Germany's Agriculture and UN's Sustainable Development Goal 15

Ulrich Hampicke

1. Introduction

The Sustainable Development Goal (SDG) 15 within UN's 2030 Agenda for Sustainable Development (UN 2015) demands a transition to sustainable life on land on Earth, including a sustainable use of terrestrial ecosystems, sustainable management of forests, combatting desertification and halting and reversing land degradation and halting biodiversity loss. More specifically, nine targets include the conservation of forests, drylands, wetlands and mountains and the forestalling of poaching, spread of invasive species and land degradation. Although to prevent extinction of species is explicitly demanded in target 15-5, the measures proposed are incomplete. As observed by Tisdell (2021, this volume), habitat loss, being the most important factor, was overlooked. This contribution confirms Tisdell's arguments in adding that restoring and reclaiming habitats is a matter of urgency not only in remaining semi-natural ecosystems worldwide. It is also imperative in the cultivated landscape, notably in efficiently used agricultural environments. Biodiversity losses are not only caused by land degradation, desertification and the like, but also by proper and (from the farmer's point of view) "sustainable" cropping. The problems involved here are given insufficient attention in SDG 15.

This contribution focuses on biodiversity losses. In addition, threats to physical resources such as groundwater and soils are addressed. Although these are less serious than in other parts of the world, industrial agriculture may also conflict with development goals such as SDG 6 (clean water and sanitation), 12 (responsible production and consumption) and 13 (climate action). Of course, any reference to agriculture must take notice of SDG 2 (zero hunger). Some important items of this goal are less pressing in wealthy nations such as Germany. There is no need to further increase crop productivity. Here, target 2.3 (double agricultural productivity) would contradict target 2.4: "implement . . . agricultural practices that . . . help maintain ecosystems . . . and improve land and soil productivity". Socially defined targets such as supporting small-scale food producers, especially women and indigenous peoples, are not relevant in Germany. Notwithstanding, any wealthy country enjoying favorable agricultural conditions has the duty to contribute to global food security. Section 3 describes how this is accomplished in indirect ways in Germany.

The problems addressed apply to Central Europe as a whole; they are very similar or are becoming so in Switzerland, France, Belgium, Poland and other countries. Therefore, in describing the character of the countryside and the history of land use, reference is made to "Central Europe". However, a more detailed and quantitative analysis applies to Germany, due to some peculiarities of its agricultural policy and the availability of statistical data.

Section 2 pictures the historical development of the countryside from prehistoric times to the present in some detail, thereby emphasizing the species richness of traditional land-use in former times (for a comprehensive account, see Leuschner and Ellenberg 2017). Section 3 outlines Germany's industrial agricultural system operating, its general features and productivity, its contribution to food security, its poor management of physical natural resources, its disastrous effects on biodiversity and some of its immanent risks. Section 4 proposes measures conducive to relieving the drawbacks described beforehand, such as abandoning unnecessary production, better funding and planning. It will turn out that although a complete return to traditional land-use is of course impossible, at least the preservation of habitats in sufficient size can be made safe at moderate costs, thereby reducing the danger of species extinction. Section 5 concludes that the problems at hand reflect the poor talent of modern societies to a sustainable management of public goods.

2. History

What is called "Central Europe" in this contribution comprises Germany together with parts or the whole of its surrounding countries. The Alps form a clear barrier to the southern Mediterranean world with distinct ecological conditions and cultural traditions while the gradients to the Atlantic, boral and continental environments, west, north and east, are gentler. Central Europe is that part of the world which, in the absence of mankind, would now largely be covered by deciduous forests, dominated by beech (*Fagus sylvatica*), although this species rose to dominance only a few thousand years ago. Furthermore, it is a part of the world where, due to the action of Pleistocene glaciers not long ago (by geological standards), natural resources such as soils are young and more resistant to mismanagement than, for instance, in the tropics.

The periglacial tundra between the northern and the alpine glaciers used to be roamed by large-deer hunters since immemorial times. The world-wide oldest examples of sculptural art, dating some 30,000 years ago, were found in the valley of the rivulet Lone in southeast Baden-Württemberg. With the retreat of the ice some 13,000 years ago, and vegetation recovering, hunters might have been forced to switch over to fishing and collecting berries, mushrooms and edible plants. Agriculture arrived some 8000 years ago, not gently diffusing but deliberately brought by invaders who left their home territories in southern Anatolia and the "Fertile Crescent" for unknown reasons (Poschlod 2015). The new way of life was adopted by the native people, presumably rather slowly. This not only changed their social life with permanent settlement, surveillance of croplands and stockpiling, but also physiologic changes took place. Gradually, the natives acquired the ability to digest lactose, thus to consume milk products (Haber 2014).

Prehistoric man's impact on the countryside has long been underestimated (Leuschner and Ellenberg 2017). Forests were cleared, less by using primitive axes but rather by fire and farm animals' destructive foraging. The Bronze Age, 3000 to 4000 years ago, saw the transformation of forests into heath, a prominent example being the "Lüneburger Heide" in North Germany. The opening of the countryside provided advantages to plant and animal species adapted to non-forest environments.

Medieval agriculture relied on the small number of crops available since prehistoric times, such as primitive varieties of wheat, other cereals and lentils (Haber 2014). However, the middle ages saw two innovations, one technical, the iron plough, and one social, the three-field system, obliging every farmer to adhere to a strict sequencing of winter cereal, summer cereal and fallow. Medieval agriculture was little productive, unreliable, prone to crop failure and wasting. Reinforced by extreme rainfall events during the "Little Ice Age", soil erosion raged (Poschlod 2015). The poor fertility of the cropland was half-way maintained by a permanent transport of nutrients from the forest, either by deliberate collection of litter or by farm animals' movements. They were driven to what had remained of the forests during the day and brought back to the crop fields in the evening in order to deposit their dung. Contrary to what is often misconceived today, medieval land-use used to be intensive. Like in poor African countries today, every paltry piece of wood was a valuable find used for cooking, every bunch of grass was collected as feedstuff. As a result, open territory with scant vegetation spread, providing optimal conditions for numerous plant and animal species adapted to warm environments, many of them of sub-Mediterranean origin. On its face, paradoxically, wastage furthered biodiversity. The remnants of these biotopes, aptly called semi-cultured landscape ("Halbkulturlandschaft", Wilmanns 1993) and now protected, offer important opportunities for recreation and enjoyment in nature today (Figure 1).

Figure 1. Remnant of semi-cultured landscape, today appreciated for recreation and enjoyment. Chalk grassland "Kleiner Dörnberg" near Kassel, Germany. Source: Photos by the author.

As late as in the eighteenth and early nineteenth century, agriculture became a matter of science and practical improvement. An outstanding personality in Germany was Albrecht Thaer. The former fallow land was now tilled with either food plants like potatoes or sugar beet, or feed, preferably clover (*Trifolium pratense*) or alfalfa (*Medicago sativa*), in order to enhance the nitrogen supply. Animals were fed regularly, feed conserves, mainly hay, provided adequate livelihood during the winter. Excrements were collected, carefully stored and brought to the fields as fertilizer. Compared with today, crop yields and animal performance remained low, but except for rare events such as the "year without summer", following the eruption of Mount Tambora in 1816, crop failures subsided. Biodiversity richness may have declined locally but not in general.

The most important developments in the nineteenth century were the destruction of what had remained as natural biotopes in the countryside, above all, the peatlands, and the dismissal of the semi-cultured countryside. As opposed to today's valuation, heath, barren grassland on limestone and sandy soil—mostly used as commons—were regarded as ugly and as waste lands. Losses became so heavy that around 1900 a conservation movement arose, and the first protected areas were established by private initiatives, such as in the "Lüneburger Heide". Equally important was the taming of almost all watercourses from small creeks to large rivers such as the Rhine (Blackbourn 2008). These activities enhanced agriculturally valuable areas and, transportation on the land being still laborious, facilitated shipping.

Although Justus Liebig propagated the use of mineral fertilizer, it came into use only very slowly until the First World War. The first pesticides appeared, preferably in viniculture, some of them dangerous for their applicants. Agricultural techniques progressed gradually but the system as a whole did not undergo revolutionary changes. In tilling and all other outdoor work, the pace was still given by horse or oxen, countless farm-laborers and maids performed their hard work. Wild plants were tolerated or even utilized in the agriculturally productive areas. Of course, weeds were regulated but never to the point of extinction. A large number of crops, almost all of them fallen into oblivion today—flax (*Linum usitatissimum*), buckwheat (*Fagopyrum esculentum*), poppy (*Papaver somniferum*) and others—offered variety for many concomitant plant and animal species. Permanent grassland used to be colorful and rich in species; a typical meadow—by then regarded as "fatty meadow" ("Fettwiese")—consisted of 40 to 60 plant species, as shown to-day in their scattered remains in plots of twenty-five square meters. Poet Annette von Droste-Hülshoff, in describing her Westphalian mother-country, wrote that " … every step on its meadows gives rise to the soaring of yellow, blue and milky-white butterflies". It is remarkable that in contrast to most crops and all fruit trees, grassland cultivation made and still makes use of indigenous plants, thus incorporating elements of former wilderness.

Nineteenth-century agriculture shows some resemblance to current organic farming. Primitive and destructive features of medieval land-use were overcome, but modern practices, detrimental to biodiversity and natural resources, were still a long way off. During the first half of the twentieth century, the first tractors appeared and chemical fertilization developed in very modest ways. Yet, by 1950, the open countryside was still more or less resembled the model developed during the nineteenth century. To be sure, natural ecosystems such as peatlands and natural watercourses were mostly lost and the semi-cultured landscape was reduced. However, agricultural biotopes proper continued to be multifarious in every respect. Cereals plus the greater part of their accompanying weeds had been introduced thousands of years ago. All species of fruit trees had been brought by the Romans. American cultures such as new-world beans, potatoes, tomatoes, maize, tobacco and others were introduced during the Renaissance epoch and later. Despite all this, agriculture never gave the impression of being a foreign matter, as in the case of New Zealand where even beetles decomposing the droppings of cattle had to be imported. To the contrary, the traditional Central European countryside was the result of 8000 years of traditions, gentle innovations, adaptation and thus unique in the world. Not least, it used to be aesthetically attractive, as immortalized in many pieces of art. As late as in 1950, nobody had the presentiment that agricultural practices could lead to the extinction of species. Beyond all doubt, it is worthwhile to preserve elements of this unique feature now and for the future.

As for forests, their destructive use in the past has already been mentioned. Remarkably, the area left to the forest today is quite the same as during the middle ages. However, former forest quality was very low, orders from sovereigns for better treatment having been fruitless in most cases. In early modern times—from the fifteenth and sixteenth century onward—various industries such as pottery, glass manufacture and metallurgy of all kind needed heat, which, before the advent of coal, could only be supplied by charcoal (Küster 2008; Leuschner and Ellenberg 2017). Despite the famous call by Carlowitz as early as 1713 to limit wood use to the volume growing up, the recovery of forests was a performance of nineteenth century foresters. Their predilection for coniferous trees, even in regions less suitable for spruce (*Picea abies*), left us with a questionable legacy, all the more so with climate change.

3. Industrial Agriculture in Germany

In this section, the physical structures of Germany's agriculture and food system 2000–2020 are outlined. Second, its performance and contribution to public welfare are appreciated. Third, its negative impact on natural resources and, most particularly, biodiversity is described in detail.

3.1. Physical Structure

A citizen of the 1950s, hypothetically transferred to 2020, would not recognize their agrarian countryside. The outstanding feature of today's agriculture is its high productivity, as compared with the traditional system. Figure 2a (left) shows a rye field as it may have existed 200 years ago, Figure 2b (right) a modern wheat field. Its yield is ten times the yield on the left. Table 1 shows some selected data on former and present productivities. Notice that yields around 1900 in the left column have already been higher than 100 years before.

(**a**) (**b**)

Figure 2. Former and current productivity of crops. (**a**) Rye field reproduced from around 1800. (**b**) Modern wheat field. Source: Photos by the author.

Table 1. Yield increases in German agriculture.

Yield (Decitons per Hectare)	1900	1950	2012–2015 Average	2015 Peaks
Cereals	16.3	23.2	74.6	120
Potatoes	126.0	244.9	439.5	
Sugar beets	256.0	361.6	711.9	
Milk (kg per cow per year)	2165	2480	7452	13,000–15,000

Source: Adapted from (StJELF 2002, p. XXVIII; StJELF 2016, Tab. 98 and 166, supplemented).

Germany's agriculture comprises roughly 17 million hectares, 12 million for crops and 5 million for permanent grassland. Figure 3 shows production and fluxes of agricultural commodities in Germany. The adequate physical measure is the energy content of every product—one kg of starch contains 17 megajoule (MJ, 10^6 Joule), one kg of plant oil 39 MJ and so on. In the graphic, energy content is the general measure; a detailed description of the calculation is found in Hampicke (2018, in German).

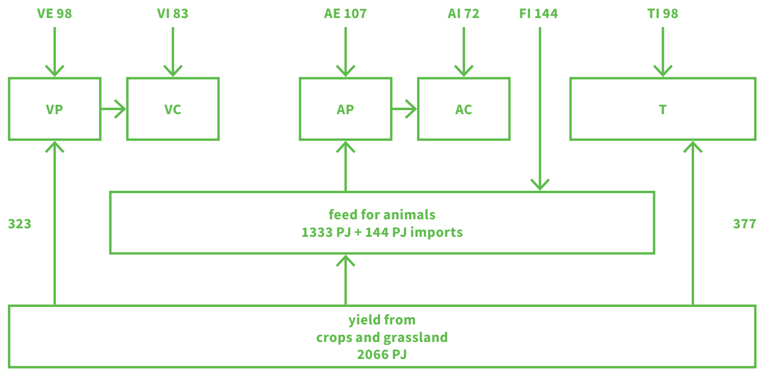

Figure 3. General structure of the German agriculture and food system. All numbers in Petajoule (PJ = 10^{15} J). VP, VC, VE, VI: Vegetable products produced (329 including fruits), consumed domestically (219), exported (98), imported (83), AP, AC, AE, AI: same for animal products (225, 110, 107, 72), FI: feed imports (144), T, TI material used for biogas, biodiesel and bioethanol plus 50 for technical raw materials, imports (98). Source: Adapted from Hampicke (2018, p. 56), simplified.

In 2013, cropland and grassland produced a harvest of 2.066 exajoule (EJ, 10^{18} J). Two thirds or 1.333 EJ were used as feedstuff, enlarged with 144 petajoule (PJ, 10^{15} J) from imports. The second largest share of the overall harvest, 377 PJ, are plants mostly used for technical energy—maize for biogas, the oil of rapeseed for diesel fuel and wheat for ethanol as additive to petrol, and some for raw materials. Vegetable food ranks only third with 323 PJ plus 6 PJ from fruits of which 219 PJ are consumed domestically, that is only eleven percent of the total harvest. Feedstuff produces 255 PJ of animal products—meat, milk and eggs—the ratio of feed energy to product energy being around seven to one due to the animals' energy requirements and for other reasons. The high energy losses in livestock production are well known.

There is much foreign trade in agricultural commodities. In total, 98 PJ in grain, potatoes and sugar are exported, 83 PJ, mostly in vegetables and fruits, are imported. For animal products, the figures are 107 PJ in export and 72 PJ in import. Altogether, Germany shows an export surplus of 15 PJ in vegetable and 35 PJ in animal products.

Given the relatively small area of German agriculture, the output is enormous. Not unexpectedly, adverse side effects on natural resources occur which will be described in the sequel. Striking features of the system are the very high share of feedstuff, the production of technical energy and export surpluses.

3.2. *Positive Welfare Effects and Unwarrantable Criticisms*

Judging justly, the system's performance in terms of food security has to be acknowledged. It should not be taken for granted that food scarcity used to be a feature only of the distant past and is definitely overcome. Germany contributes in some respect to the world-wide availability of food in that it is self-sufficient and imports products almost entirely from economically well-off countries, for instance vegetables and oranges from Spain. Its exports will be discussed later.

As for product quality, commodities produced in conventional cropping contain residues of chemicals, especially pesticides, for the most part within dosages permitted by regulations. Health risks cannot be ruled out altogether but they are modest as compared with those posed by street traffic, sport activities, alcohol consumption, smoking, unhealthy diet and obesity. It should not be ignored, however, that the latter risks are often run of one's own free will while those from pesticide residues are difficult to avoid.

Some criticisms of modern agriculture are exaggerated. Although its fossil energy requirement is poorly documented, it does not exceed three to four percent of the net energy consumed by the nation. Traffic, often of questionable necessity, needs thirty percent. The reader is invited to consult Table 5 in Section 4.2.1. An often-heard reproach is the energy requirement of mineral nitrogen fertilizer, produced by Haber-Bosch technology. The requirement is around 40 kilojoules per gram nitrogen. Multiplied by 1.7 million tons of mineral nitrogen fertilizer applied per year, this amounts to 68 PJ or 0.76 percent of net energy consumption.

Statistics inform that German agriculture produces 11.5 percent of the nation's greenhouse gases, thus contributing to anthropogenic climate change. Table 2 shows details. Evidently, emissions C are partly avoidable although at some cost. Cropping in peatlands and converting grassland to crop land (D plus E) must be curtailed anyhow for other reasons than caring for climate. There remain emissions of methane (CH_4) from ruminants and nitrous oxide (N_2O) from fertilizers (A plus B). Assuming these emissions and some from C to be unavoidable, agricultural contribution to climate hazards would reduce to some six to seven percent, a very modest share in view of the fundamental necessity to produce food.

Table 2. Greenhouse gas emissions from German agriculture.

Emission Source	Processes	Million t CO_2 Equivalent
A Fermentation	CH_4 emissions from ruminants	24.9
B Soils	N_2O emissions from fertilizers	26.5
C Various	losses of CO_2 from organic fertilizers, application of lime to soils and others	14.6
D Crop soil	using mires for cropping	14.7
E Grassland	conversion to crop land	22.9
Total		103.6

Source: Adapted from WBA and WBW (2016, p. 19).

3.3. Negative Effects on Physical Resources

Although misuse of soils leading to massive water erosion such as in the middle ages is rare, not all soils receive sufficient care. Crop fields in eastern Germany sometimes comprise several hundred hectares. The absence of hedgerows, coppices and other structures facilitates wind erosion. One such event in 2011 produced a dust-cloud leading to a mass accident in a motorway, causing eight fatalities.

Growing specialization results in the separation of regions with excessive livestock rearing, mostly in the northwest, from others confined to cropping. In the latter, mostly eastern regions, soils receive no organic fertilizer, fertility is safeguarded alone by chemical inputs. Although yields still appear satisfactory, consequences in the long run are dubious.

Both shortcomings mentioned could be mitigated within the system given. This is more difficult and expensive regarding the problems addressed in the sequel. Table 3 shows the general nitrogen balance of the German agriculture. Inputs from mineral fertilizer, imported protein feed and other sources amount to roughly 2.6 million tons per year while exports in vegetable and animal products sum up to only 0.9 million tons. The difference of 1.7 million tons per year is lost in the countryside. Almost two thirds trickle with water leakage, jeopardizing groundwater quality. Only 50 percent of 692 measurements in agricultural regions disclose good drinking water quality (less than 25 milligrams NO_3^- per liter), 28 percent surpass maximum permissible loads decreed by European law (50 mg/L), and 22 percent lie in between (BMUB and BMEL 2016). Germany has been sentenced by the European Court of Justice for not realizing the European Nitrate Directive. Until today, the situation would be much worse without the biogeochemical process of denitrification in subsoils. In the absence of oxygen (O_2), some bacteria are able to transform the nitrogen contained in NO_3^- into innocuous N_2. These bacteria consume organic matter diffusely distributed in the subsoil and quit their benevolent activity once this matter together with pyrite (FeS_2) is exhausted. Obliged to prepare for such a future, action re-establishing a controlled nitrogen management is imperative. The deterioration of drinking water, essential to life, cannot be tolerated.

Table 3. Nitrogen budget of German agriculture.

Supplies	Tons per Year
A Leguminous plants symbiotic with N-fixing bacteria	225,000
B NO_x deposition from industry, traffic and other sources	160,000
C Import of protein feeds	450,000
D Mineral fertilizer	1,750,000
Total	2,585,000
E Export in vegetable and animal products	910,000
Losses	1,675,000

Source: A and B adapted from (Bach 2008), D from (StJELF 2016), Table 75, average 2014–2016, C and E from (Hampicke 2018).

Forty percent of the nitrogen losses are transformed into gaseous ammonia (NH_3). German agriculture produces 680,000 tons of ammonia per year (Haenel et al. 2016), a quantity strongly reduced for a long time past had it been emitted by industrial sources. Although part of it subsides to crop fields and meadows these fertilizing, a large share is lost to biotopes which should not be fertilized in this way. Terrestrial eutrophication by ammonia is an important factor of biodiversity decline, in addition to the factors described later. In forests and in the open countryside, nitrophilous plant species profiting from fertilizing suppress and displace many other less competitive species. In forests, species-rich ground vegetation is replaced by uniform stands of blackberries (*Rubus spec.*) and aggressive grasses such as *Calamagrostis spec.*

Agriculture being an open system, it is impossible to avoid nitrogen losses altogether, but the disorganization of the nitrogen circle on the current scale is intolerable. The most important agent is animal husbandry. In regions with excessive livestock rearing, too much manure is deposited in the fields; regulations are lax. Ammonia is emitted from stables, from manure deposits and by inappropriate methods of manure distribution. To a lesser extent, groundwater and atmosphere are also affected by cropping and viniculture. Among mineral fertilizers, urea is increasingly used for its low price. It easily decomposes to ammonia.

3.4. The Extermination of Biodiversity

The strong word in the headline of this section is warranted. Upon meticulous studies of hundreds of vegetation assessments 60 to 70 years old and their comparison with the current situation, a research group at the University of Göttingen concluded that the population sizes of common plant species (not orchids or other rarities) omnipresent in the agrarian countryside for thousands of years have declined to little more than five percent their sizes in the 1950s (Leuschner et al. 2014 and other contributions in the volume). This loss has been aptly called an unintentional large-scale ecological experiment with unknown consequences (Nentwig 2000). The fact that these formerly common plants have still become not rare enough to include them into "Red Data Books" on endangered species misleads to underestimate the consequences of their decline. Butterflies, bees and other insects, depending on these plants, for instance their blossoms, have dramatically declined both in numbers of species and in population sizes (Vogel 2017). While bird populations in forests, at the seashore and even in cities are rather stable, birds adapted to crop fields and meadows, often breeding on the ground, have become rarities or vanished altogether (Hötger et al. 2014).

The reasons are obvious and partly clearly visible: Loss of habitat, ubiquitous eutrophication, exposition to pesticides and others. Let us distinguish four types of biotopes: semi-cultured landscape, grassland, crop fields and structures such as hedgerows, coppices, watercourses and others.

Fortunately, most areas of semi-cultured landscape that survived "cultivation" efforts during the nineteenth and early twentieth century (see Section 2 above) are protected today. Others owe their persistence to military training activities. While the area of these biotopes is less of a problem, their quality is often unsatisfactory. In order to preserve favorable conditions for their characteristic plant and animal species, activities carried out there for thousands of years have to be continued, otherwise coppice and finally wood will invade the areas. A case in point is sheep grazing on barren but species-rich grassland and heather. In some regions, such activities are carried out with considerable success, in others less so. Semi-cultured biotopes and grassland alone, often blending each other, comprise around forty percent of all endangered plant species listed in "Red Data Books" (see Box 1). However, due to conservation efforts, rare species on calcareous soils, among them orchids much appreciated by naturalists, sometimes fare better than sorrel (*Rumex acetosa*) in agricultural biotopes proper. Wet environments may also be qualified as semi-cultured when they interpose between the poor remnants of mires still in a natural state and moist grassland utilized more thoroughly. Plants and animals there, mostly members of "Red Data Books" too, face even worse conditions than those in dry environments.

The area of permanent grassland is diminishing. Daily, almost 70 hectares are withdrawn from agriculture to the benefit of settlements, traffic ways and so on (BfN 2016, p. 80). If cropland was affected, its losses were compensated by the transformation of grassland into cropland so that grassland alone paid the toll. Today, some regulations are retarding the process. A certain portion of grassland must be cultivated intensively, implying high fertilizer input and frequent mowing or grazing, High-yielding milk cows depend on energy-rich feed not producible otherwise. This kind of grassland is worthless for biodiversity, very few plant species are present such as white clover (*Trifolium album*), dandelion (*Taraxacum officinale*) and some grasses (Dierschke and Briemle 2002). None the less, it is still valuable for erosion control and carbon storage.

Box 1. Endangered plant species in Germany.

The Red Data Book on plants (Korneck et al. 1998) designates all species assumed to be endangered or already extinct. Several degrees of threat are distinguished and the species are classified according to the biotopes they live in. So it is possible to assess which biotopes and which kinds of land use contribute most to the threat. In Table 4, four groups of biotopes are distinguished: (1) agricultural areas including the semi-cultured countryside, (2) biotopes often in contact with agricultural activities, such as peatland near moist meadows, (3) forests and (4) others, mostly covering limited areas. In the first two groups, sub-groups are distinguished.

The entry "crop area" comprises all species in cropland-dominated landscapes; weeds proper, dependent on tillage, are much worse off. The relatively favorable situation in productive grassland is due to the fact that till today, only plants resistant to eutrophication and other factors have survived there. Forests appear less beset with endangering, but this is true only for higher plants, the situation for mosses, lichens, fungi and insects is far from favorable. None the less, important conclusions can be drawn. Dry grassland and heather, the semi-cultured landscape, contribute a quarter of all endangered species, agriculture proper together with semi-cultured landscapes contribute nearly half. Add a substantial share of the entry "biotopes in contact or influenced"—peatlands dried, waters eutrophicated and others—then agriculture is contributing directly and indirectly almost two thirds to the process of endangering higher plant species. It is to be assumed that the situation is similar regarding animals.

Table 4. Extinct and endangered plant species according to the biotopes they occur.

Biotops	Numbers of Extinct	Numbers of Endangered But Not Extinct	Percentage of Extinct and Endangered Species per Biotope Type	Share of a Biotope Type of All Extinct and Endangered Species in the Country
Agriculture	**26**	**244**	**27–54**	**46**
- among them				
crop area	13	84	36	7
productive grassland	0	47	25	3
wet grassland	3	103	52	7
dry grassland and heather	9	261	53	26
Biotopes often in contact with agriculture or influenced	**19**	**287**	**11–85**	**22**
- among them				
peatland	3	114	50	6
nutrient-rich waters	3	83	50	6
nutrient-poor waters	4	35	83	2
Forests	**4**	**199**	**13–27**	**14**
Others and alpine	**8**	**168**	**10–56**	**18**

Source: Adapted and compiled by author from Korneck et al. (1998).

Unfortunately, permanent grassland (Figure 4) not confined to these restrictions is losing its species richness by a lingering process. Colorful traditional meadows are replaced by uniform biotopes once the yearly input of nitrogen exceeds 100 kg which is reached easily. Modern techniques add to the impoverishment, mowing with efficient equipment at high speed kills grasshoppers, frogs and hare kids (Oppermann and Krismann 2003; Humbert et al. 2009).

As documented above, the productivity of current conventional crop fields is up to ten times higher than it used to be in pre-industrial agriculture. Stalks of cereals are packed in such a dense way that no living space for weeds would remain even if these had not been eradicated long ago by herbicides (Figure 2b). About 250 plant species in Central Europe are typical for landscapes dominated by crop fields, about 150 depend obligatorily on cropping. This flora element is reduced more than all others, conservation efforts have been neglected for decades and are still insufficient. Due to their poor competitiveness, the majority of weeds are innocuous. They represent interesting plants for various reasons, perform functions in the landscape, not a few are aesthetically attractive and have the potential of becoming ornamental plants (Meyer and Leuschner 2015). Yet, all are unappreciated by the farmer whose ideal—no plant or animal in the field except the crop—has come true frequently.

Figure 4. Colorful meadow in the Alps not yet affected by intensification. Source: Photo by the author.

The dense packaging of stalks in cereal fields offers optimal conditions for fungi causing plant diseases so that fungicides have become indispensable in conventional cropping. Some cultures such as rapeseed are attacked by a number of insects, aphids have to be combated in cereals. So insecticides add to the menu of pesticides regularly applied to crop fields and thus to one third of Germany's area, menacing many species innocuous to agriculture.

As for structuring elements, the main problem is their mere scarcity. For decades, so-called farmland consolidation measures in East and West Germany have eliminated hedgerows, coppices, road margins, terraces and other elements in order to make farming more efficient. During the socialist epoch in East Germany, many small watercourses have been pressed into subterranean tubes. In particular in the northern plains, the landscape was and still is regarded as an opportunity to unfold the capacities of industrialized cropping in full measure, disregarding all other functions and benefits the countryside can bestow, let alone its aesthetics.

Summing up, within a few decades, the colors and richness of biotopes and species developed over millennia have been reduced, and in large regions eradicated almost altogether. Despite the abundance of food and other products brought about by this process and despite it relieving farm people from hard work, the past 60 to 70 years in Central Europe represent an example of non-sustainability, contradicting some of the demands of SDG 15, which urgently needs correction.

3.5. Negative Impacts on Agriculture

Far-sighted agricultural experts increasingly realize the risks farmers incur when they continue the unbalanced way of cropping which has become customary. Crop rotations have become impoverished due to the very small number of economically sound crops with severe risks for soil quality and plant health. Fifty years ago, an expert wrote "the rotation rapeseed—winter wheat—winter barley is to be strictly avoided, diseases both for rapeseed and cereals will accumulate in the soil" (Andreae 1968). Today, this is the standard crop rotation in northeast Germany, the expert's forecast having come true. The overall preference for winter cereals results in upcoming resistance of weeds against herbicides. So, despite heavy spraying, "problem weeds" such as foxtail (*Alopecurus myosoroides*) are becoming serious nuisances. Equally, harmful insects have developed resistance against insecticides, often stimulated by improper and unnecessary spraying.

The situation is aggravated by strict regulations of authorities. A number of pesticides, used for decades, have lost their admissibility or will lose it in the future. One reason among others is the dramatic reduction of insect populations, particularly bees, in recent years. The chemical industry is reluctant in developing new products. Pessimistic forecasts are heard, for instance that rapeseed cultivation will become impossible under these circumstances. The general opinion expressed by experts is that cropping methods must improve substantially in the future.

4. Alternatives

Of course, it is neither possible nor desirable to restore pre-industrial agriculture as a whole. Unfortunately, the discussion is charged with various misplaced arguments expressed even by conservationists. Some argue that valuing the pre-industrial countryside is a purely nostalgic matter, held by people unwilling to accept change.

Colorful meadows, so the argument goes, have not been "natural" in the past but man-made and therefore lack intrinsic value. Commonly, it is added that it is unbearably expensive to conserve what was useful in the past but no longer is, without supporting this assertion by numbers and calculations.

Three aspects contradict such misconceptions: First, to avoid extinction of species is a moral and legal duty. If all species of the traditional countryside, favored by human action or not, were out of danger in other ecosystems or other countries, their disappearance here would be tolerable in terms of sustainability. However, this is far from true. Most endangered species in Central Europe are also endangered in other regions or will become so in the future once land-use methods here are introduced there. As a wealthy nation having signed the Convention on Biodiversity Conservation, Germany cannot shift the responsibility to conserve to other, mostly less wealthy countries. Second, the public strongly welcomes the remnants of the traditional countryside. The scarcity of colorful meadows is regretted, industrialized agriculture or "agro-factories" are of ill repute, also due to their methods of livestock rearing which cannot be addressed in this contribution. Polls elicit a considerable willingness to pay for conservation and the preservation or restoration of a beautiful landscape (Meyerhoff et al. 2012). Third, the costs for the achievement of substantial progress in biodiversity conservation are low in macroeconomic terms, as will be shown below.

4.1. Organic Agriculture

As already mentioned in Section 2, modern organic agriculture is in a way akin to pre-industrial farming, except for the mechanical techniques used. So it is near at hand to suggest replacing conventional by organic farming altogether. Despite the enthusiasm expressed by many devotees, no thorough and quantitative assessment of the consequences has ever been published. Refusing mineral nitrogen fertilizer, at least 25 percent of the cropping area must be left to clover or other plants symbiotic with nitrogen-fixing bacteria. There are two consequences: The area producing food for humans is reduced while feed for ruminants is oversupplied to the point that ecologically valuable grassland runs the risk of becoming abandoned. The modest supply of nitrogen together with the refusal of phosphorous fertilizer easily absorbable by plants results in yields per hectare far below those in conventional cropping. It is doubtful whether the system would be able to meet the nutrition needs even of a frugal actual population consuming less animal products.

Organic agriculture is not rejected in this contribution, to the contrary it is appreciated as an interesting alternative to what is criticized above. Some features, such as its renunciation of pesticides, are strongly welcome. However, rather than adhering to ideological principles almost one hundred years old, it should be open to further development. Perhaps a synthesis of conventional and organic agriculture, in particular avoiding the drawbacks of the former, is the best prospect for the future.

4.2. Remedies

Returning to Section 3.1, we first discuss three measures conducive to practices less injurious to both physical resources and biodiversity in the countryside. They come to the same conclusion: commodity production should and can be reduced. Thereupon, we point to some problems solvable by more generous funding in combination with spatial planning and expedient practices.

4.2.1. Reduction of Agricultural Output

Twenty years ago, prices of customary agricultural commodities were still unsatisfactory so that new assignments for farmers were in demand. With much enthusiasm and much public money, the production of plant material providing technical energy was propagated and necessary equipment was organized. Today, almost twenty percent of the cropping area is used to produce biogas (CH_4) mostly from maize, diesel fuel from rapeseed (FAME) and ethanol as an additive to petrol from cereals and sugar beets. From an engineer's point of view, the biogas system fed with maize is exceptionally cumbersome. After maize is grown, harvested and ensilaged, it is filled into a reactor producing gas which drives a motor generating electric power. Only a fraction of the energy harvested is transformed into electric current.

The agricultural biogas system supplies 4.5 percent of Germany's electricity consumption, FAME and ethanol contribute less than two percent of the energy necessary in transportation. In particular, the biogas system is extremely expensive, its costs are shifted to private households forced to pay high prices for electricity (WBA 2007). Its contribution to climate stabilization is negligible. Table 5 shows that renewable sources supply around fifteen percent of Germany's net energy, the lion's share allotted to wind and solar power. Domestic agricultural plants contribute only negligibly. While biogas production from materials not demanding areas such as old fatty stuff and the like may be sensible, letting agricultural energy production with poor output have 2.3 million hectares must be regarded as questionable policy.

Table 5. Germany's technical energy budget 2018.

	PJ	%
Gross or primary energy	13,106	100.0
from regenerative sources	1804	13.8
Losses in conversion to electricity and other losses	3221	24.6
Non-energetic uses in chemical industry	889	6.8
Net or end energy available for consumers	8996	100.0
from regenerative sources a)	1333	14.8
from domestic agricultural plants b)	max. 150	1.7
Consumption		
Mining and industry	2651	29.5
Traffic	2705	30.1
Households	2291	25.5
Other businesses, trade and services c)	1350	15.0

Source: a) 668 PJ used directly plus electricity produced from regenerative sources, b) around 100 PJ electricity produced from biogas plus FAME and ethanol, c) including agriculture. a) and b) estimated by Hampicke, all other figures from AG Energiebilanzen e.V. (2021), www.ag-energiebilanzen.de, Auswertungstabellen 1990–2018.

Two hundred years ago, David Ricardo (Ricardo 1817) published his famous theory on foreign trade. Every country should export products it owns in abundance or produces more efficiently than others, e.g., wool from England and wine from Portugal. Germany is exporting its scarcest resource—its area. Around one million hectares produce vegetable and animal commodities for export, the area devoted to the latter would be even larger without the feedstuff imports mentioned in Section 3.1. Although a balanced exchange of agricultural commodities may add to overall welfare, net exports (exports in excess of imports) to the extent reached in Germany are questionable (see Box 2). The country is not in need of foreign currency, to the contrary, its balance of trade is too favorable (unfavorable of others). Exports hardly mitigate food scarcity in poor countries but go to solvent consumers, for instance in Russia and China. In some cases, they may even harm domestic production in other countries.

Energy production and net export claim over three million hectares, eighteen percent of Germany's agricultural area of around 17 million hectares. Although "wasted" may be too disparaging an expression, the area is used inefficiently and for the satisfaction of less important demands—in economic terms, it is used inferiorly.

At the same time, area is in urgent need for improving the ecological quality of the countryside; for letting space for structural elements and re-establishing less productive but species-rich traditional cropping and grassland areas. It must be noticed that the energy plant system has been introduced fully by political decisions, in no way by the market. It could be abandoned likewise by a wiser decision which appears not to be impossible in the future. Exports are promoted massively by the government with public money. One objective is to stabilize prices, for instance for hog meat exported to China. More fundamentally, export is promoted in order to grant fodder suppliers, livestock rearers, dairies, the meat industry and traders finding sufficient sales or even the scope to grow facing diminishing domestic demand. In short, three million hectares are used in the first place to the benefit of small minorities and to the disadvantage of the public.

Box 2. Agricultural area exported.

Area agriculturally cultivated in 2013 was 16.7 million hectares (StJELF 2016, table 85). According to Section 3.1 above, total yield was 2.066 EJ. Average productivity was therefore $2066 \times 10^{18}/16.7 \times 10^{6} = 123.7 \times 10^{9}$ J/ha, roughly equivalent to a harvest of 8 tons of grain per hectare.

Annual excess export of vegetable products was 15 PJ. Excess export of animal products of 35 PJ has to be multiplied by seven in order to assess the amount of feed necessary. In total, 245 PJ minus 144 PJ of feed imported amounts to 101 PJ, the entire export surplus to 116 PJ.

Having $116 \times 10^{15}/123.7 \times 10^{9} = 938{,}000$, and given rounded average figures, the area exported is roughly one million hectares per year.

As an aside, the much criticized feedstuff imports, mostly protein concentrates, are re-exported completely in animal products and do not contribute to domestic consumption, as frequently asserted.

The argument that Germany's agricultural imports should be balanced by exports is flawed. First, the figures measure net export, export in excess of import. The area imported is probably overestimated because to a large extent, imports consist of vegetables and fruits, often produced in glasshouses needing only limited area. Second and more important, even a net import of agricultural area would not necessarily deserve criticism. No country has the duty to balance imports and exports of the same class of commodities. It would be perfectly right if Germany balanced its net imports of agricultural products by exports of other, for instance industrial products in rich supply, according to Ricardo.

It is true that some countries (Egypt, Saudi Arabia) are forced to import food. It would be wiser to import from area-rich countries in need of foreign currency rather than from narrow Germany.

The dubiety of Germany's net export can also be expressed otherwise: In years with average yield, about ten percent of cereals are exported. Without export, yield per hectare could be ten percent lower without decreasing domestic provision. Such de-intensification would add substantially to unburden the countryside from stress produced by excessive fertilization and pesticide spraying

Allusion has been made to a third factor conducive to reducing the stress on the agricultural countryside: decreasing demand. A general reason is aging population, aged people eat less. More specifically, not a few people reflect upon their diet. The "German Society for Nutrition", an expert body, recommends a yearly consumption of meat per person of 30 kg for reasons of heath; the present average is 60 kg per year. In total, 35 percent of the average daily energy intake is from meat, dairy products and eggs. A tendency to avoid excessive meat consumption is observed, specifically among younger people. The reasons are health care, the demand for more quality in exchange for quantity and not least ecological considerations. The massive energy losses incurred in feeding animals as noticed in Section 3.1 are becoming aware to increasing numbers of considerate people. Already a moderate reduction in the consumption of animal products results in a multiple reduction of feed demand. Although extreme reorientations, for instance in favor of veganism, will have to be observed in the future as to their durability, the prospects for reducing stress on the countryside on the part of consumers should not be underrated.

4.2.2. Funding and Planning

Of course, many benevolent reorientations cost money which is the very reason for their neglect. This is particularly true when caring for the integrity of physical resources. The reduction of ammonia emissions requires costly investment in stables, among others filters collecting the gas. Equally costly is equipment depositing liquid manure on or beneath the soil surface instead of throwing it in the air as has been practiced for a long time.

Another important case where money alone solves a problem is the care for the semi-cultured landscape. As mentioned in Section 3.4, sheep grazing is obligatory for maintaining barren chalk-grassland. Similar biotopes, too, demand grazing animals, mechanical care by mowing being often less effective in the long run. Table 6 shows that traditional sheep grazing cannot be carried out by receipts from product sales alone, costs are much higher. The shepherd's very important contribution to landscaping requires payments in excess, just as caring for parks in towns requires funding. It is interesting to notice that in the semi-cultured landscape, no conflict with farmers exists and no ideological obstruction has to be overcome. Everybody loves these biotopes, not a few young people are willing to become shepherds. Some funds are operating, but mostly in the short term, discouraging idealistic people to venture upon a risky future.

Table 6. Receipts and costs in landscaping with sheep grazing.

	Euro/ha·Year
Receipts from product sales	231.74
Costs for fodder concentrates, water and other inputs	232.11
Feed	238.30
Work	275.40
Fixed costs for machinery	139.70
Other costs	63,30
Total	948.81
Deficit = funding necessary for landscaping	717.07

Source: From Berger (2011).

Landscape planning is traditional in Germany for decades, university chairs and numerous private firms are active. Its power to enforce its ideas in practice is poor, however. Often plans are produced "for the filing cabinet". Yet, urgent problems call for authoritative spatial planning. The lamentable division of the country into regions rearing far too much livestock and others with only few farm animals has been mentioned in Section 3.3. Even upon an overall reduction of livestock rearing along the lines suggested in Section 4.2.1, groundwater quality can only be safeguarded by a more even distribution of livestock, at the same time providing more soil with organic manure. Lacking instruments to incite farms to agree to such reorientation, techniques are elaborated to condense liquid manure and transport it over long distances. This is fussy and expensive.

Landscape planning is not even capable of safeguarding a sufficient provision of structuring elements in the agrarian countryside. If a motorway is planned, it is built within a few years, a hedgerow, urgently needed against wind erosion, will meet its realization postponed to all eternity.

Paradoxically, the costs for the achievement of substantial progress in biodiversity conservation are low in macroeconomic terms. Table 7 shows a compilation of measures suggested by Hampicke (2014) in a study for a renowned foundation. Comprised are four measures: (1) Safeguarding the ecological quality of the semi-cultured landscape by funding grazing, as already mentioned; (2) de-intensification of grassland providing feed for young cattle not in need of energy-rich grass, as is practiced with great success in the Eifel region in western Germany; (3) low-input cropping in regions with less fertile soil; and (4) provision of a sufficient number of structuring elements in highly productive regions. Around thirteen percent of Germany's agricultural area would be included in such a project, enough to improve substantially the condition of biodiversity. The overall costs are in the range of two thousand million Euros per year, 0.7 per mil (not per cent) of the annual gross national product. A country declaring herself to the Conservation of Biodiversity should be ready to defray this sum, all the more so because it could be affordable by a reorientation of funds already in existence but utilized little efficiently such as the "first pillar" of the Common Agricultural Policy (CAP) of the European Union, comprising around five thousand million euro per year.

Table 7. Suggestion for a program in favor of conservation in German agriculture.

	Area, ha	Euro/ha·Year	Million Euro/Year
Semi-cultured landscape and grassland valuable for conservation	1,000,000	550	550
Restoring 10% of high-productive grassland for young cattle	400,000	1200	480
Setting aside 10% of one quarter of least-productive cropland	150,000	400	60
Structuring elements on 7% of area in highly productive regions	630,000	800	500
Total	2,180,000		1590
Round up for possible underestimates and recent price rises			2000

Source: From Hampicke (2014).

5. Conclusions and Economic Interpretation

The lamentable condition of biodiversity in Germany's rural landscape violates moral and legal duties. German Law of Nature Protection demands the preservation of all wild species. Not only is the situation at variance with the demands of UN's Sustainable Development Goal 15. Furthermore, National and European programs plead for a reorientation. In 2007, the German Federal Government passed a "National Strategy for Biodiversity" (BMU 2007) whose melodious promises remain on paper ever since. As for agriculture, the "Biodiversity Strategy 2030" of the European Union (European Commission 2020) puts in claim concrete targets, among others: reduction of pesticide use by 50%, reduction of nutrient losses by 50% which demands a reduction of application of 20%, establishment of organic agriculture on 25% of the area, reclaiming high-diversity biotopes on at least 10% of the area.

One is tempted to state that the Common Agricultural Policy (CAP) of the European Union has had at its disposal decades in the past to achieve at least some of these goals. Forty years ago, experts gave sufficient advice and presented examples of success (Schumacher 1980). It is easy to demand to dispense with 50% of the pesticide use without wondering about consequences. Doing without 50% of pesticides and leaving everything else unchanged results in confusion. The cropping system as a whole would have to be revised. This is not to say that the targets are not worth aspiring to, but it appears unrealistic to achieve them as soon as 2030, which is in less than ten years.

This contribution shows that considerable improvement is possible even in shorter terms provided there is sufficient political volition. Unnecessary production should cease. The public neither needs energy crops nor excessive export of agricultural commodities, reclaiming three million hectares. Renunciation of both would relieve the stress and open scope for reducing the intensity of cropping and for devoting science and practice to the targets of EU's "Biodiversity Strategy 2030".

A plenitude of agricultural products could be produced, and farmers could enjoy satisfactory incomes—without biodiversity losses witnessed to the present degree. Costs for substantially improving the situation are moderate, funds are available in principle. In a general welfare-economic setting, abandoning uneconomic energy crops even results in avoiding social costs. The general public enjoys beautiful landscapes and regrets biodiversity losses; biotopes as shown in Figure 1 are crowded on weekends by recreationists. Economic studies attest a considerable willingness-to-pay for biodiversity conservation (Meyerhoff et al. 2012).

In the public debate, actors are blamed for being responsible. The government is unwilling to engage in conflicts with farmers, farmers ignore the necessity to conserve, and agricultural lobbyism is too strong, the general public wants cheap food products, and so arguments go on. Although some may be not altogether wrong, they remain superficial.

We have to look for deeper reasons. All agricultural products, some of them supplied in excessive quantity, are commodities, private goods, tradable in the market. All works done in too short supply for the integrity of physical resources and for biodiversity conservation are public goods. A public good is characterized by non-rivalry in consumption and non-excludability. A private good is owned by the one who paid for it in the market. A public good, once it exists, exists for everybody and cannot be traded in the market (we ignore refinements, see Cornes and Sandler 1996).

The provision of private goods can be left to the market which has been functioning extremely successfully for a long time. So the superabundance of agricultural commodities is not surprising. Public goods have to be provided by collective action. Just as the attempt to supply private goods by collective decisions in socialist systems ended up in overall scarcity, the scarcity of benevolent public goods in the countryside is anything but astonishing.

Elementary economic theory attributes the scarcity of public goods to their non-excludability. Smart consumers acting as free riders, there will be no suppliers because they are unable to recover costs. This is half true at best. In fact, there are three possibilities (Hampicke 2013):

1. No sufficient willingness-to-pay for a public good exists. Consumers are disinterested and would not buy the good even if it was available in the market.
2. Willingness-to-pay exists in principle but is spoiled by free riding.
3. Willingness-to-pay exists, is not spoiled by free riding but is ineffective because of missing or ill-designed institutions capable of bundling individual contributions.

Certainly (1) and (2) are not fully absent in society. However, prevailing opinion in the public and numerous results from scientific studies on willingness to pay for nature conservation indicate that (3) is to blame in the first place. Policy does not ignore its duties, considerable funds are granted in the "Second pillar" of the CAP (see Lakner et al. 2021, this volume). However, oddly enough, strange inconsistencies are observed. As for the management of nitrogen and its damage done to water and atmosphere, policy has been timid for decades, farm lobbyism had and partly still has an easy task in preventing more effective measures. The nearly total failure of landscape planning, equally brought about by lobbying, is particularly regrettable. Add to this well-meaning but ill-considered political decisions such as the furthering of energy plants. On the other hand, payments granted to farms for nature-friendly cropping and grassland managing practices—translating the public concern for conservation into practice—after having operated quite successfully in former years, have mostly degenerated to a system dominated by bureaucracy and unjust sanctions frightening off potential participants.

These are subjected to the control of their activities five times as thorough-going as farmers unwilling to participate in conservation measures. Upon minor irregularities, for instance slightly incorrect documentation of the area involved, they have to pay back the funding they received and face other sanctions in addition. It is a small wonder that the number of farms willing to participate is decreasing. It has been shown that most conflicts arising in this field are caused by unclear regulations and ill-informed authorities rather than by unlawfully acting farmers (Kannegießer and Trepmann 2016). Cases are reported where the financial expenditures for controls exceeded the damage done by mistaken action on the part of farmers almost 60-fold (BfN 2017, p. 34).

Experience shows that farmers are successfully persuaded to cooperate in measures to enhance biodiversity upon two conditions: First, measures must minimize bureaucracy, must recognize the economic necessities of the farm and must be accompanied by the guidance and advice of people in the confidence of farmers. Second, action must be designed long-sighted. Although individual contracts may confine to a couple of years in order to grant flexibility, the general setting demands patience and trust. A case in point is the work done by Wolfgang Schumacher in the Eifel region (west of Bonn) which made his home county (Landkreis Euskirchen) probably the only county in Germany where aspirations of the European Union to stop species reduction have come true. Crop field margins are embellished by weeds no longer in danger of extinction, meadows producing hay for young cattle and other livestock not demanding high-energy feed are colorful (Schumacher 2007).

Society may choose among two alternative designs for agriculture: Either farmers restrict themselves to the maximum production of commodities, thereby regarding limitations protecting natural resources and biodiversity as obstacles for their activity which have to be complied with the least possible. Or they consider the active preservation of the countryside to be part of their business, in a like manner as commodity production, on the condition that a just financial appreciation by society is granted. Unfortunately, the first alternative has gained attraction in recent years, possibly furthered by globalization. Of course, the second alternative is far more promising and would be the optimal way to comply with the demands of SDG 15. To conclude, mismanagement of natural resources and the demise of the traditional countryside are examples of the poor talent of modern societies to design suitable institutions holding trust in public goods.

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