In this chapter, we review the animal and vegetal biomass flows of Spanish agroecosystems based on the evolution of net primary productivity, its different components and livestock production. This enables us to examine the performance of biophysical, land and livestock fund elements as well as the changes that took place throughout the twentieth century to meet society’s biomass requirements. As explained in the introduction, our analysis moves away from the standard narrative on Spain’s agricultural sector and its contribution to economic growth. A historiographic review of the main transformations in Spanish agriculture since 1900s was, however, presented in the first section of this chapter. Based on both traditional discourse and new historiographical contributions, we determine the milestones of change and then submit them to the discussion. The following sections aim at laying the foundations of an alternative narrative based on the study of Spanish agroecosystem productivity since 1900.

The second section is dedicated to changes in types of land use since 1900 until now. We discuss whether Spain’s evolution really did follow the so-called forest transition and its associated theory of productive intensification. We later analyze the NPP of agroecosystems, breaking it down into categories to verify whether production efforts affected their health. We then center on the domestic extraction entity over time and its progressive concentration in cultivated lands. Subsequently, we focus on these lands’ specialization in specific Mediterranean crops oriented towards both national and international markets. Next, we turn our attention to livestock, a critical activity in recent decades, focusing first on its evolution before examining livestock production. To finish, we propose a holistic understanding of the biophysical implications of the sector’s industrialization.
2.1 Traditional Historiographical Narrative of Agricultural Transformations During the Twentieth Century

When using agricultural production increase as the main indicator and applying conventional measurements, i.e. in tons of fresh products or in money, the outlook is frankly positive. Spanish agriculture strongly intensified and multiplied its production by 3.3 between 1900 and 2008, reaching a peak at the start of this century turning out over 104.2 million tons, almost four times more than in 1900. These figures emerge from the analysis of agricultural production measured in fresh matter, without compensating the distortion relating to the water content of agricultural products. According to our own data collected in Table 2.1, all crops increased their yields because cultivated areas decreased in size, as we will see later. Cereals, fruits and vegetables, forage plants and olive groves grew particularly sharply, reflecting Spain’s progressive specialization.

Livestock production grew even further, multiplying by a factor of 8.2 over the same period (Table 2.2). It also progressively reached a heavier weight, from 7% of

| Table 2.1 | Evolution of agricultural production in million tonnes (Mt) of fresh matter |
|-----------|------------------|------------------|------------------|------------------|------------------|------------------|
|           | 1900  | 1960  | 1990  | 2000  | 2008  | 2015*             |
| Cereals   | 6.24  | 8.62  | 18.83 | 21.24 | 23.00 | 20.14             |
| Legumes   | 0.50  | 0.90  | 0.24  | 0.33  | 0.23  | 0.50              |
| Vegetables and tubers | 5.37 | 9.77  | 16.77 | 15.95 | 14.99 | 17.09            |
| Fruit trees | 1.85 | 3.66  | 8.59  | 9.68  | 10.20 | 10.81            |
| Vineyard  | 3.78  | 2.63  | 5.33  | 6.14  | 5.40  | 5.80             |
| Olive groves | 1.09 | 1.95  | 2.93  | 5.23  | 6.26  | 7.35             |
| Industrial and others | 1.27 | 4.43  | 9.39  | 9.42  | 6.73  | 4.92             |
| Forage crops | 8.40 | 25.52 | 35.61 | 36.34 | 28.33 | 25.41            |
| Total     | 28.50 | 57.48 | 97.70 | 104.32| 95.14 | 92.04            |

|           | 1900  | 1960  | 1990  | 2000  | 2008  | 2015*             |
| Cereals   | 100   | 138   | 302   | 341   | 369   | 323              |
| Legumes   | 100   | 179   | 49    | 66    | 46    | 100             |
| Vegetables and tubers | 100 | 182   | 312   | 297   | 279   | 318             |
| Fruit trees | 100 | 197   | 463   | 522   | 550   | 584             |
| Vineyard  | 100   | 70    | 141   | 162   | 143   | 153             |
| Olive groves | 100 | 179   | 270   | 482   | 577   | 735             |
| Industrial and others | 100 | 349   | 739   | 741   | 529   | 387             |
| Forage crops | 100 | 304   | 424   | 433   | 337   | 302             |
| Total     | 100   | 202   | 343   | 366   | 334   | 323             |

Source Yearbooks of agricultural statistics and own calculations

*The 2015 data correspond to provisional estimates based on the Yearbook of Agricultural Productions (MAPAMA 2016)
agricultural production to almost 17%. Meat and eggs were the major players in this unusual growth of livestock production. Milk production increased fivefold, despite already being the main livestock product in 1900. On the other hand, traditional products associated with extensive breeding such as wool declined throughout the century and became residual (Table 2.2).

Growth in agricultural production seems even more remarkable when measured in monetary terms. We do not dispose of a Final Agricultural Production (FAP) series covering our entire period under study. We do dispose of sector accounts drawn up by the Ministry of Agriculture since the early fifties, but they use three different methodologies, as we will see in Chap. 5. By connecting the annual values of the three series (see Chap. 4), we can conclude that the value of FAP multiplied by 5.1 (Graph 2.1a) at constant prices between 1953 and 2003. Furthermore, agricultural production in Spain continued to grow until the turn of the century (Graph 2.1b), unlike in the rest of Western Europe where growth came to a halt at the end of the eighties (Martín-Retortillo and Pinilla 2015). In Spain, growth was interrupted as of 2003. Between that year and 2014, the Agricultural Industry’s production dropped by 6.4% in real terms (Graph 2.1b). At the beginning of the fifties, Spain was still subject to Franco’s dictatorship’s autocratic economic policy anyway. Consequently, agricultural production was low in relation to that achieved during the Second Republic. Despite this, the figures reveal spectacular growth that must be attributed to the economic effects of agriculture’s industrialization. According to estimations by Prados De La Escosura (2003), Spanish agriculture GDP multiplied by 3.6 between 1900 and 1990.

Table 2.2  Evolution of livestock production, in thousands of tons of fresh matter

|       | 1900 | 1960 | 1990 | 2000 | 2008 | 2015* |
|-------|------|------|------|------|------|-------|
| Meat  | 517  | 971  | 5.200| 7.427| 8.005| 8.701 |
| Milk  | 1.355| 3.252| 6.737| 7.196| 7.308| 7.865 |
| Eggs  | 54   | 197  | 558  | 656  | 656  | 639   |
| Wool  | 26   | 31   | 29   | 31   | 28   | 23    |
| Honey and wax | 6   | 8    | 24   | 34   | 34   | 35    |
| Total | 1.959| 4.460| 12.548| 15.253| 16.031| 17.264|

|       | 1900 | 1960 | 1990 | 2000 | 2008 | 2015 |
|-------|------|------|------|------|------|------|
| Meat  | 100  | 188  | 1.007| 1.438| 1.550| 1.682|
| Milk  | 100  | 240  | 497  | 531  | 539  | 580  |
| Eggs  | 100  | 366  | 1.034| 1.048| 1.217| 1.183|
| Wool  | 100  | 117  | 109  | 119  | 106  | 88   |
| Honey and wax | 100 | 130  | 377  | 528  | 517  | 583  |
| Total | 100  | 228  | 641  | 779  | 818  | 881  |

Source Yearbooks of agricultural statistics and own calculations
*The 2015 data correspond to provisional estimates based on the Yearbook of Agricultural Productions (MAPAMA 2016)
The upward trend can be broken down into four different periods. The first period corresponds to the years between 1900 and 1936, when production grew by 52%, confirming findings from previous studies (GEHR 1991; Simpson 1997) according to which this period was one of the agricultural growth and sector “modernization”. Between 1900 and 1931 land productivity grew by 1.2% per year and labor productivity by 1.9% (Gallego Martínez 1993, modified by Soto 2006). Both productivities could have increased more, but according to traditional historiographical narrative, there were insufficient incentives to spread chemical fertilizers or mechanization. However, cereal production, for which rainfed lands offered low yields and little competitiveness, maintained itself and even increased thanks to the domestic
demand of a growing population. Spain became the biggest wine exporting country
and the second biggest oil-exporting country in the 1890s after Italy (Infante and
Parcerisas 2013; Infante-Amate 2014). But this avenue would not lead to continued
expansion in export markets, because of stagnant demand and powerful competitors
in the sector (Pinilla and Serrano 2008; Infante-Amate 2014). Spain began to spe-
cialize in fruits and vegetables. This activity was to play a critical role decades later,
but it was burdened at the time by scarce public investment in irrigation as well as
fresh export food transport difficulties. In comparative terms, the factor productivity
evolved in parallel, similar in size to that of other European countries (Bringas 2000;
Clar et al. 2016, 183).

The traditional narrative generally describes this period as one of slow or insuffi-
cient growth and “modernization”. The Spanish economy’s sluggish industrialization
meant that urban demand for labor and agricultural products was not sufficiently stim-
ulated, which in turn failed to drive an in-depth modernization of agriculture. More-
over, high capital costs and the abundance of labor in the countryside failed to trigger
speedier transformations (Gallego 2001). Nevertheless, it is important to remember
that with a few exceptions, demand for agricultural products during this period came
from the domestic market. Undoubtedly, population growth and the satisfaction of
food and energy demands were decisive. The overcoming of the depression at the
turn of the century and agricultural growth itself must have nevertheless increased the
purchasing power of a large share of the rural population, substantially improving its
diet during the first third of the twentieth century (Cussó 2005; González de Molina
et al. 2014).

The second period covers the first two decades of Franco’s dictatorship. According
to an increasingly widespread historiographical consensus, this period can be quali-
fied as simply tragic. It began with the end of the Civil War, the regime’s international
isolation and its autarchic economic policy. Spanish agriculture’s “modernization”
experienced a sharp reversal, widening the gap with other European countries. The
lack of chemical fertilizers, due to the shortage of foreign currency and obstacles to
international trade, partly explain the decline in yields. Livestock activity was also
affected by the decreasing availability of animal feed, which, in turn, aggravated the
shortage of fertilizers—organic fertilizers in this case (Fernández Prieto 2007). Pow-
erful State intervention, through the National Wheat Service (Servicio Nacional de
Trigo), guaranteed low prices to avoid wage increase sand ended up subjecting agri-
cultural policy to industrial policy, providing poorly remunerative prices that failed to
stimulate agricultural production growth (Barciela 1986; Baricela and López 2003).

Falling agricultural and livestock production caused shortages in the domestic market
and a sharp drop in food availability led to spells of hunger and malnutrition affect-
ing different segments of the population, an unprecedented chapter in the country’s
recent history (González de Molina et al. 2013). The data we provide and present
later indisputably confirms this.

Things would begin to change in the fifties, once autarchic policy had proved
to be unviable. At the end of that decade, coinciding with the start of the so-called
“Stabilization Plan” (1959), our third period of study began, i.e. Spanish agricul-
ture’s last industrialization phase. Liberalization led to the sector’s rapid transforma-
tion. It was financed by foreign investment, remittances from emigrants and income from tourism. Yields per unit area multiplied thanks to the use of the green revolution’s complete package: improved seeds, synthetic chemical fertilizers, phytosanitary treatments, and irrigation. Production quickly recovered, doubling between 1900 and 1960, tripling by 1980 and almost quadrupling by the end of the century (Table 2.1). Cereal production, so far on the decline, forewarning the abandonment of traditional agriculture, promptly rebounded thanks to the growing demand of feed grains.

The expansion of irrigation surfaces played a major part thanks to the construction of large hydraulic infrastructures. According to Cazcarro et al. (2014), two-thirds of Spanish agricultural production was obtained from irrigated lands. Changes in the agricultural policy encouraged the growth of livestock, leading to an increase in its share of final agricultural production, eventually reaching one-third of total production (Clar et al. 2016, 190). The support given to the imports of feed and to intensive livestock farming based on little or no land allowed to maintain incentives for traditional production, especially wheat. Agrarian trade balances became increasingly negative, although this fact was compensated by the loss of the relative weight of the agricultural sector in the overall trade balance and Spain’s economy generally.

Final agricultural production also grew at unprecedented rates, while its share of total employment and Spanish GDP declined. This behavior is viewed positively, as it is characteristic of agricultural growth and industrialization, and common to most economically advanced countries. During the first decades of industrialization, the sector was driven by the green revolution’s new technologies and in the eighties, the impetus was given by resulting factor productivity gains. Despite this, agricultural incomes are still today on the decline, compensated by CAP aid. Major productivity improvements facilitated the transfer of labor from rural areas to urban-industrial activities. Between 1960 and 2008, the active agricultural population fell from almost five million to just over one million individuals. This population transfer from the countryside to cities has also been judged as a highly positive contribution of the agricultural sector to Spain’s economic growth.

Overall, the role of agriculture was redefined during its industrialization process. Agriculture shifted from providing food and labor—its basic functions during the first two periods under study—to becoming mainly a supplier of raw materials to an agri-food complex, a business made up of the agro-industry, food distribution, and agricultural input manufacturers. This shift is considered to be another notable contribution to Spain’s economic growth. In fact, the agri-food trade has been generating a surplus in monetary terms since the beginning of the 1980s, based on quality differentiation and greater external competitiveness. The sector’s transformation also sparked other concerns relating to environmental management and rural development, that is no longer directly linked to agricultural activity. Public administrations have become worried about nature conservation and rural depopulation, though these issues are only vaguely related to the model of agricultural growth that has been followed since the late fifties.
2.2 The Evolution of Land Uses

A biophysical study of this evolution, however, projects a less comfortable picture and gives us more reason to be critical. We can begin with changes in net primary productivity that originated, in turn, in modified land uses and land productivity differences.

In Graph 2.2 we summarize the changes in land uses based on six differentiated categories: unproductive lands, pastures, meadows, coppice, timberlands, and cultivated areas. A detailed account of the methodology used to estimate forestland mass can be found in Infante-Amate et al. (2014). In this work, we propose an unprecedented long-term estimate of nationwide forestland uses. The task was challenging. As already pointed out by other historians who have worked extensively with these types of indicators: “It is difficult to determine the current state of Spanish woodlands because sources are based on different methodologies and figures on woodlands differ significantly. In addition, as recognized in agricultural statistics, changes in the criteria used to establish forest statistics make it impossible to connect data series” (Barciela et al. 2005: 256–257).

Our strategy was to draw up estimates of unproductive surface areas and cultivated areas in each province using Agrarian Statistics data. These data are more consistent than those relating to woodlands. We then assumed that remaining areas would be wooded or forested. Subsequently, we extracted all the sources of information on forest areas at provincial levels. We soon observed the inconsistencies described by Barciela et al. (2005) as we encountered changing definitions of forest mass or unlikely shifts over time of the same forest mass. Our job was to adjust the least plausible changes within each province and create a series of woodland data falling into the four forest categories mentioned above.

![Graph 2.2](image-url)  
**Graph 2.2** Evolution of land uses, in million hectares
Generally, the main process of change emerged from opposing trends between cultivated areas and woodlands. Cultivated areas grew continuously from 1900 to the 1970s, reaching almost 21 million hectares (Table 2.3). They have steadily declined ever since reaching a little more than 17 million hectares by 2008. The fall in cultivated areas is attributable to the drop in cereal system surface area. As we shall see later, this does not imply a fall in cereal production. Rather, rainfed lands in the interior of the country, with low yields, have decreased, often because agricultural activity has been abandoned. We will come back to this issue in Chap. 4.

As mentioned, woodlands followed the opposite trend. In the mid-nineteenth century, Spain’s total forested area was about 32 million hectares (MH), occupying almost two-thirds of the land.¹ By 1900, the first year for which we can make a reasonable estimate, it had fallen to 29.85 MH. In 1960, the figure was 25.92 MH (Table 2.3). More than 6 MH, one-seventh of the country’s territory, had been deforested. Deforestation processes have taken place all over the world. It is estimated that since the invention of agriculture, 15–45% of woodlands have disappeared, at a different pace and according to distinct regional patterns throughout history (McNeil 2001: 229). In Europe, by the mid-seventeenth century, more than a third of the entire continent had been deforested (Williams 1990), thus accentuating a process initiated in ancient times (Kaplan et al. 2009). Since 1500, the disappearance of woodlands and the consequent shortage of forest resources seems to have become clearly problematic for most European countries, as it kept worsening well into the nineteenth century (Allen 2003; Warde 2006: 41–42; Radkau 2008: 139, 2011; Parrotta and Trosper 2012: 216). Spain’s deforestation, therefore, is part of a process common to the whole continent in which increasing pressure on resources and the expansion of agricultural borders ended up substantially reducing woodland areas (Boserup 1965, 1981). Spain, however, presented some peculiarities. Loss of forest mass lasted until the mid-twentieth century (Table 2.3), while in much of Europe it had already slowed down throughout the nineteenth century and forests were beginning to be managed intensively, concentrating on timber production once fossil fuels began to replace firewood (Table 2.3).²

In all events, according to the reconstructed data used in this work, the total forest area fell during the first half of the twentieth century by 3.38 MH, of which only 0.86 MH were forested (Graph 2.3). That is, the loss of forest masses concentrated in bush and pasture areas, that dropped by more than 2.52 MH. Deforestation during these years did not imply, therefore, a big loss of trees. The surface area of timber woodlands increased from 2.84 to 3.70 MH between 1900 and 1950 (Graph 2.4).

Thus, Spanish woodlands began to specialize in timber, a trend that greatly intensified in the second half of the twentieth century (Graph 2.4). This development is much better accounted for mainly because “complete” woodland statistics began to be published, and timber woodlands grew sharply, reaching 7.46 MH in 2000. Thus,

¹Though we do not know which parts were forested.
²According to Warde (2006: 37) we can get a glimpse of this process in Central Europe in the 14th century, though it really boomed at the end of the 19th century. See: Williams (2003: 164), Radkau (2008: 214), Agnoletti et al. (2011) or Parrotta and Trosper (2012: 219–20).
Table 2.3  Land use in Spain in thousands of hectares

| Year | Cultivated lands | Timber woodlands | Coppice | Meadows | Wooded | Bush and pasture | Forest | UAA | Unproductive | Total |
|------|------------------|------------------|---------|---------|--------|-----------------|--------|-----|--------------|-------|
| 1900 | 16.479           | 2.836            | 7.126   | 2.989   | 12.951 | 16.901          | 29.852 | 46.331 | 4.169        | 50.500 |
| 1910 | 17.228           | 2.980            | 6.872   | 2.814   | 12.666 | 16.437          | 29.103 | 46.331 | 4.169        | 50.500 |
| 1920 | 18.799           | 3.336            | 6.549   | 2.702   | 12.587 | 14.845          | 27.432 | 46.231 | 4.169        | 50.500 |
| 1930 | 20.368           | 3.558            | 5.843   | 2.586   | 11.987 | 13.976          | 25.963 | 46.331 | 4.169        | 50.500 |
| 1940 | 18.782           | 3.759            | 6.115   | 2.626   | 12.501 | 15.049          | 27.550 | 46.331 | 4.169        | 50.500 |
| 1950 | 19.856           | 3.697            | 5.619   | 2.776   | 12.092 | 14.383          | 26.476 | 46.331 | 4.169        | 50.500 |
| 1960 | 20.413           | 4.929            | 5.076   | 3.320   | 13.325 | 12.594          | 25.919 | 46.331 | 4.169        | 50.500 |
| 1970 | 20.885           | 6.240            | 4.640   | 3.835   | 14.715 | 11.190          | 25.905 | 46.789 | 3.680        | 50.470 |
| 1980 | 20.499           | 6.741            | 4.824   | 4.033   | 15.598 | 10.691          | 26.289 | 46.788 | 3.684        | 50.472 |
| 1990 | 20.172           | 7.189            | 4.979   | 3.636   | 15.805 | 10.746          | 26.550 | 46.723 | 3.746        | 50.469 |
| 2000 | 18.304           | 7.460            | 5.055   | 3.893   | 16.408 | 11.645          | 28.053 | 46.357 | 4.143        | 50.500 |

1 Cultivated: Arable and crop lands. 2 Timber woodlands: Wooded areas where benefit methods are applied, that is, cutting trees so they regenerate. Not generally used as pastures and aimed at timber production. Strong presence of conifers. 3 Coppice: areas where coppicing methods are applied. Aimed at firewood production. The landscape’s morphology depends on the part of the country. Some scrublands are intensive while others are more similar to pastures. Mainly oak trees. 4 Meadows: usually meadows, though this category also includes another type of farm characterized by low tree density combined with pastures. Strong presence of oak trees. 5 Wooded: All three previous categories together. Spanish statistics, since 1973, refer to this heading as forest, including only forested areas. 6 Bush and pasture: land of agrarian use, not tilled and not wooded. It includes natural meadows, pastures, wasteland pastures, esparto fields and areas with a variety of scrubs. 7 Forest: sum of wooded and bush and pasture areas. Corresponds to non-cultivated agricultural areas in our categorization. 8 UAA: Useful agricultural area. Includes forests, pastures and bush lands. 9 Unproductive: Agricultural areas that are unproductive and areas with other uses such as rivers, lakes or urbanized areas. 10 Total: Spain’s geographical area. Sum of unproductive areas and the UAA.
**Graph 2.3** Total forest, wooded and timber woodlands in Spain in thousands of hectares. *Source* see text

**Graph 2.4** Surface area of timber woodlands and wooded areas in thousands of hectares. *Source* see methodology section
during the second half of the twentieth century, total forested areas in Spanish woodlands reversed their downward trend, increasing from 12.09 to 16.41 MH (Graph 2.3). Reforestation plans that started to be implemented at the beginning of the twentieth century were implemented from the 1940s onwards, so forest policies focused on the upsurge of conifers and fast-growing timber species. The Spanish economy demanded increasing amounts of timber as a raw material while firewood scrublands lost relevance (Graph 2.4).

This growth of woodlands is a textbook case of the process we describe today as forest transition (see Lambin and Meyfroidt 2011), that is, a shift from decreasing to increasing forest areas. The case of Spain epitomizes what happened in many other industrialized countries where the advance of agricultural areas eventually halted, giving way to the recovery of forest areas. However, as we will see later, the process can often be explained by the fact that cultivated areas have been displaced to other countries. Strictly speaking, countries that increased their forest areas actually displaced deforestation to other parts of the world (Meyfroidt et al. 2010). This seems to be the case in Spain. As estimated in another study (Infante-Amate et al. 2018), at the beginning of the 20th century Spanish imports represented a little over 700 thousand hectares of embodied land (due to biomass imports). In 2008, the figure reached over 11 million hectares, a much higher figure than that of woodland growth, and that has not exceeded 3 million hectares since that date.

2.3 Evolution of Actual Net primary Productivity

Contrary to interpretations in Sect. 2.1, agricultural production as a whole, that is, actual net primary productivity (NPP_{act}), did not grow as spectacularly as fresh matter or monetary statistics seem to imply. NPP_{act} grew by only 28.5% between 1900 and 2008, though not in a uniform way over the period (Graph 2.5). During the first half of the century, productivity increased by only 5%, while in the second half of the century, growth was much more significant, reaching 22%, coinciding with major changes in the sector (Graph 2.5). At the turn of the century, growth seems to have slowed down: actual NPP only grew by 1% between 2000 and 2008. In any case, industrialization did not actually lead to greater yields per unit area if we consider the agroecosystems’ overall capacity to produce biomass. This observation should challenge the view that industrialization is associated with the massive use of external inputs and yield increases. What actually occurred, as we will see at the end of this chapter, was that production efforts were concentrated in a handful of plants, and biomass was translocated focusing on the socially useful parts of plants; this phenomenon had greater repercussions than the increase in yields per unit area and crop.

Table 2.4 shows comparative data according to the evolution of land use. Worthy of note, woodlands include forested or woodlands directed mostly at timber use, while pasture lands include not only meadows and grasslands but also forests for livestock use and pasture plots; therefore, the data on uncultivated surfaces in Table 2.5 and the data in Table 2.4 are not the same. Given that woodland and livestock use are both included in woodlands, when calculating the NPP/ha, we assumed that woodland
Graph 2.5  Net primary productivity according to production origin, in Mt of dry matter

Table 2.4  Net primary productivity according to land use, in Mt of dry matter

|        | 1900 | 1933 | 1950 | 1970 | 1990 | 2008 |
|--------|------|------|------|------|------|------|
| Farmlands | 66   | 91   | 73   | 84   | 99   | 104  |
| Pastures  | 122  | 111  | 131  | 127  | 117  | 130  |
| Woodlands | 57   | 54   | 54   | 73   | 76   | 81   |
| Total     | 245  | 256  | 258  | 283  | 293  | 314  |

| Interannual variation | 1900 | 1933 | 1950 | 1970 | 1990 | 2008 |
|-----------------------|------|------|------|------|------|------|
| Farmlands             | 100  | 138  | 111  | 127  | 150  | 157  |
| Pastures              | 100  | 91   | 107  | 104  | 96   | 107  |
| Woodlands             | 100  | 95   | 96   | 129  | 134  | 142  |
| Total                 | 100  | 105  | 105  | 116  | 120  | 128  |

| Real NPP/ha | 1900 | 1933 | 1950 | 1970 | 1990 | 2008 |
|-------------|------|------|------|------|------|------|
| Farmlands   | 4.0  | 4.5  | 3.7  | 4.0  | 4.9  | 6.0  |
| Pastures    | 4.5  | 5.0  | 5.7  | 6.4  | 6.1  | 6.3  |
| Woodlands   | 1.9  | 2.1  | 2.0  | 2.8  | 2.9  | 2.8  |
| Total       | 4.8  | 5.1  | 5.1  | 5.6  | 5.8  | 6.2  |

Source Agrarian statistics
Table 2.5  Net primary productivity according to origin, in Mt of dry matter

|                        | 1900 | 1933 | 1950 | 1970 | 1990 | 2008 |
|------------------------|------|------|------|------|------|------|
| Woody crops (aerial)    | 1.1  | 1.4  | 1.7  | 2.0  | 2.0  | 2.1  |
| Woody crops (roots)     | 0.5  | 0.5  | 0.7  | 0.7  | 0.7  | 0.6  |
| Woodlands (aerial)      | 0.5  | -0.1 | 0.7  | 9.3  | 10.4 | 9.8  |
| Woodlands (roots)       | 9.6  | 9.1  | 9.0  | 9.7  | 10.4 | 11.1 |
| Total accumulated biomass | 11.7 | 10.8 | 12.0 | 21.7 | 23.4 | 23.7 |
| % of real NPP           | 4.8  | 4.2  | 4.6  | 7.7  | 8.0  | 7.5  |
| Crops (aerial)          | 19.0 | 26.9 | 19.9 | 15.5 | 20.6 | 27.0 |
| Crops (roots)           | 21.1 | 29.6 | 22.5 | 21.2 | 22.1 | 22.1 |
| Pastures (aerial)       | 53.6 | 44.9 | 49.9 | 64.3 | 60.3 | 64.6 |
| Pastures (roots)        | 54.2 | 49.4 | 58.0 | 56.3 | 52.2 | 57.8 |
| Woodlands (aerial)      | 16.3 | 15.4 | 15.4 | 19.3 | 20.0 | 21.6 |
| Woodlands (roots)       | 19.2 | 18.1 | 18.5 | 26.9 | 27.6 | 29.0 |
| Total non-harvested biomass | 183.4 | 184.3 | 184.2 | 203.5 | 202.9 | 222.1 |
| % of real NPP           | 75.0 | 72.0 | 71.4 | 71.8 | 69.3 | 70.7 |
| Domestic extraction     | 50   | 61   | 62   | 58   | 66   | 68   |
| % of real NPP           | 20.2 | 23.7 | 23.9 | 20.5 | 22.6 | 21.8 |
| Total aerial biomass    | 140  | 149  | 149  | 168  | 180  | 194  |
| Total root biomass      | 105  | 107  | 109  | 115  | 113  | 121  |
| Total real NPP          | 245  | 256  | 258  | 283  | 293  | 314  |

Source Agrarian Statistics and author’s own compilation

corresponded to all land classified as such, including pasture woodlands. Therefore, we subtracted forest from these woodlands to calculate potential grazing areas. Obviously, the actual NPP per hectare grew in the same proportion as in absolute terms as the stock of useful land is fix, except for marginal fluctuations of unproductive surfaces. However, annual amounts of biomass production differed according to the type of land use (Table 2.4). The actual NPP increased more in cultivated areas (57%) and in woodlands (42%) than in the pastures which grew by only 8% (Table 2.4). This means that human pressure to increase production concentrated mainly in cultivated areas, where biomass utility is greater. It measured essentially the same area size in 2008 than in 1900. In fact, by 2008, at the end of the series, productivity per hectare had grown by 50% compared to 1900. This growth took place despite relative extensification pointed out when analyzing agricultural production in fresh matter in recent years (Table 2.1).

The increase in woodland biomass, however, was due, as we have seen, to the increase in woodland area, the increase in forests, improved management and, paradoxically, the abandonment of many traditional types of use, especially firewood collection. When comparing woodland productivity per hectare between 1900 and 2008, an increase of 46% can be observed compared to the beginning of the cen-
tury (Table 2.4), resulting from forested area growth from 2.8 million hectares to 8.3 million hectares. The small increase in pasture NPP can be explained both by the decrease in surface area and, paradoxically, by Spain’s abandonment and under-
usage of lands dedicated to this use. This becomes more evident when looking at productivity per hectare, which increased by almost 40% since 1900 (Table 2.4).

Interesting aspects of actual NPP’s evolution come to light when broken down into different categories. As we have already observed, the net primary productivity of woodlands grew the most, after farmlands. This was largely due to a notable growth of forested areas and accumulated biomass, which doubled over the period, revealing a growing percentage of total net primary productivity, from 4.8 to 7.5%. Accumulation of biomass in the aerial parts of woodlands, which multiplied almost 20-fold, was the main factor (Table 2.5). Woody crops, which hardly doubled, made a much less significant contribution. Biomass accumulated in the roots of woodlands and woody crops grew even less (Table 2.5). This accumulation can be explained by a dual phenomenon: on the one hand, areas with trees multiplied threefold, on the other, the use of firewood from Spanish forests was disappearing as the energy transition progressed in households and firewood was replaced with butane gas as well as electricity (though to a lesser extent). Biomass accumulated in trees and in general in forests because it was no longer harvested for firewood. This accumulation greatly intensified from the sixties onwards and explains the proliferation of recorded forest fires in public woodlands ever since (González de Molina and Casero 1992). Although forested areas grew throughout the century, this progression accelerated over the last decades for two reasons: a peak in household energy transition and the implementation of public policies of conservation and declaration of protected natural spaces.

Unharvested biomass, i.e., biomass that is not appropriated for human use, supports trophic chains. It provides food for the herbivorous species inhabiting the agroecosystems and therefore it also helps to sustain their diversity. As we will see later, unharvested biomass is a good indicator of agroecosystem health. Its evolution throughout the period somewhat reflects the deterioration of the land fund

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Graph 2.6  Evolution of Net primary productivity according to the use, in Mt of dry matter
2.3 Evolution of Actual Net primary Productivity

Overall, this biomass type grew by 21% in absolute terms, but in relative terms, it contributed the least to the growth of total NPP, clearly below the average (Graph 2.6). This means that its importance dropped in relative terms from 75 to 70.7%. This drop was worst in pastures and farmlands and we will see the consequences of this later. Until the 1960s, Spain’s annual biomass production remained essentially stable, growing by only 2% during those decades (Graph 2.6). It actually began to grow from that period onwards and would accelerate in the 1990s (Graph 2.6). The growth was due, as in the case of accumulated biomass, to the expansion of woodlands, i.e., of forested mountains, especially aerial parts and the falling use of harvest residues in croplands.

Only approximately one-fifth of total NPP was appropriated throughout the period by humans (Graph 2.6), that is, it was extracted from agroecosystems. This amount of biomass is called Domestic Extraction, which we analyze below.

2.4 Evolution of Domestic Extraction

Graph 2.7 shows the evolution of vegetal biomass extracted from Spanish agroecosystems between 1900 and 2008, in percentage. As pointed out earlier, dry matter is the most suitable way of measuring the real significance of the changes. This is because current varieties have higher water contents and a shift towards crops that require more water affects total production weight. In addition, irrigation allowed multiplying yields per unit area. Crops that are impossible to produce in rainfed conditions have turned into Spanish agriculture’s main specialization, as is the case of

![Graph 2.7](Image)

**Graph 2.7** Evolution of net primary productivity according to the use, in percentage
fruits and vegetables. Domestic Extraction (DE) of biomass, that is, biomass appropriated directly or indirectly by Spanish society, grew by 38% throughout the period, i.e., more than NPP (28%) (Graph 2.7). The increase in agricultural production based on our measurements differs from the increase obtained using conventional calculations: while in monetary terms “agricultural production” grew almost sixfold, it grew only by 38% in physical terms. Agriculture’s great leap forward following its industrialization can be put into perspective if we consider not only commercial biomass, but all the biomass appropriated by Spanish society: both that with end uses in society and biomass reused in agroecosystems to feed livestock, used as seeds, etc. The difference is even more notable when considering the total biomass necessary to reproduce the fund elements that maintain agroecosystems production capacity, i.e., the NPP. These “costs” are usually not included in national accounts nor, therefore, in agricultural sector accounts (Table 2.6).

We can, therefore, argue that Domestic Extraction growth was, in fact, modest, which explains that its share in Spanish agroecosystem NPP hardly increased, going from 20.2% in 1900 to 21.8% in 2008. The period of maximum levels of relative

| Table 2.6 Biomass domestic extraction in Mt of dry matter |
|-----------------------------|-----|-----|-----|-----|-----|-----|
|                             | 1900| 1933| 1950| 1970| 1990| 2008|
| Crops                       | 11  | 17  | 14  | 25  | 36  | 38  |
| Harvest residues            | 13  | 16  | 15  | 19  | 18  | 14  |
| Pastures                    | 14  | 17  | 23  | 6   | 5   | 8   |
| Woodlands                   | 11  | 11  | 11  | 8   | 8   | 9   |
| Total                       | 50  | 61  | 62  | 58  | 66  | 68  |
| Crops                       | 100 | 149 | 124 | 222 | 318 | 336 |
| Harvest residues            | 100 | 123 | 111 | 148 | 138 | 108 |
| Pastures                    | 100 | 123 | 160 | 43  | 35  | 57  |
| Woodlands                   | 100 | 102 | 96  | 70  | 68  | 83  |
| Interannual variation       | 100 | 123 | 125 | 117 | 134 | 138 |

| Productivity per ha         |
|-----------------------------|
| Crops                       | 0.7 | 0.8 | 0.7 | 1.2 | 1.8 | 2.2 |
| Harvest residues            | 0.5 | 0.7 | 0.6 | 1.0 | 0.9 | 0.7 |
| Pastures                    | 5.0 | 4.8 | 6.1 | 1.0 | 0.7 | 0.9 |
| Woodlands                   | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Domestic Extraction per ha  | 6.4 | 6.5 | 7.7 | 3.3 | 3.5 | 4.0 |

Source Agrarian statistics

3Water in semi-arid climates like that of Spain has been one of the key factors of agricultural industrialization. Irrigation is of fundamental importance. However, the complexity of the subject requires a separate study and we do not address the issue in this book. We are currently fine-tuning our approach to water and its role in Spanish agriculture from the metabolic point of view. A future work is thus under way on this question.
extraction took place in the 1950s, coinciding with the end of traditional agriculture (23.9%), when production difficulties caused by Francoism led to the highest level of appropriation of biomass, in a context of falling yields. However, in absolute terms, the largest amounts of biomass were extracted in the year 2000, reaching almost 70 million tons of dry matter, mostly from crops (77%) (Graph 2.8).

A disaggregated analysis shows that Domestic Extraction growth concentrated on the marketable portion of the plants, increasing by 236% compared to 1900, due to a limited 8% growth in residues. In contrast, biomass appropriated by pastures and forests decreased, respectively by 46 and 17%. The different behaviors of biomass types become clear when observing the evolution of productivity per hectare. Primary crop productivity increased threefold, while residue productivity only increased by 40%. Pasture abandonment and underuse explain an extraction drop of up to 81% for these lands, below one ton per hectare, despite having reached more than six tons in the 1940s and 1950s. Forest conservation policies and household energy transition, as mentioned above, explain the decrease in woodland extraction per hectare (17%). Either way, the evolution of Domestic Extraction uncovers significant changes where primary crops were favored over other kinds of biomass. In this sense, the industrialization of agriculture led to a significant increase in produced biomass, but this increase concentrated in the cultivated lands and more specifically in the most commercially oriented crops. In fact, extraction in these lands went from 22.5 to 54.8% of total Domestic Extraction in 2008, reflecting Spanish agriculture’s production specialization, as we will see in the following section.

Important changes also took place in the end uses of Domestic Extraction (Graph 2.9). Biomass aimed at human food accounted for 9% in 1900 rising to 14% in 2008. Similarly, use of biomass as a raw material went from 1% in 1900 to 4% today. The major change, however, concerned biomass aimed at animal feed. As early as 1900, it represented 56% of extracted biomass, which is logical since main
agricultural tasks were carried out using working animals. In 2008, that percentage rose to 57.5%, reaching its highest percentage in 1960 with a share of almost two thirds (Graph 2.9). Since that decade, around 40 million tons of dry matter have been used to feed livestock, despite animal traction no longer being used. As we will see below, growth of livestock has reached unprecedented levels in recent decades, linked to notable diet changes, specializing in meat and dairy products.

On the other hand, Domestic Extraction aimed at timber and firewood decreased considerably, from 32% in 1900 to 21% in 2008 (Graph 2.9), mainly due to the lesser weight of biomass energy use, thanks to the arrival of gas to Spanish households. However, the drop in firewood use, especially from woodlands, was partially offset by the use of wood as a raw material. This fact is consistent with the growth of forested woodlands mentioned previously. Spanish forest Domestic Extraction thus dropped by only 17%, less than firewood consumption based on this source. Strikingly, as from the 1950s, burnt harvest residues eventually reached 3.6 megatons in the 1990s, i.e. 5.5% of total Domestic Extraction, a real wastage. The prohibition of stubble-burning, a measure taken to prevent forest fires, led burning to fall by half (Graph 2.9).

As shown in Graph 2.10 and Table 2.7, Domestic Extraction decreased per capita by 26%. This drop was due to several processes: firstly, population growth, despite total consumption increase, and secondly the steep decline in firewood use. Per capita extraction of wood and firewood from forests was almost 600 kg in 1900 dropping to almost 200 kg in 2008. On the other hand, extraction from agricultural land went up in accordance with food consumption increase, going from 600 kg per capita in 1900 to 815 kg in 2008, a 36% increase. Conversely, harvest residue extraction and pasture use dropped significantly, in line with pasture abandonment and the burning of residues. Progressive decoupling between consumption and extraction, especially notable since 1960 also had a major impact, as we will see, on the decline of Domestic...
2.4 Evolution of Domestic Extraction

Graph 2.10 Domestic biomass extraction per inhabitant in several countries and the world average, in tons per inhabitant per year

Table 2.7 Destination of domestic extraction in Mt of dry matter

|                | 1900 | 1933 | 1950 | 1970 | 1990 | 2008 |
|----------------|------|------|------|------|------|------|
| Human food     | 4.4  | 6.6  | 5.3  | 8.0  | 10.0 | 9.4  |
| Animal feed    | 27.8 | 36.6 | 39.0 | 33.2 | 36.6 | 39.4 |
| Seeds          | 0.6  | 0.9  | 0.7  | 1.1  | 1.2  | 1.3  |
| Wood and firewood | 16.0 | 15.7 | 15.9 | 13.4 | 13.4 | 14.6 |
| Raw materials  | 0.7  | 0.8  | 0.6  | 0.8  | 1.5  | 1.3  |
| Burned residues| 0.0  | 0.0  | 0.2  | 1.5  | 3.6  | 1.3  |
| Total          | 49.5 | 60.7 | 62   | 58.1 | 66.3 | 68.5 |
| Human food     | 100  | 149  | 119  | 179  | 224  | 212  |
| Animal feed    | 100  | 132  | 140  | 120  | 132  | 142  |
| Seeds          | 100  | 155  | 115  | 180  | 191  | 209  |
| Wood and firewood | 100  | 98   | 99   | 84   | 84   | 91   |
| Raw materials  | 100  | 114  | 98   | 126  | 229  | 392  |
| Burned residues| 0    | 0    | 100  | 756  | 229  | 616  |
| Interannual variation | 100 | 123  | 125  | 117  | 134  | 138  |

Source Agrarian statistics and author’s own compilation

Extraction. While Domestic Extraction per capita fell by 6.5% between 1960 and 2000, Domestic Consumption grew by 5.7%. 4

In comparative terms, the drop in Domestic Extraction per capita throughout the twentieth century was less significant than in other countries such as Japan or the USA, but higher than in the rest of the world (Graph 2.10). One reason is the partial

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4Consumption and trade dynamics are analyzed in detail in Chap. 6.
replacement of biotic materials with abiotic materials in the Spanish economy’s metabolism flows. Vegetal biomass lost part of its energy functions (especially as a domestic fuel source or stockfeed), but its use as a raw material for industry increased, especially in the case of wood, which in many industrial processes, is very difficult to replace (Infante-Amate et al. 2014b). In other words, Spanish agroecosystems that once provided most of society’s needs in energy and raw materials now specialized in human and animal food as well as raw materials for industry. This is the reason why Domestic Extraction and production efforts concentrated in crops and, to a lesser extent, in wood production. In this sense, the most significant transformations undergone by agroecosystems are related to the growing importance of animal feed in Spanish agriculture, as we will see in the following sections, and in industrial wood demand.

2.5 The Specialization of Spain’s Agricultural Production

The analysis of the evolution of net primary productivity and Domestic Extraction in Spanish agriculture has shown how growth has concentrated mainly in crops, and especially in grains rather than residue. In this section, we analyze the evolution of different crop groups and their specialization patterns. The analysis of dry matter, unlike conventional approaches based on fresh matter described in the first section of this chapter, facilitates the appreciation of specialization patterns. By combining dry and fresh matter analyses, we can uncover some of the problems of Spain’s agricultural specialization during its industrialization process.

According to the data in Table 2.8, virtually all crops increased their production throughout the twentieth century. The crop that grew the most was olive trees, in line with its expansion throughout the twentieth century (Infante-Amate 2014). The only exceptions were legumes, which went from 4% of total production at the beginning of the century to becoming marginal, as well as potatoes. Potato production increased until mid-century, undoubtedly due to its key role in peasant diet, and its weight decreased thereafter. Production levels in 2008 were similar to those of 1900. This was a general European phenomenon for two essential reasons: a reduction in per capita consumption, and the increase of imports. Beyond this rapid growth in overall crop production, especially visible in the second half of the twentieth century, dry matter figures draw a quite different picture of specialization compared to that of fresh matter. Indeed, the most commercial and export-oriented crops (horticultural crops above all) incorporate water quantities, as well as water demands, that are far higher than other crops such as cereals, with a much higher content of dry matter. In 2008, these accounted for 53.8% of dry matter, compared to 21.9% of fresh matter. This different way of presenting the data shows that Spanish agriculture specialization has been based on water export and the increasing use of water resources in an eminently semi-arid country, as pointed out in the literature (Cazcarro et al. 2015; Duarte et al. 2014).
Table 2.8  Crop domestic extraction (without residues) in Spain in Mt of dry matter, 1900 = 100 and in percentage

|          | 1900 | 1910 | 1922 | 1933 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2008 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|
| Cereals  | 5.5  | 6.3  | 6.8  | 7.9  | 5.0  | 5.9  | 7.6  | 10.7 | 13.1 | 16.5 | 18.6 | 20.2 |
| Legumes  | 0.5  | 0.6  | 0.7  | 0.7  | 0.5  | 0.5  | 0.7  | 0.6  | 0.3  | 0.2  | 0.3  | 0.2  |
| Grapes   | 1.1  | 0.8  | 1.1  | 1.0  | 0.9  | 0.7  | 0.8  | 1.2  | 1.8  | 1.6  | 1.8  | 1.6  |
| Olives   | 0.6  | 0.6  | 0.9  | 1.0  | 0.8  | 0.9  | 1.1  | 1.1  | 1.4  | 1.6  | 2.8  | 3.4  |
| Potatoes | 0.5  | 0.7  | 0.7  | 1.1  | 0.8  | 0.8  | 1.0  | 1.1  | 1.3  | 1.2  | 0.7  | 0.5  |
| Fruit and vegetables | 0.7  | 0.9  | 1.1  | 1.5  | 1.5  | 1.2  | 1.5  | 1.7  | 2.0  | 2.5  | 2.6  | 2.7  |
| Industrial and other | 0.5  | 0.5  | 0.6  | 0.7  | 0.5  | 0.7  | 1.3  | 1.9  | 2.4  | 3.5  | 3.2  | 2.4  |
| Artificial meadows and fodder | 1.8  | 2.3  | 3.0  | 2.9  | 2.7  | 3.1  | 6.1  | 6.5  | 8.5  | 8.5  | 8.5  | 6.7  |
| Total    | 11.2 | 12.6 | 14.9 | 16.7 | 12.7 | 13.8 | 19.9 | 24.8 | 30.8 | 35.6 | 38.7 | 37.5 |

(continued)
| Table 2.8 (continued) | 1900 | 1910 | 1922 | 1933 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2008 |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| Artificial meadows and fodder | 100  | 128  | 168  | 163  | 151  | 174  | 339  | 362  | 471  | 475  | 475  | 371  |
| Total                   | 100  | 113  | 134  | 149  | 114  | 124  | 178  | 222  | 275  | 318  | 346  | 336  |
| 1900                    | 100  | 113  | 134  | 149  | 114  | 124  | 178  | 222  | 275  | 318  | 346  | 336  |
| Cereals                | 49.0 | 49.9 | 45.5 | 47.1 | 39.6 | 42.4 | 37.9 | 43.0 | 42.6 | 46.5 | 48.2 | 53.8 |
| Legumes                | 4.2  | 4.5  | 4.4  | 4.0  | 3.8  | 3.9  | 3.4  | 2.4  | 1.1  | 0.6  | 0.8  | 0.6  |
| Grapes                 | 9.8  | 6.2  | 7.5  | 5.7  | 6.8  | 5.3  | 3.8  | 4.8  | 5.8  | 4.4  | 4.6  | 4.2  |
| Olives                 | 5.2  | 4.6  | 5.8  | 5.9  | 6.6  | 6.2  | 5.3  | 4.5  | 4.5  | 4.4  | 7.3  | 9.0  |
| Potatoes               | 4.7  | 5.5  | 5.0  | 6.4  | 6.0  | 5.6  | 5.1  | 4.6  | 4.1  | 3.3  | 1.8  | 1.3  |
| Fruit and vegetables   | 6.7  | 7.5  | 7.5  | 9.0  | 11.8 | 8.9  | 7.6  | 6.8  | 6.5  | 7.0  | 6.9  | 7.2  |
| Industrial and other   | 4.3  | 3.6  | 4.1  | 4.3  | 4.1  | 5.1  | 6.5  | 7.7  | 7.9  | 9.9  | 8.4  | 6.3  |
| Artificial meadows and fodder | 16.1 | 18.2 | 20.2 | 17.6 | 21.3 | 22.5 | 30.5 | 26.2 | 27.5 | 24.0 | 22.1 | 17.7 |
| Total                  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  |

Source Agrarian statistics and author’s own compilation
One of the most notable results is that not only has the weight of cereals in grain crop production actually not declined, but it also grew throughout the twentieth century (Table 2.8). The reason is not an increase in the share of cereals in the Spanish diet but rather a reorientation of the production of the cereal system. In fact, the percentage of cereals in all crops decreased until the 1960s because of diet changes, implying a greater varieties and the presence of other Mediterranean diet products (González de Molina et al. 2014, 2017). The percentage began to grow back from that date onwards. Among the crop groups, cereals grew the most between 1950 and 2008 (244%), coming only after olives. This growth must be linked to livestock specialization in the second half of the twentieth century, a factor that underpins most of the arguments put forward in this chapter. In fact, figures in Table 2.9 show that this livestock reorientation concentrated in farmlands. The production of crops for animal feed increased from 49% in 1900 to 65% in 2000 and 2008. In contrast, human food fell from 40% of production in 1900 to 25% in 2008. This reorientation mainly concerned fodder and cereals, although the evolution of fodder was different from that of cereals. Its share in crop production grew to 30% in 1960 and dropped to 17% in 2008 (although in absolute terms, this was one of the groups that grew the most throughout the period).

As we will see in the next section, this production reorientation was related to livestock transformations. It can also be observed in cereal group transformations (Table 2.10). The two cereals that grew the most were barley and corn, both of which are mostly used for stockfeed. In fact, barley replaced wheat as the main cereal since 1980, though over the last decades a growing share of wheat has also been used for animal feed. In the same way, cereals such as rye destined for human consumption and that used to be at the heart of Spanish organic agriculture have become marginal, as in the case of legumes.

### 2.6 Spanish Livestock in the Twentieth Century

In this section, we study the evolution of livestock and its relationship with the land. Livestock is the other biophysical fund element that we considered crucial to agroecosystems. It was a core element for the reproduction of traditional organic agriculture, providing services as essential as manure, traction for heavier work, transport or the provision of food and indispensable raw materials. In recent decades, livestock activity has played an unprecedented economic and nutritional role, which should have attracted greater attention from agricultural historians. There are numerous gaps, however, in this fundamental chapter of the sector’s history.

We overview Spanish livestock transformations throughout the twentieth century, its changing role in the sector as a whole and its relationships with agriculture.\(^5\) To perform the study, we compiled the data of all livestock censuses carried out in Spain between 1891 and 2012. In Annex I, we examine the reliability of these censuses and

\(^5\)Starting with the pioneering works of GEHR (1978, 1979) and García Sanz (1991).
Table 2.9 Destination of domestic extraction of crops (without residues) in Spain in Mt of dry matter and in %

| Year | Human food | Stockfeed | Seeds | Industrial use | Total |
|------|------------|-----------|-------|---------------|-------|
| 1900 | 4.4        | 5.5       | 0.6   | 0.7           | 11.2  |
| 1910 | 5.0        | 6.4       | 0.7   | 0.8           | 12.6  |
| 1922 | 5.7        | 7.7       | 0.8   | 0.8           | 14.9  |
| 1933 | 6.6        | 8.4       | 0.9   | 0.8           | 16.7  |
| 1940 | 4.9        | 6.5       | 0.6   | 0.6           | 12.7  |
| 1950 | 5.3        | 7.2       | 0.7   | 0.8           | 13.8  |
| 1960 | 7.1        | 11.2      | 0.9   | 0.8           | 19.9  |
| 1970 | 8.0        | 14.9      | 1.1   | 1.1           | 24.8  |
| 1980 | 9.3        | 19.3      | 1.1   | 1.5           | 30.8  |
| 1990 | 10.0       | 22.9      | 1.2   | 2.6           | 35.6  |
| 2000 | 9.9        | 25.2      | 1.0   | 2.6           | 38.7  |
| 2008 | 9.4        | 24.3      | 1.3   | 2.6           | 37.5  |

| Year | Human food | Stockfeed | Seeds | Industrial use | Total |
|------|------------|-----------|-------|---------------|-------|
| 1900 | 40         | 49        | 5     | 6             | 100   |
| 1910 | 39         | 51        | 6     | 5             | 100   |
| 1922 | 38         | 52        | 5     | 6             | 100   |
| 1933 | 40         | 50        | 6     | 5             | 100   |
| 1940 | 39         | 51        | 5     | 5             | 100   |
| 1950 | 38         | 52        | 5     | 4             | 100   |
| 1960 | 36         | 56        | 4     | 4             | 100   |
| 1970 | 32         | 60        | 4     | 3             | 100   |
| 1980 | 30         | 63        | 4     | 4             | 100   |
| 1990 | 28         | 64        | 3     | 3             | 100   |
| 2000 | 26         | 65        | 3     | 3             | 100   |
| 2008 | 25         | 65        | 3     | 7             | 100   |

Source Agrarian statistics and author’s compilation
Table 2.10  Domestic extraction of grain cereals in Spain in Mt of dry matter and in %

|       | 1900 | 1910 | 1922 | 1933 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2008 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| Wheat | 2.7  | 3.1  | 3.3  | 3.8  | 2.2  | 2.8  | 3.8  | 4.4  | 4.0  | 4.2  | 5.5  | 6.0  |
| Barley| 1.3  | 1.4  | 1.6  | 2.1  | 1.3  | 1.5  | 1.7  | 3.5  | 5.9  | 8.3  | 7.9  | 9.1  |
| Oats  | 0.2  | 0.4  | 0.4  | 0.6  | 0.4  | 0.4  | 0.4  | 0.5  | 0.4  | 0.7  | 0.9  |      |
| Rye   | 0.5  | 0.6  | 0.6  | 0.5  | 0.3  | 0.4  | 0.4  | 0.3  | 0.2  | 0.2  | 0.2  | 0.2  |
| Corn  | 0.5  | 0.6  | 0.6  | 0.6  | 0.6  | 0.5  | 0.9  | 1.6  | 2.0  | 2.7  | 3.5  | 3.2  |
| Rice  | 0.1  | 0.2  | 0.2  | 0.3  | 0.2  | 0.2  | 0.3  | 0.3  | 0.4  | 0.5  | 0.7  | 0.6  |
| Others| 0.1  | 0.0  | 0.1  | 0.1  | 0.0  | 0.0  | 0.0  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  |
| Total | 5.5  | 6.3  | 6.8  | 7.9  | 5.0  | 5.9  | 7.6  | 10.7 | 13.1 | 16.5 | 18.6 | 20.2 |

|       | 1900 | 1910 | 1922 | 1933 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2008 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| Wheat | 49.8 | 49.8 | 48.3 | 48.4 | 43.2 | 48.5 | 50.6 | 41.0 | 30.7 | 25.5 | 29.5 | 29.5 |
| Barley| 23.3 | 22.2 | 24.3 | 26.5 | 25.7 | 25.3 | 22.3 | 32.7 | 45.3 | 50.4 | 42.5 | 45.0 |
| Oats  | 4.2  | 6.0  | 6.2  | 7.3  | 8.3  | 7.1  | 5.8  | 4.1  | 3.5  | 2.4  | 3.5  | 4.4  |
| Rye   | 9.3  | 9.5  | 8.8  | 6.1  | 6.5  | 6.6  | 5.3  | 2.5  | 1.5  | 1.5  | 0.9  | 0.9  |
| Corn  | 9.6  | 8.8  | 8.3  | 7.7  | 11.8 | 8.0  | 11.3 | 15.1 | 15.0 | 16.1 | 19.0 | 16.1 |
| Rice  | 2.7  | 2.9  | 3.4  | 3.2  | 3.8  | 3.9  | 4.5  | 3.1  | 2.8  | 2.9  | 3.9  | 2.9  |
| Others| 1.0  | 0.8  | 0.8  | 0.7  | 0.8  | 0.5  | 0.2  | 1.5  | 1.3  | 1.1  | 0.8  | 1.1  |
| Total | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  |

Source Agrarian statistics and author’s compilation
livestock counts are corrected wherever reliability problems were found. The annex explains the method used to verify and correct the figures (Table 2.11).

Overall, Spain’s livestock changed fundamentally throughout the twentieth century, shifting from organic-based livestock, closely linked to the territory, to livestock of an industrial nature, mostly stabled, landless and thus much more dependent on stockfeed, industrial inputs and international trade. This change brought about notable growth of total herds, from 54 million heads to 838 million heads, with significant transformations to their composition, destination of products and services, management and feeding. In terms of live weight, the livestock multiplied by 2.4, from 2.8 million tons at the beginning of the twentieth century (with peaks

| Years | Bovine | Ovine | Goats | Porcine | Equine | Poultry | Rabbits | Total |
|-------|--------|-------|-------|---------|--------|---------|---------|-------|
| 1900  | 690    | 543   | 102   | 141     | 636    | 43      | 8       | 2163  |
| 1910  | 856    | 601   | 121   | 180     | 713    | 50      | 9       | 2530  |
| 1922  | 1173   | 550   | 116   | 251     | 756    | 58      | 11      | 2915  |
| 1933  | 1339   | 630   | 151   | 373     | 794    | 67      | 13      | 3366  |
| 1940  | 1454   | 662   | 225   | 430     | 723    | 54      | 15      | 3562  |
| 1950  | 1422   | 544   | 175   | 292     | 754    | 53      | 7       | 3248  |
| 1960  | 1198   | 648   | 100   | 309     | 655    | 90      | 78      | 3078  |
| 1970  | 1402   | 545   | 79    | 315     | 418    | 661     | 39      | 3458  |
| 1980  | 1681   | 485   | 70    | 634     | 203    | 1334    | 206     | 4612  |
| 1990  | 1876   | 858   | 124   | 1043    | 159    | 1258    | 45      | 5363  |
| 2000  | 2238   | 826   | 90    | 1370    | 101    | 2007    | 88      | 6720  |
| 2008  | 2215   | 705   | 91    | 1547    | 101    | 2078    | 89      | 6826  |

*Source* Corrected livestock censuses (see Annex I)
of around 3.4 million in the 1930s), to almost 7 million in the middle of the last decade (Table 2.11). This huge increase would also have considerable environmental impacts, especially those generated by intensive livestock farming and the increase of GHG emissions (Lasaletta et al. 2014a, b).

The pace of change during the twentieth century, however, was irregular. Livestock increased by 55.6% between 1900 and 1940, stalled between 1950 and 1960 and rose again rapidly between 1970 and 2008 (97%) (Graph 2.11). The first third of the twentieth century was a period of livestock growth. Significantly, this increase was consistent with a notable rise in agricultural production. Throughout the first 30 years of the twentieth century, most of biomass Domestic Extraction growth concentrated in cultivated lands. These cultivated lands also continued to expand at the expense of pasture and coppice. However, this fact did not affect the growing numbers of livestock, since the biomass aimed at livestock feed also increased. The reason was the rising amounts of stockfeed harvested on farmlands (forage crops, artificial meadows, cereals and legumes for animal feed, harvested residues, etc.), leading to a rise in its share of total stockfeed from 49% in 1900 to 54% in 1930. This was due to a moderate growth inland productivity that took place during the first decades of the twentieth century and increasing domestic extraction in the pastures, despite reductions in their surface area. Imports of stockfeed were not significant during these years.

After 1936, the analysis of censuses and livestock production yields show opposite and seemingly incompatible results (Graph 2.11). Apparently, livestock must have declined considerably during the Civil War, a drop that is not reflected in the census after 1936. This census presents an even larger livestock than that of 1933. An examination of the censuses described in Annex I show that 1940 and 1950 data appear to be plausibly adjusted to livestock feeding capacity. How can we explain this ostensibly odd livestock evolution? Our data do not invalidate the sector’s likely depression after livestock destruction during the war, but they show an abnormally high number of offspring in the 1940s’ census. Our hypothesis, which would need to be confirmed by a subsequent study, is that considerable efforts must have been made

Graph 2.11  Evolution of live livestock weight in thousands of tons
during those years to recover the livestock, allowing many more offspring to reach adulthood. This would explain that livestock production was as low as shown in the statistics, while the censuses indicated such high values. On the other hand, during the second half of the twentieth century, the Western World adopted an industrial or intensive livestock model, closely linked to the considerable increase of products of animal origin in diets. The Civil War and the Autarchy delayed Spain’s adoption of this model, in lockstep with the industrialization of agriculture and of the Spanish economy generally (Infante et al. 2015).

Circumstances under early Francoism help to understand the extent of the transformations undergone since the sixties. Contrary to previous reports (Domínguez 2001a, b), livestock industrialization, and that of agriculture as a whole, did not concern an agricultural sector such as that had existed before the war. The sector had gone back to being almost entirely organically based and its territorial balance had been shattered by two decades of autarchic agricultural policy. This point is relevant because peasants were much less able to adapt to market-induced changes and the State’s food policies than in the first third of the twentieth century (Fernández Prieto 2007).

Livestock’s internal composition and its end uses also underwent considerable transformations that we can categorize into four major groups. The first series of changes is related to labor and transport livestock, which was characteristic of agriculture prior to mechanization. Labor and transport livestock lost ground to livestock aimed at human food. The reason is that livestock was replaced by internal combustion engines, both for mechanization and transport (since trucks are used more than rail in Spain). In fact, equine livestock became almost marginal over time. Horses, mainly dedicated to recreation or sports activities, barely reached 240,000 heads nationwide in 2008, while mules did not exceed 28,000 heads and donkeys 55,000. In contrast, at the beginning of the twentieth century, equine livestock represented 29.4% of live livestock weight, to which we should add a large part of the cattle, which then represented 32% of the total.

The second major transformation was the loss of relative importance of traditional livestock breeding. Ovine and goat livestock, once tied to pasture and forest lands according to their feeding needs and breed and thus better adapted to land and climate conditions, shrunk and lost importance throughout the century. At the beginning of the twentieth century, both types of herds represented 29.1% of live weight. In 2008, sheep accounted for little more than 10% of herds, specialized in the production of lambs and to a lesser extent, of milk for cheese. Goat livestock, on the other hand, represented only 1.3% and was dedicated to the same purposes as sheep.

The third transformation was that experienced by cattle. In 1900 beef cattle represented 31.9% of live weight and represented the main species. Today, cattle’s relative weight has increased slightly, reaching almost one-third of the total. However, big changes have taken place within this category, related to breeds, specialization, and feeding. A large share of cattle used to be dedicated to fieldwork and to a lesser extent to transportation. The use of yokes of oxen was very common for tillage or threshing at the beginning of the last century. Oxen-pulled carts were commonly used to transport goods. Cows were dedicated to breeding and punctual agricultural tasks.
Most of the milk was thus used to breastfeed calves, in turn rarely aimed at meat production. This livestock’s life cycle exceeded 10/12 years. They were sacrificed once their useful life—whether in the field or for reproduction—had come to an end. Beef livestock predominated in the center and south of the peninsula, while mixed livestock, also dedicated to the production of meat and milk, was prevalent in the north. This diversified use was gradually substituted by livestock specialized in meat and milk. Breeds were improved to maximize production, they were stabled and fed with compound feed.

Porcine livestock followed a similar path. At the beginning of the century, pigs represented almost 6.5% of livestock in terms of live weight and the predominant breeds were those belonging to each agrarian area of the country. This type of livestock was fattened, slaughtered and preserved as cold meats and sausages to serve as a supply of quality proteins for the whole year. It was associated with the survival of the poorest strata of the peasantry. Pigs’ diet was based on oak acorns in pasture land and forests and, to a lesser extent, on domestic organic waste. Today porcine herds represent 22.7% of livestock, coming after cattle and poultry in total livestock weight. Pig breeding has now become a highly industrialized activity that provides meat at affordable prices. It represents one of the pillars of the Spanish diet. They are bred in large intensive farms, are stabled on a permanent basis, given compound feed and undergo frequent veterinary treatments.

The fourth and final series of transformations concerned poultry. Breeding, especially that of poultry, is today a major livestock activity also involving intensive production and permanent stabling. In 2008, poultry represented 30.4% of total livestock live weight with almost 737 million heads dedicated to the production of meat and eggs, with increasingly shorter breeding cycles and fed with grains and concentrates. Poultry breeding, feeding, and use have radically changed. At the beginning of the last century, chickens were raised to produce eggs and when production declined they were slaughtered for meat or other dishes. Chickens’ diet competed with human food, as in the case of pigs, hence their limited numbers. They were fed household organic waste or crops. Rabbits followed a similar trend but to a lesser extent. Once the most popular hunting product, they became farm animals.

To summarize, these transformations reflect the reorientation of Spanish livestock throughout the industrialization process from a multifunctional use of animals, typical of traditional organic agriculture (suppliers of food, labor, manure and raw materials such as wool, fats, skins, etc.) to livestock centered on the production of food mainly for human consumption. The species that grew the most in terms of live weight and number of heads were pigs and poultry, that is, monogastric livestock, to the detriment of herbivorous livestock, with the consequences that we will see below.

Livestock feeding thus depended mainly on pastures and harvest residues (45% and 25%, respectively) until the 1960s. From then on, it began to depend on quality feed from crops and industrial processing. Since the 1980s, an increasing share of this feed has come from foreign trade. In 2008, 48% of stockfeed came from primary crops and 15% from net imports (Graph 2.12). Meanwhile, a large part of the agricultural area used was abandoned or the pastures were underutilized, as shown by the drastic reduction in grazed biomass.
Livestock, once closely linked to agriculture and pastures, lost part of its ties to the land and the food it produced. As is commonly known, in organic agrarian systems, livestock not only provided food products to society, but also played an essential part in sustaining agricultural activity, both in terms of work and replacement fertility. For this reason, simply comparing this type of livestock with later livestock, especially with intensive livestock farming, in terms of productivity and market links, is inappropriate. The industrial livestock model is compatible only with industrialized agriculture that relies on industrial inputs. As we have pointed out, the model’s adoption is mostly linked to profound changes in the animal feeding model. The model favors breeds that are dependent on grain food thus increasing reliance on industrial feed. Over the last fifty years, this dependence has relied on growing biomass from crops to the detriment of pastures, and on the increase of feed imports.

Meanwhile, livestock has become increasingly central to Spanish agriculture as a whole. Its significance in monetary terms was highlighted in the first section of this chapter, but it can also be appreciated in biophysical terms. Domestic Extraction for animal feed went from 27.8 Mt of dry matter in 1900 to 39.4 Mt in 2008, from 56% to 57.5% of total extraction. Furthermore, livestock has grown at a much higher rate than the domestic availability of stockfeed (a 215% increase in live weight between 1900 and 2008 compared to an 82% increase of stockfeed). As a result, levels of Domestic Extraction have shown to be insufficient to maintain the livestock growth rate and its food requirements, explaining the need to resort to feed imports.

2.7 Livestock Production

The evolution of livestock production logically reflected the transformations reviewed above. We can decompose its analysis into three major periods: first, that of
continuous production growth until the mid-thirties, marking the end of the agrarian
crisis at the end of the century; second, the period of crisis including the Civil War
and autarchy that lasted until the mid-sixties; and a third and final period of accel-
erated production growth, especially of meat and milk, from the 1960s until today.
The first period was characterized, as we have seen, by sustained growth of livestock
leading to increased livestock production. Nevertheless, the production downturn
of the last third of the 19th century was not overcome until the 1920s (García Sanz
1991; Garrabou and González de Molina 2010). Meat production grew considerably,
by 86% compared to 1900 (Table 2.12), which explains why apparent consumption
could increase from 14.1 kg per capita per year in 1900 to 21.1 kg in 1933, that is an
increase of 50% (González de Molina et al. 2014, 167). This level of consumption
would not be reached until the 1960s (González de Molina et al. 2017, 2348). Pork
and beef grew the most, by 157 and 86%, respectively (Table 2.12). Egg production
also grew (55.6%) as well as milk production (42.1%). Within milk production, cow
milk grew the most, by 70% (Table 2.12). During those years, milk breeds were
introduced from Switzerland and Holland.6 Farms specializing in these types of live-
stock emerged in or around main cities. Other livestock productions remained stable
or grew slightly, for example in the case of wool or honey production.

As mentioned in the previous section, the Civil War had a major impact on live-
stock activity, in line with falls in production and agricultural productivity. Biophysical
production data obtained from official post-war statistics show reductions in food
available for livestock, due, above all, to the drop in grains and residues from culti-

| Table 2.12  | Livestock production in tons of dry matter, 1900–1950 |
|-------------|------------------------------------------------------|
| 1900   | 1910   | 1922   | 1933   | 1940   | 1950   |
| Beef   | 53.838 | 66.740 | 99.928 | 105.626 | 41.514 | 52.763  |
| Lamb meat | 44.487 | 49.257 | 50.942 | 52.892  | 26.429 | 39.289  |
| Goat meat | 9.468  | 11.238 | 11.956 | 14.121  | 5.228  | 6857    |
| Pig meat | 40.641 | 51.889 | 83.351 | 104.444 | 73.397 | 82.522  |
| Horse meat | 0     | 0      | 0      | 0       | 1.632  |         |
| Poultry meat | 4.115 | 4.813  | 5.545  | 6.403   | 6.255  | 4.673   |
| Rabbit meat | 491   | 574    | 661    | 764     | 3.342  | 4.453   |
| Total meats | 153.040 | 184.509 | 252.383 | 284.249 | 192.190 | 313.347 |
| Eggs    | 12.728 | 14.886 | 17.150 | 19.805  | 19.347 | 31.435  |
| Wool    | 21.933 | 24.285 | 22.190 | 25.442  | 32.605 | 24.762  |
| Cow milk | 104.417 | 127.514 | 134.290 | 177.739 | 226.804 | 259.956 |
| Sheep milk | 17.147 | 18.986 | 29.013 | 8.672   | 13.748 | 13.610  |
| Goat milk | 36.577 | 43.411 | 33.129 | 38.223  | 38.749 | 33.155  |
| Honey   | 4.908  | 4.908  | 4.908  | 4.908   | 5.149  | 5.391   |

Source Agrarian statistics and author’s compilation

6Ministerio de Fomento (1892, 1920).
vated areas. This led to more intense use of pastures than in the 1930s (Graph 2.12) and is consistent with the drop in total livestock production (12%) and especially meat (−45%) reflected in the statistics (Table 2.12) compared to 1933. A decline in agricultural production between 1940 and 1950 compared to 1936 and the impossibility to sustain raw material imports to manufacture chemical fertilizers made it unfeasible to maintain the livestock feeding model of the first third of the twentieth century as described above. Based on the data in Graph 2.12, maintaining the size of livestock as indicated in the 1940 and 1950 censuses implied a much better use of pastures than during the first third of the twentieth century.

The third and last period coincides with the industrialization of Spanish agriculture and livestock. As we will see in Chap. 6, this process was linked to big increases in demand for eat and milk (Domínguez 2001a) and to the rapid adoption of consumption patterns moving ever further away from the Mediterranean diet (González de Molina et al. 2013, 2017). The Franco regime also directly encouraged the model’s adoption via its agricultural policies, which fostered intensive or industrial livestock and the production of cereals to manufacture feed, at the expense of cereals intended for human consumption (Clar 2005). Both livestock slaughtering (Graph 2.13) and milk production (Graph 2.14) grew considerably between the mid-1960s and the mid-1980s (Table 2.13).
### Table 2.13 Livestock production in tons of dry matter, 1960–2008

|                | 1960      | 1970      | 1980      | 1990      | 2000      | 2008      |
|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Bovine meat    | 81.744    | 148.877   | 212.630   | 256.673   | 341.350   | 330.754   |
| Sheep meat     | 58.492    | 74.284    | 77.361    | 128.693   | 132.289   | 97.780    |
| Goat meat      | 5.844     | 6.401     | 5.731     | 8.819     | 7.890     | 5.203     |
| Pig meat       | 135.268   | 256.874   | 547.244   | 1,013.979 | 1,611.507 | 1,888.429 |
| Horse meat     | 6.298     | 5.458     | 3.853     | 2.325     | 2.475     | 2.216     |
| Poultry meat   | 20.962    | 207.108   | 365.622   | 388.947   | 545.374   | 604.380   |
| Rabbit meat    | 4.739     | 11.306    | 45.616    | 35.895    | 45.984    | 30.600    |
| Total meat     | 313.347   | 710.308   | 1,258.058 | 1,835.332 | 2,686.869 | 2,959.362 |
| Eggs           | 46.535    | 97.860    | 134.455   | 131.665   | 133.341   | 154.882   |
| Wool           | 25.575    | 21.660    | 18.093    | 23.981    | 26.104    | 23.191    |
| Cow milk       | 316.742   | 523.777   | 707.568   | 718.461   | 755.555   | 751.934   |
| Sheep’s milk   | 30.860    | 30.326    | 25.377    | 35.685    | 45.711    | 56.314    |
| Goat’s milk    | 36.208    | 33.155    | 33.291    | 43.694    | 50.486    | 56.372    |
| Honey          | 6.295     | 6.816     | 9.883     | 18.255    | 25.071    | 25.081    |

Source: Agrarian statistics and author’s compilation

After this date, milk production stabilized because of Spain’s entry into the European Economic Community and the establishment of the quota system. Meat production continued to grow, however, until the beginning of the century (Table 2.13). This growth is clearly correlated with the evolution of livestock herds (Graph 2.11). As we saw, sheep and goats lost relative weight in overall livestock. Although livestock grew by 75% between 1965 and 2008, poultry (354%) and pigs (452%) grew the most because of rising domestic demand for low-priced meat (González de Molina et al. 2017) and even for export. The industrial model undeniably permitted market-oriented livestock production to grow to an extent that would have been unthinkable in traditional organic agriculture. However, this growth came at the expense of a quasi-complete rupture of ties between livestock and the land, as well as an almost entire loss of traditional multifunctionality.

### 2.8 An Overview of Spanish Agriculture Industrialization

Changes caused by the industrialization of agriculture profoundly affected both the entity and the final use of biomass produced by agroecosystems. These changes were due to ongoing efforts to increase the size of commercially oriented biomass production to meet the growing demand for raw material, as well as human and animal food. Any increase in biomass production comes with its corresponding increase in land costs. Compensation was thus sought through changes in labor and technology. Agricultural production grew essentially in two different ways: on the one hand, the
total amount of biomass per hectare increased and, on the other, an increasing share was appropriated. We can synthesize these changes taking into account the scale of the process, as described below.

At an aggregate scale, the changes consisted of the increase of $NPP_{act}$, which was more notable in croplands and lower in woodlands. This increase was at any rate far lower than the extent of growth based on a conventional analysis, measured in monetary terms or fresh matter, primary crops and some residues. Within NPP, croplands (47%) and woodlands (42%) grew as well as pastures, though to a much lesser extent (7%). Second, patterns of use of $NPP_{act}$ changed. The growth of wooded areas and the loss of use of forest firewood, as well as the growth of woody crops, increased the accumulated biomass. On the other hand, Domestic Extraction increased moderately and unharvested biomass somewhat decreased, especially in croplands. Finally, reused biomass grew by 48%, i.e., more than total NPP, reflecting Spanish agroecosystems ever-greater orientation towards livestock. In turn, the increasing size of appropriated biomass was sustained because of extraction efforts, that took place more in croplands than in pastures and woodlands, despite the fact that woodland areas almost tripled since 1900. Croplands grew steadily until the 1970s and then regularly declined until 2008. Cultivated land surface areas rose by merely 5% when comparing surface areas in 2008 with those of 1900. Consequently, productivity per hectare of this type of land increased by almost 50%. Production pressure on Spanish agroecosystems thus centered on this type of land.

In terms of Domestic Extraction in croplands, production efforts centered in turn on primary crops, instead of “residues”. Among all extracted biomass components, biomass from primary crops grew the most, more than tripling. In turn, the bulk of extracted biomass concentrated on crops of greater commercial value, resulting from production specialization and Spanish agriculture relations with markets. Added to this, agricultural production since the 1960s, and more intensely since the 1990s, centered ever more on stockfeed production, sustaining livestock specialization that, as we have seen, the Spanish agricultural sector has been experiencing in recent decades.

In summary, Spanish agriculture over the last century evolved towards increasing production commodification and significant changes in the patterns of biomass use. Both production and technological efforts have been directed towards maximizing the share of biomass of highest commercial value, entailing, as we will see, the reduction of crop multifunctionality. In other words, agricultural production growth has been much greater than the growth of agroecosystems’ NPP. The process went through three distinct phases: the first period lasted until the 1960s and was characterized by the growth of agricultural production; over a second phase, livestock played a major role, and agricultural production was subjected to stockfeed; in the third and final phase, livestock production continued to increase, not only at the expense of agriculture, that stabilized production since the beginning of this century (as confirmed by the provisional data presented for 2015), but also at the expense of international trade, that is, of other countries, as commented earlier.

At landscape or at agroecosystem scale as a whole, Spanish agriculture’s industrialization led to increasingly segregated land uses, and the loss of productive synergies based on agrosilvopastoral integration. This resulted from certain land use types tak-
ing over others and the rupture of the previous ecosystemic equilibrium, in turn reflecting growing specialization trends. As we have seen, production efforts concentrated on cultivated lands, thus perpetuating the process of “agricolonization” or the encouragement of agricultural use that had already been taking place since the nineteenth century. Livestock growth mainly relied on intensive landless farms, without any food ties to the land. In this way, close ties within agroecosystems between agricultural and livestock activities, not only in terms of food but also in terms of replenishing animal fertility and traction, were broken up into two almost distinct activities. The introduction of synthetic chemical fertilizers and mechanization rendered use segregation viable. The same phenomenon affected forest lands, dedicated to forestry or conservation policies, that often excluded or restricted other possible uses. In short, the trend towards production specialization and intensification has been a growing requirement of Spanish agriculture’s growth model that has tended to impose specialized land uses on the territory based on market demands, soil attitude, or the endowment of natural resources especially water. The result is loss of geodiversity and spatial heterogeneity. Flows of energy and materials, once more local and contained, have ended up being globalized and of fossil origin.

At a farm scale, productive specialization entailed the following consequences: a strong tendency to suppress crop associations and polycultures; the simplification of rotations and their later suppression; the quasi elimination of fallows or their substantial reduction; and the fostering of crop alternatives governed by market demands. Agriculture shifted from crop and plant heterogeneity and their layout adjustments to monocultures, entailing significant reductions of genetic, structural and functional diversity (Gliessman 1998). If at the agroecosystem scale this phenomenon progressively reduced the capacity of agroecosystems of autonomous replacement fertility, at a farm level, the relative demand for fertilizers significantly increased. The spread of chemical fertilizers made this fundamental change possible. It sparked, in turn, the desire to suppress fallow and legume sowing. Cultivation of legumes was reduced to less than half since 1900. At that time, it represented 1.76% of total agricultural production in fresh matter and was a habitual part of wheat and barley crop rotations. In 2008, it represented only 0.25% and had disappeared from many cereal productions. As we will see in Chap. 5, this led to a reduction in the flow of nitrogen from symbiotic fixation and the ability of agroecosystems to replace soil fertility by themselves.

At the crop level, very important transformations affected both plants’ morphologies and their uses. This evolution also applies to different livestock species. At the beginning of the century, when agriculture and livestock were still organic, cultivated plants and livestock species each served different purposes. Livestock provided meat and milk, but also carried out agricultural tasks or transported goods. In a previous study, we referred to Cantabrian Cornice cattle, of “mixed aptitude”, i.e., both for agricultural and livestock use (Fernández Prieto 1992). High cereal stalks were aimed at producing large amounts of straw, the basis of horse stockfeed. Precisely because of progress in crops, a type of livestock was developed that could feed on croplands without competing with human food.
The aim of farmers was to maximize the harvestable parts of plants, especially those with highest commercial value; in turn, the aim of ranchers was to select the species and breeds generating the largest quantity of meat and milk yields. Thus, in the case of phytomass, seeds were selected and improved to concentrate photosynthetic capacity in the marketable part of cultivated plants, for example, by modifying cereals’ morphology to concentrate more biomass in grains and less in straw. The process was applied to most arable crops and led to the considerable growth in grain yields per hectare. The “Green Revolution” was largely based on the genetic change that produced crop types with a lower “waste” weight. The phenomenon is visible in the changing relationships between grain and straw in cereals and legumes (Graph 2.15). Traditional cereal and legume varieties had high straw stems, therefore less grains, and were an essential part of animal feed. With the industrialization of agriculture, these were replaced with varieties that produced more grains and less straw (Graph 2.15).

In the case of woody plants, breeding and changes to management practices consisted of translocating stem and leaf biomass to the harvestable fruit. Multifunctional usage has been superseded by a preference for the commercial use of fruits. The case of olive-growing is paradigmatic: from producing firewood, foliage and olive kernel oil for livestock, table olives, domestic lighting, and edible oil, olive groves now almost exclusively produce oil, leading to changes in grove management and tree morphology (Graph 2.16) (Infante-Amate 2014; Infante-Amate and González de Molina 2013).

All these changes explain the remarkable increase of some crop yields (620% in the case of corn between 1900 and 2008 or 332% in the case of wheat), a much higher growth than that of NPP per hectare in cultivated areas (50%) or Domestic Extraction per cultivated ha (102%). In other words, the land’s biophysical productivity has grown at a much lower rate than grain or fruit yields per hectare. The reason is the concentration of biomass in grain or harvestable fruit and, therefore, the reduction of harvest residues. Another factor is the reduction of grass (e.g. weeds) that accom-
pancies crops based on mechanical or chemical means. Moreover, the introduction of improved and hybrid seeds, in the quest for maximum grain yields or the selection of woody plants varieties with high yields have led to a substantial loss of genetic diversity. This process has favored a more frequent and intensive use of fertilizers. The result has been the abandoning of seed varieties that were better adapted to soil and climate conditions and that, as far as we know, demanded less nutrients (Carranza et al. 2018).

In the case of livestock, a radical transformation has taken place. As livestock and production grew, extensive stock farming became less important and resorted more often to off-farm feeding. The bulk of livestock has lost its land ties and is stabled in intensive farms. Feed from abroad is often used, and breeds specialized in the production of meat or milk are imported from other countries. Labor livestock has almost completely disappeared and thanks to cheaper feed, monogastric livestock now have an unprecedented role. Ever bigger quantities of straw have been either burned or left on the farm. What remains of extensive stock farming is today the refuge of the traditional livestock breeds.

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