the Northern Hemisphere to the Southern Hemisphere and back. Gene banks for existing breeds and wild plants have been built up and their genomes have been identified by molecular techniques. Molecular markers combined with computer models allow the performance of newly desired breeds to be predicted based on genomic selection. Genetic technologies such as DNA sequencing, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) and nanotechnologies could revolutionize plant breeding and pest control in agriculture (Gao 2018; Mitter and Hussey 2019; Chen et al. 2019). CRISPR is also being used to speed up the introduction of viral resistance in plants (OECD/FAO 2019), in animal breeding and in the use of animals to produce human vaccines and organs.

On the other hand, molecular-genetic technologies bear increased risks for the farmers, rural regions and societies. Farmers may no longer freely decide how they manage their crops. For example, they may no longer be able to save and use their own harvested seeds. Growing the most effective seeds promotes the simplification of rotations over large regions. Effects on genetic diversity and biodiversity are not easy to predict. Growing genetically modified seeds can have detrimental pollination effects on the plants of adjacent organic farmers. Beekeepers face limitations on and risks in their actions, their bees and their products (Binimelis and Wickson 2018). CRISPR technologies have the potential to create new life based on combinations of genes from all kinds of existing species, humans included. This can have unforeseeable risks for the existence of current life on earth and raises ethical questions regarding the need for control (Helliwell et al. 2019).

In general, the actions and effects of animal and plant breeding occur within agricultural landscapes but are largely beyond the influence of farmers and the rural population. It is very important to monitor and assess environmental safety (Ricroch et al. 2018), and the efforts and expenses required for independent monitoring will increase considerably.

1.3.1.5 Animal Factories

The demand from the urban populations for cheap meat in supermarkets has led to the factory farming of animals. These factories are the result of extreme intensification in livestock husbandry. More than three quarters of the global pork and poultry production is industrialized (Herrero et al. 2013). The industrial livestock sector has become de-coupled from the land base with regard to feed inputs and the supply of power and manure for crop production (Naylor et al. 2005). This requires increased efforts and high standards of quality control.

Humans and animals become alienated from one another in those factories, and animals alienated from nature. Feed no longer comes from local or regional cropping systems and contains genetically modified plant material from soybean or maize in most cases. Antibiotics are applied as growth promoters and therapeutic agents in these factories. The development of antibiotic-resistant bacteria is a common risk. These antibiotics enter food chains and seriously affect the human immune system, growth and metabolism (Muhammad et al. 2019). Antibiotics are environmental contaminants leading to growing public health concerns. Screening methods have been developed to detect them in the wastewater of industrial pig production (Wang et al. 2019). Methods to eliminate or ameliorate their harmful effects have been initiated (Ngigi et al. 2019). However, new interactions with other agents and factors are constantly being detected, requiring food web experiments and other forms of multi-layered research intervention (Danner et al. 2019). Animal factories are emitters of nitrogen and other chemically, physically and biologically harmful substances, creating wet and dry local deposition loads in the rural environment.

Agriculture and rural areas both cause and are victims of these developments. Animal factories are not just a fundamental ethical problem; their sites are risk areas for humans and the environment. Their effluents contribute to pollution sources in agricultural fields and landscapes. They reduce the quality of life in rural landscapes.

1.3.1.6 Locally Disturbed Nutrient Cycles, Eutrophication of Soil, Water and Air

The specialization of farms in the course of agricultural intensification has de-coupled cropping agriculture from animal husbandry. A typical trend in Western and Central Europe has interrupted local nutrient cycles in agricultural soils and created regions of high nutrient surpluses, while other regions have problems maintaining the humus content of soils.

Today, many farms are specialized in the market production of grain, oilseeds and other crops without any animal husbandry. Fertilization is provided by imported mineral fertilizer. Other farms have specialized in milk, pork or poultry production, often combined with biogas plants. High-energy feed, mainly from soy, maize or wheat, is being bought on the world market. Those enterprises lack land. Dung and liquid manure from animal production or digestate from biogas plants are potentially valuable to restore soil fertility on agricultural land. However, a lack of land is leading to high nutrient surpluses in some landscapes and regions and to great effort and high transport costs for disposing of manure and digestate. Equipment for transporting and applying liquid manure is heavy and causes soil compaction and damage to roads. Agricultural land use is contributing to water pollution (Schmalz and Kruse 2019). High surpluses of phosphorus and nitrogen are a threat to open waters and for drinking water (Eulenstein et al. 2016).

1.3.1.7 Land and Soil Degradation

Well-managed, fertile, healthy soils are the basis for productive and multifunctional agriculture. Soils provide humans with most of the food they consume (Kopittke et al. 2019). The fertility and health of the soil and land are largely determined by management practices and environmental changes. Land and soil degradation (Fig. 1.9) mean loss of land and soil or of land and soil functions (Blum 2003).

This can be assessed by a decline in the performance of the land to produce biomass, a loss or change in vegetation and/or by the deterioration of the soil's physical, chemical or biological parameters. A reduction in the land's capacity to provide resources for human livelihoods, a loss of biodiversity and increased vulnerability of the environment or people to disturbances are further examples of the effects of land degradation. Water is often the most important limiting factor for agriculture (D'Odorico et al. 2018). Land degradation is a particularly serious problem in drylands, resulting in desertification (Dregne 2010), but can affect all croplands, grasslands, rangelands, and in a broader sense, all lands worldwide.

Agricultural intensification such as continuing monoculture, over-fertilization, over-use of pesticides, ill-adapted irrigation practices (leading to salinization), over-grazing, industrial breeding, forest clearance and wetland drainage can pose threats to the soil's resource quality and functioning (Kopittke et al. 2019). This has created knowledge gaps (FAO and ITPS 2015). Land and soil degradation can be considered a major global environmental issue of this century, threatening food security, human security and environmental quality (Eswaran et al. 2005; Barbut and Alexander 2016; D'Odorico et al. 2018). The livelihoods of over two billion people worldwide depend on 500 million small-scale farmers for their food security, and about one-third of all agricultural land is now considered either highly or moderately degraded (Barbut and Alexander 2016). Growing problems of land degradation in Africa are causing food insecurity, conflicts and migration (UNCCD 2017), urgently requiring local sustainable agricultural intensification (Jayne et al. 2019). Land and soil degradation is exacerbated by the increasing population and climate change, contributing to conflict due to water scarcity, lack of land and food insecurity (Behrend 2016; Lal 2019).

Loess soils, which are usually considered the best soils for agriculture worldwide, have also experienced distinct degradation (Schreiner and Meyer 2014; Chendev et al. 2015; Frühauf et al. 2020). In the Loess region of China, soil degradation is an old problem. Terracing of hillsides was a good solution to prevent soil erosion (Jiang C 2019a, b). Most reclaimed lands, such as in the Siberian steppes (Schreiner and Meyer 2014) and in the Brazilian Cerrado (Gomes et al. 2019), are experiencing severe degradation through erosion and soil nutrient depletion.

The status of the Central Asian grasslands and rangelands seems to be particularly critical, as desertification appears to be triggered by grassland degradation. It would be useful to establish an international project group to work out methodical guidelines for the evaluation of grassland sites and to prepare a trans-national land inventory of Central Asia (Mueller et al. 2014b).

Urban sprawl and intensification in the exploitation of natural resources beyond agriculture are also major causes of land and soil degradation. This occurs mainly by land take, soil sealing, and soil and land pollution (FAO and ITPS 2015; UNCCD 2017).

From the latest data of the United Nations Convention to Combat Desertification (UNCCD 2017), it can be estimated that the half of the world's population lives in regions of degraded agricultural lands. This tendency is increasing dramatically in developing countries, and on all continents except Europe

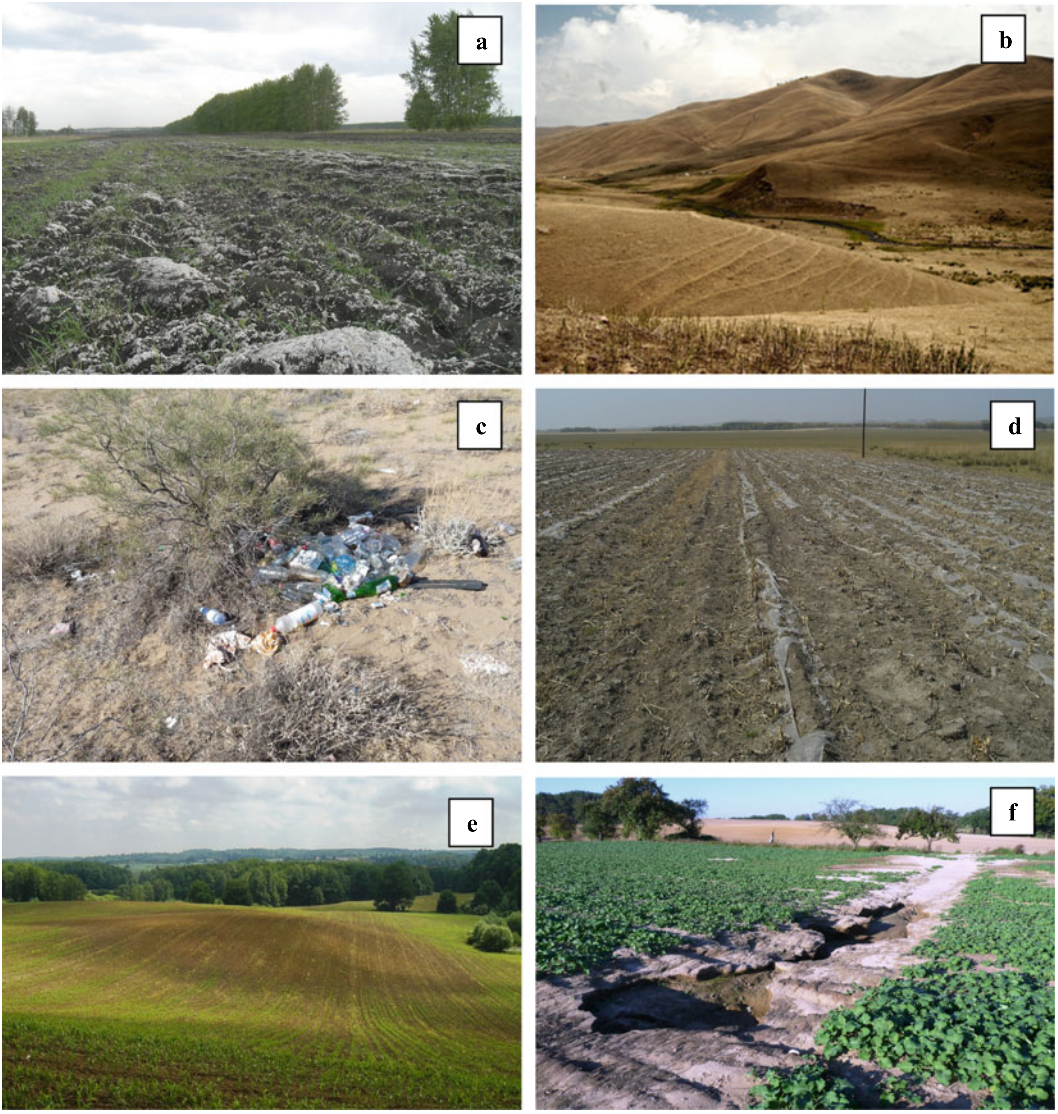

Fig. 1.9 Examples of soil and land degradation. **a** Salinization of ploughland in the Baraba steppe, west Siberia. **b** Overgrazed degraded pasture in Central Asia. **c** Landscape pollution through illegal waste disposal in the steppes of Central Asia. **d** Soil pollution through plastic material use in agriculture, North China. **e** Topsoil removal through tillage erosion in Germany. **f** Water erosion effects on a canola field in Germany

(UNCCD 2017, Chapter 7, p. 141). Scenarios of shared socio-economic pathways (UNCCD 2017) indicate increasing problems of land degradation. They show significant expansion of agriculture on tropical soils, which are particularly vulnerable to erosion, nutrient depletion and other forms of degradation. Willy et al. (2019) have found that soil degradation is associated with high population densities in Kenya. Where densities exceeded 600 persons/km^2, soil quality indicators and crop yields were markedly diminished.

1.3.1.8 Agroecological Problems: Loss of Biodiversity

Ecological problems of agriculture in the 21st century are particularly evident due to biodiversity losses. The loss of insect biodiversity has gained public attention in Europe, and agriculture is held largely responsible for this.

Insects are an indispensable part of the food web and biological cycles in agricultural landscapes. Many are essential pollinators in agriculture and horticulture. Others are crop pests in modern agriculture and in many cases are reliably controlled with insecticides. Insects have a sophisticated ontogenesis. Their metamorphosis to the imago is based on complicated biochemical processes both in their habitat and in their body. Insecticides applied in agriculture and environmental toxins from other areas of human activity can easily attack and work through their respiratory or digestive system or via skin contact. Many insects (mainly in their larval stage) spend long periods of their development in water or soil. There, they are exposed to complex effects of climate change (Lehmann et al. 2018), altered microbiological populations and relationships with, e.g. fungi or bacteria, or antibiotics, pesticides and other chemicals.

The decline of insects has accelerated due to the elimination of field margins, the draining of wetlands, reduced crop rotation systems, monocultures, loss of wildflowers (Durant 2019) and the large-scale application of pesticides such as neo-nicotinoids, herbicides such as glyphosates and other agrochemicals (Stenoien et al. 2018; Schäffer et al. 2018; Vray et al. 2019). The loss of pollinator communities in agricultural landscapes is concentrated on species which have a long evolutionary history (Grab et al. 2019). Pollinator decline in agricultural landscapes (Holzschuh et al. 2016; Kovács-Hostyánszki et al. 2019) is a clear indicator of unsustainable agriculture.

Conventional agricultural intensification has led to a decline in butterflies (Habel et al. 2019) and other invertebrate species. The disappearance of insects has a negative impact on insectivorous birds, amphibia and other predator species which are already stressed by habitat loss and other anthropogenic impacts (Berger et al. 2018). It reduces the possibilities of controlling detrimental insects in agriculture by means of natural regulatory mechanisms.

Bird decline due to habitat loss resulting from agricultural intensification has been demonstrated by Manton and Angelstam (2018) and Manton et al. (2019). A sharp decline beyond the benchmark for sustaining species occurred in the second half of the 20th century, pointing to an urgent need for habitat restoration (Fig. 1.10).

The decline of many other taxa in above- and below-ground ecosystems is becoming increasingly evident. For example, Banerjee et al. (2019) found few mycorrhizal keystone taxa in the root microbiome under conventional agricultural intensification practices and higher numbers under organic farming.

Open waters, the habitat of many waterborne insects and other species, have suffered disappearance, or reduction and shifts in temperature and changes in their hydrological regime due to agricultural intensification and urbanization, combined with climate change. This negatively affects ecosystem services such as pollination and biological control services to agriculture (Raitif et al. 2019). Only about half of the rivers and lakes in the EU have a good ecological status, and many lakes, ponds and streams have disappeared or are strongly polluted. In Central Asia, about 90% of amphibia and a quarter of freshwater invertebrate species are thought to be threatened, although there is a lack of reliable data for that region (Gozlan et al. 2019).

There is a need to develop improved and comprehensive eco-toxicological monitoring systems for agrochemicals (Schäffer et al. 2018), with a special focus on insects (Scherber et al. 2019) and other species in agricultural landscapes.

1.3.1.9 Status of Rural Landscapes in Europe, Drivers and Trends of Change

Within the EU, rural areas cover three quarters of the land area, but they are inhabited by only 28% of the total population (Castillo et al. 2019). Rural landscapes have been developed over

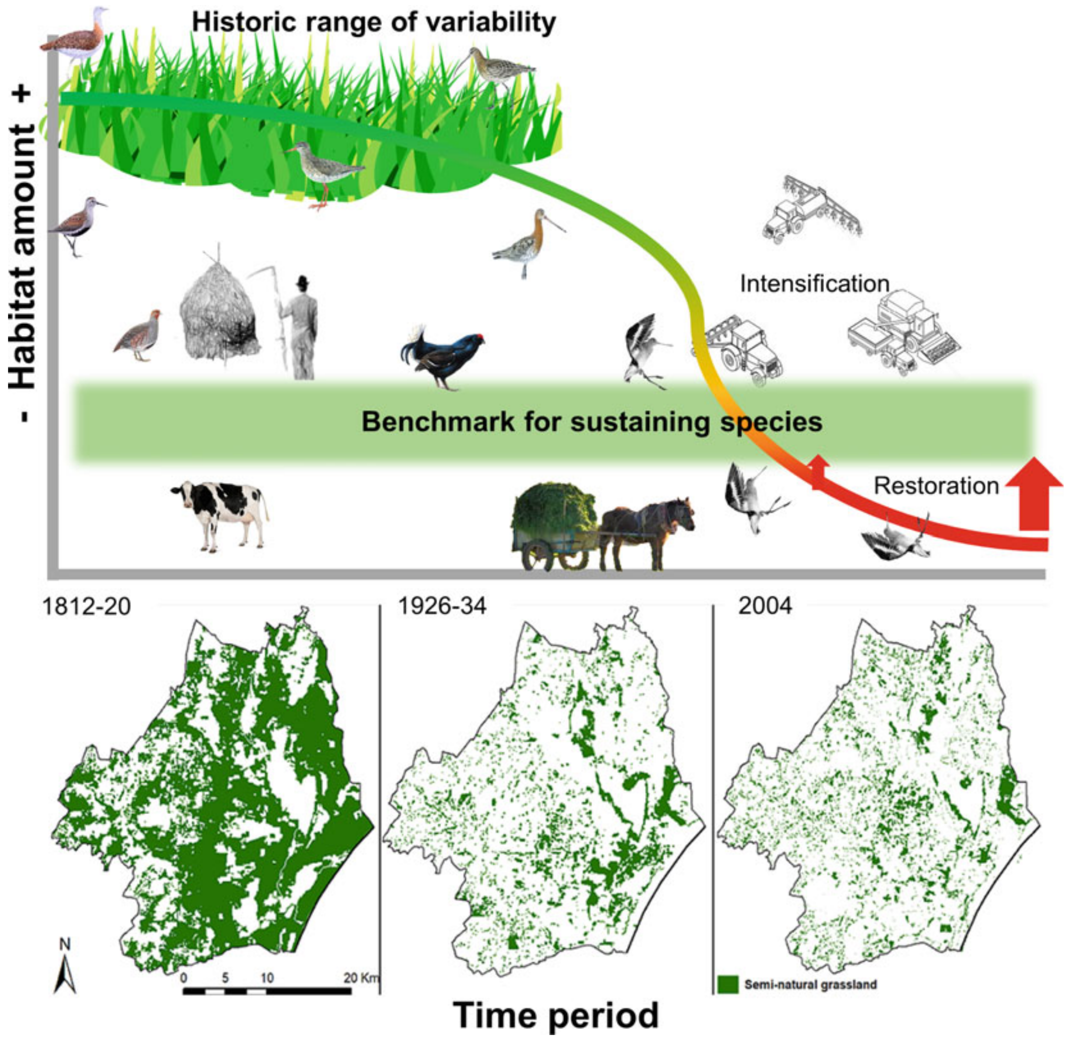

Fig. 1.10 Loss of semi-natural grassland in the Kristianstad region (southern Sweden) and associated decline of breeding birds. Figure modified from Manton and Angelstam (2018). The grassland cloud at the top of this figure represents the range of historical variability. The benchmark area illustrates the proportion of the historical range of variability that forms the benchmark level required for ecological sustainability. The change over time in land cover and associated risks are shown by the line changing from green to red. The arrows indicate the need for landscape restoration and for pro-active spatial planning directed towards multifunctional land use. The maps below show the spatial decline of semi-natural grassland from 1812 to 2004

centuries. A viable infrastructure has enabled a good quality of life for the rural population. However, in present-day developed economies, the percentage of people working in agriculture is very low compared with typical agricultural and transitional economies. Local and regional agriculture, which has formed and shaped these landscapes as cultural landscapes, is losing ground.

Cultural landscapes have undergone a rapid transformation within only a few decades (Tarolli et al. 2014). Mediterranean agriculture, which is based on the great cultural traditions of the Romans, has followed a dual process of intensive production in more fertile lands, and the marginalization and abandonment of the least productive lands (Ruiz Perez 1990). The main driving forces responsible for the landscape change are agricultural practices, leading to intensification in some areas and abandonment in others, urbanization, and landscape conservation policies (Poudevigne et al. 1997; Schulp et al. 2019). The abandonment of farmland (Nelson 1990), farm buildings (van der Vaart 2005) and villages had become common at the end of the 20th century. The abandonment of historical terraces (Agnoletti et al. 2019; Narbarte-Hernández et al. 2019) is a typical recent example of the degradation of rural landscapes that have heritage value. A quarter of all EU agricultural land is expected to be subjected to moderate, high or very high risk of abandonment by 2030 (Castillo et al. 2019).

Agricultural intensification has led not only to high productivity but also to disturbances, damage and decline of ecosystems and rural cultural landscapes in most regions of Europe (Succow 2012; Stöven et al. 2015; Eulenstein et al. 2016; Schnug and de Kok 2016). The current trend of the transformation of many agricultural landscapes into powerfully networked agro-industrial landscapes, designed for maximum productivity of animal factories, feedstocks, energy and market crops at high input rates of agro-chemicals, is a critical issue requiring better monitoring, planning and management.

The food industry operates in large, automatically controlled units. The transport distances for agricultural products to food processing industries such as dairies and sugar refineries have become so extended that agriculture in some regions is no longer able to produce certain commodities such as milk or sugar.

Rural landscapes are experiencing a breakdown of the rural infrastructure and depopulation. Rural populations are suffering from the centralization and closure of schools, shops, post offices, doctors' surgeries, libraries and restaurants. Administrative units are getting bigger and the distances rural people have to travel to the authorities or to hospitals are increasing.

Farmers and other rural residents have lost their lobby in decision-making organizations regarding rural problems. Instead, the food industry has become the new lobby for agriculture. Their decisions follow the global market economy rather than the interests of the rural population. In some cases, sparsely populated rural regions are prone to landscape transformation into waste disposal and recycling landscapes.

1.3.1.10 Peculiarities of Rural Landscapes in Post-soviet Regions

The collectivist era created a form of employment for all of the rural population in the USSR and in the countries under its domination. Agricultural production was conducted on large collective and state farms and fields in most countries (Bauerkamper and Iordachi 2014). In most regions, it was associated with certain behaviour patterns among the rural population, such as passiveness, demotivation, a mindless attitude towards cultural and ecological values, and a loss of entrepreneurial skills (Gelencsér et al. 2012). Traditional family farming was extinguished. In the post-Soviet era, government promoted conversion to industrial-style farming. Large, speculative investors were favoured. Profits from farming flowed into other regions and this promoted the breakdown of local rural infrastructure, leading to a rapid rural exodus in many regions (Gelencsér et al. 2012).

The introduction of industrialized production and collectivization since 1960 led to the devastation of vegetation structures, habitat degradation and biodiversity loss, for example in the Loess region near Leipzig, east Germany. Crop yields have stagnated in this region since 2000 (Baude et al. 2019). Large fields and farms, implemented during the period of the Soviet Russian control of eastern Europe, are still quite productive, but have paved the way for an accelerated loss of biodiversity, infrastructure and culture in these agricultural landscapes.

The Common Agricultural Policy of the EU and other regulations have not been able to stop these negative processes. On the contrary, regulations such as carbon crediting, the biofuel economy and the sale of state and federal lands to the highest bidder have promoted unsustainable development. Currently, this process is speeding up. Increasingly, land is owned by people who feel no responsibility for maintaining living rural landscapes (Agrarbündnis 2015–2018). Farmland privatization processes for non-farmers have been associated with people becoming alienated from the land (Bluwstein et al. 2018), nature and landscapes and from the principles of sustainability. These processes need to be stopped and cultural landscapes maintained and sustainably developed (Succow 2012).

1.3.1.11 Urban–Rural Interactions and Pollution Pressure on Rural Landscapes

Life in cities and mega-cities dictates the pace of human development today. Decisions about the future of humankind, nations, regions and landscapes are made in cities. Agriculture and rural landscapes play a role as suppliers and servers of cities. However, globalization has changed the traditional model of supplying the city from its immediate surroundings.

Modern urban agglomerations have a high metabolism, which the biomass trade plays an important role in feeding. The high consumption of agricultural and other products in urban agglomerations affects neighbouring and remote rural landscapes through teleconnections (Seto et al. 2012), which can be better understood and quantified by analysing telecoupling processes (Friis and Nielsen 2019). Embodied human-appropriated net primary production (eHANPP Haberl et al. 2009) can be used to quantify food trade processes.

Urban water demand is expected to have increased by 80% by 2050 (Flörke et al. 2018). Competition between cities and agriculture for water is increasing. Cities require water to be of drinking quality, while cleansed wastewater can be used for agriculture. Water and soil in peri-urban and rural landscapes are prone to degradation due to pollution induced by urban pressure. More and more urban waste has reached a status of hazardous material requiring special treatment such as burning or permanent disposal. Urban wastewater and urban waste are rich in nutrients and have the potential to be used in agriculture. This effective procedure of nutrient recycling has been a common practice over many decades. Meanwhile, antibiotics, hormone preparations and several organic substances of unknown behaviour, heavy metals, and other pollutants in the food web have been widely detected in water and soils (Yi et al. 2019). This requires permanent analytical control, monitoring and risk evaluation. Investments in improving agricultural water use could thus serve as an adaptation strategy to tackle water scarcity (Flörke et al. 2018). Waste disposal sites have become a typical feature of rural landscapes.

1.3.1.12 Bio-Energy Landscapes

Public awareness and concerns about human-made climate change, and the scarcity of fossil fuels, have led to a boom in the “biofuel economy” in Western Europe. Energy from renewable resources such as wind, solar radiation and biomass reduces carbon dioxide emissions (Qiao et al. 2019). Farmers and other investors in wealthy countries have used the opportunity to stabilize their income by state-subsidized investments in biogas plants and wind generators. Since the beginning of this millennium, wind parks, solar farms and biogas plants have shaped landscapes in Europe, and especially agricultural landscapes. Many landscapes around the globe have been transformed into bio-energy landscapes (Fig. 1.11).

The production of biofuel, mainly ethanol, requires agricultural land, in the magnitude of about 2% of the total cropping area (Langeveld et al. 2013; Kopittke et al. 2019). The next generation of biofuels will be produced from lignocellulose, non-food materials, algal biomass and energy crops grown on marginal lands, requiring further technical innovations and new economic solutions (Kumar et al. 2020).

The production of biogas is often coupled with animal factories for pork and poultry meat production. Sometimes, land use for biogas competes with land for food and feedstock cropping. Future agricultural biogas production

Fig. 1.11 Bio-energy landscapes shape rural regions in Europe. **a** Wind generators have become typical features. Due to some detrimental side effects on villagers and nature in rural landscapes, their acceptance in rural regions has declined. **b** Reconstructed historical windmill, part of landscape heritage and local identity. **c** Model of a bio-energy village, presented at the "Green Week" agricultural fair in Berlin, Germany, in 2019

must be an integral part of a regional circular bioeconomy primarily based on residues from other production systems (Theuer et al. 2019).

Biomass from woody plants can be used for wood-chip furnaces, where it can be burned instead of coal. The results of life cycle analyses (LCAs) from Sweden show that harvesting forest residues decreases forest carbon stocks in the landscape, while growing willow on previous fallow land increases the total carbon stocks (Hammar et al. 2019). In the forest zone, biomass yields from woody plants are high without the application of agrochemicals, exceeding yields of fertilized crops. Strategic land-use conversion in some agricultural landscapes can mitigate the environmental impacts of current crop production, while providing biomass for the bioeconomy. For example, perennial plants can be grown as riparian buffer strips and filter zones, reducing nutrient and other agrochemical emissions from arable land, or as shelter belts for reducing erosion damage (Englund et al. 2019).

Wind generators reach hub heights of 100 metres or more and have a strong visual impact on the landscape. In addition to their critical need for power storage and control, they are effective in converting wind into electrical energy in the range of 3 to 25 m/s wind speed. More than 27,000 wind turbines have so far been installed in Germany, the majority of them on agricultural land (Bunzel et al. 2019). Meanwhile, forests and coastlines are increasingly occupied by wind turbines. Wind energy systems can have several detrimental side effects on landscapes and their inhabitants (UNCCD 2017), which need to be mitigated by planning and design. They range from pressure on bird and bat communities and their habitats (Law and Fuller 2018; Millon et al. 2018; Fernández-Bellon et al. 2019) to physical and mental health problems among villagers (Taylor and Klenk 2019).

Photovoltaic systems shape roofs of buildings, abandoned military airfields and many closed waste disposal sites. Increasingly, they have been installed on agricultural lands. Agrivoltaic systems try to combine photovoltaic systems with cropping or horticultural systems (Leon and Ishihar 2018; Weselek et al. 2019). This can work in greenhouses and small production units but is difficult or impossible for large systems and under the conditions of large-scale agriculture. It competes with the use of land and solar radiation for food and other biomass production under those conditions. With respect to the expansion of solar photovoltaic systems, their use is generally limited by agriculture and nature conservation in rural regions, but they have sufficient potential to contribute significantly to regional energy independence (Dias et al. 2019).

Bio-energy landscapes face several challenges. For example, land consumption and landscape degradation for new transmission lines are underestimated. The largely hidden system of subterranean energy transmission lines can degrade soils through compaction and increased heating. Technical solutions will be developed for most problems. Aesthetic concerns can be diminished and the population's acceptance of energy landscapes can be improved by altering the design (Pasqualetti and Stremke 2018).

Nonetheless, new conflicts over land, other resources and social concerns are emerging in the context of "renewable" energy production (Backhouse and Lehmann 2019). Their solution or mitigation is difficult to achieve at a global scale. The recent deterioration of rainforests and peatlands in Indonesia due to palm-oil cropping to meet the EU and USA's demands for cheap biodiesel (Rulli et al. 2019) is one example of a green bio-energy strategy having counterproductive results. The result may be increased GHG emissions, reduced biodiversity, legitimization of new land grabs, and new social conflicts (Backhouse and Lehmann 2019).

Even at a local level, acceptance of regenerative energy systems among villagers and their communities is limited in wealthy countries. The benefits of the energy produced and the value added are largely de-coupled from the rural population, while negative side effects are a burden on them. Municipalities can play a crucial role in the definition of strategies to ensure future efficient, balanced and sustainable "renewable energy" zoning in rural areas (Poggi et al. 2018).

1.3.1.13 Education and Science for Agriculture and Rural Landscapes

Education: the example of Europe. Comprehensive systems of education have improved knowledge generation and dissemination, promoting the upswing of agriculture after World War II in Europe. This was a reality on both sides of the iron curtain. Knowledge about agricultural processes combined with practical training was part of school education. Agriculture was an important business and an attractive subject of higher education. Most farm managers had a university education. These well-educated farmers were decision makers and initiators of local rural life. Peasants were acknowledged members of society in eastern Europe until the 1980s.

The alienation of agriculture from society has led to an "Age of Agricultural Ignorance" (Evans 2019) in Western Europe and the USA. The number of agricultural students and those dealing with applied biological processes in nature has been declining. They instead prefer information technologies and technical and economic disciplines. Those who want to engage in applied biological processes now prefer study programmes such as landscape ecology or environmental management.

Research: global trend. Agricultural productivity depends on investments in research and development (R&D). Well-educated, experienced farmers operating with modern technologies have a significant influence on agricultural productivity but there is a time lag between R&D and its benefits (Cai et al. 2017; Kijek et al. 2019). The current uncertain future regarding population growth, competition for resources, social and political stability, and climate change makes it difficult to forecast future R&D funding requirements. Most popular scenarios suggest that global society should accelerate R&D spending for agriculture up to 2050, moderating this growth rate thereafter (Cai et al. 2017). The structure of R&D expenditure has changed over recent decades. Important branches of agricultural research such as breeding, the development of agrotechnology and agrochemistry, food storage and processing, and analytics for food quality control, are profitable and thus in the hands of globally operating firms. About two-thirds of investment in R&D come from the private sector in the leading countries: the USA and China. Related to purchasing power parity (PPP), China now spends more than the United States on agricultural R&D for both the private and the public food sectors (Pardey et al. 2018; Chai et al. 2019).

As countries get richer, the amount of public R&D devoted to agriculture declines. The USA and most European countries have reduced their expenditure on public research in agriculture, forestry and fisheries. In high-income member countries of the OECD, public spending on agricultural R&D has fallen in real terms since at least 2009 (Heisey and Fuglie 2018).

Agricultural education and research in Russia and China. The system of higher agricultural education in Russia and China has always been particularly broad. Besides agricultural faculties at most universities, large agricultural universities have provided the highest scientific education for farm managers, the personnel of agricultural authorities, business people in the agricultural sector, and scientists. The Kuban State Agrarian University in Krasnodar, Russia, the largest agricultural university in Europe, educates 35,000 students. Some agricultural universities in China educate more than 40,000 students in agriculture and related disciplines.

Agricultural academies of sciences were the main pillars of research in former communist countries. The Chinese Academy of Agricultural Sciences (CAAS 2019) has about 10,000 employees and a modern, broad experimental research infrastructure, and is internationally well connected. The Russian Academy of Agricultural Sciences (RAAS) existed from 1992 to 2013 as a successor organization of the Soviet Academy of Agricultural Sciences (VASKHNIL, Lenin All-Union Academy of Agricultural Sciences, 1929 to 1992). It was an economically independent scientific academy which owned land for scientific experiments and had a self-managed research infrastructure (Mueller et al. 2016b). After the reform of the Russian academic system in 2013, it became the Agricultural Science Department of the Russian Academy of Sciences (RAS 2019; Agricultural Department RAS 2019) without its own financial power. The system and network of agricultural institutes and long-term experiments installed during the time of VASKHNIL and RAAS currently provide an excellent basis for solving agroecological scientific issues (Mueller et al. 2016b; Sychev et al. 2016).

Importance of independent public research for agricultural landscapes. Maintaining a strong public research sector for agriculture and rural development is important for securing states' dominance and ensuring that their independent power-parity institutions can explore and develop agricultural landscapes. These scientific institutions and their researchers need to work to high scientific and ethical standards and must be independent to avoid conflicts of interest with big food industries. Without this, insufficient evidence-based strategic decisions, risks of unregulated introduction of harmful technologies into agriculture, and a lack of independent tests and monitoring systems for food safety would be a consequence. Innovative and objective work by independent research institutions and scientific societies is a precondition for the production of safe food in living cultural landscapes.

1.4 Conclusions

1. Agriculture is the basis for the development and survival of human societies, states and humankind, satisfying people's demand for food. History shows that famines, political and social unrest, wars, and the breakdown of civilisations have often been associated with poorly performing agriculture.
2. Agriculture is a field of activity with particularly close interactions with nature, its resources (soil, land and water) and its processes (weather, biological diversity and cycles). Agricultural landscapes are the workspace of agriculture and the living space of the rural population. They are a cultural achievement.
3. The effects of agricultural intensification and unsustainable land management have significantly contributed to irreversible human-made changes to ecosystems and led to the Anthropocene being identified as a new geological epoch.
4. Research is needed to improve our understanding of how agricultural landscapes function and to forecast possible changes caused by climate and human development. More cooperation and knowledge transfer within Eurasia and beyond would provide synergy effects for evolving agricultural systems and landscapes.

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