Number, Size and Energy Consumption of Draught Animals in European Agriculture

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This paper provides information on the number of draught animals of various kinds that were used in agriculture in Europe during the nineteenth and early twentieth centuries, and the sources and assumptions we have used in making our estimates. Tables provide animal numbers in thousands for each country at benchmark dates.

The aim of the paper is to provide a methodological approach to assessing the availability of draught power over time, and an explanation of how the available statistical information from various European countries can be employed to this end. This paper will be linked to a more detailed analysis of the role of draught power in raising agricultural output and factor productivity in European agriculture in the period 1800-1914.

However, our main concern has not been to estimate draught power (although it would indeed be desirable to know this figure), but the energy consumption of draught livestock. In other words, we are interested at this stage in energy inputs into the animals, not the final consumption of energy used for useful work, or indeed the power output of the animals when working. The energy consumption of the animals is energy contained in the fodder that they consume. This is in turn a function of the animal's size, the length of time spent working, and the intensity of their work. The last two figures could only be very roughly estimated on the aggregate level of the agricultural sector across nations, and we have not attempted to do this. We have however built a simple model of likely energy consumption levels based on estimates of the average size of animals at benchmark dates. This is the subject of the second part of the paper.

The paper proceeds on a country-by-country basis. While the principles underlying the calculations made for each country are generally the same, the procedures followed by contemporary statisticians who assembled the data varied, as will be seen. This has required methods of estimation tailored to suit each individual country.

Part One: Draught Animal Numbers

In this article we present new series for draught animals available for use in agriculture for all the countries concerned. The livestock series are based on a mixture of already available series, previously available data adjusted to improve accuracy, and material collected from printed statistical sources. However, almost inevitably, inconsistencies remain between series that are assembled from data collected using different premises. For example, they contain aggregates of different animals, in part because of genuine differences in agricultural practice (thus it is of no importance that donkeys or mules do not appear in the English series). Wrigley's schema did not embrace donkeys or mules, but they are of some significance in Mediterranean agriculture, including that of southern France. There is rather less data on the amount of work performed by these beasts, or what they consumed, than for horses and oxen. This is unimportant for England and Wales, or the Netherlands, where nearly all work was done by horses, but is probably significant elsewhere. Equally, not all series contain cows, although they were widely employed for draught purposes and outnumbered draught oxen in Germany as late as the beginning of the twentieth century. For aggregating the number of animals we first use the principles outlined by Wrigley in 1988 and 1991 to calculate 'raw' data of livestock numbers, where one ox equals two-thirds of a horse (exactly the proportion also employed by contemporary German statisticians). Similar allowances are made for other animals: one mule is assumed to equal one horse, a donkey half a horse, and a cow one-third of an ox, i.e. two-ninths of a horse.

A very important further problem is assessing how many of these animals out of the national herd were actually used in the agricultural sector. This disaggregation is rarely made although in some countries total numbers of beasts give a very misleading impression as to those available for draught use in agriculture. In England the number of horses employed on-farm is very clearly recorded from 1867. In estimates from the early nineteenth century, it seems that agricultural horses made up around 60% of the total number of horses, less than half by 1870 and a mere third by the start of the twentieth century. In 1852 72% were so employed in France, falling to 53% by 1890. In the German states as a whole the first comprehensive statistics from 1873 suggest that 70% of horses were predominately used in agriculture, and a

similar level in the 1890s.[1] The share in Sweden was also about 70% in the early nineteenth century, and declined slightly over the century. Similar estimates have to be taken for the proportion of oxen, mules and donkeys used for draught power in agriculture, although here the statistical data is rather sparse and less reliable. Many of these animals that dwelled on farms were certainly used in the transport sector, but we have no accurate measure of the extent of this use. The figures also need to be adjusted for the age at which horses and oxen generally started working, where the proportion of foals and calves is not explicitly recorded. For example, although in 1873 some 70% of all German horses were employed in agriculture, 81% of horses of a working age were so employed.[2]

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Sweden

Year	*Horses*	*Oxen & Cows*	*Horse Equivalent*
1815	280	278	466
1840	293	319	507
1850	296	333	519
1860	299	352	535
1870	295	344	525
1880	320	378	573
1890	336	367	582
1900	367	348	600
1913	454	275	638

Horses

The total number of horses was reported annually during the nineteenth century by county agricultural societies for each parish and city within its area up until 1916. This information was not reliably updated and it did not reveal what use the horses were put to. Large local investigations were undertaken in 1916, not least to gain information of the number of horses that could be mobilized in case of Swedish involvement in the World War. The share for horses below 3 years was a rather stable 15-16%. For the year 1901, 4.4% of all horses

[1] Prussian statistics from 1861 suggest that the proportion was a few per cent higher in that year. *Statistisches Jahrbuch des deutschen Reiches*, (1887).
[2] *Statistik des deustchen Reiches,* Bd.VIII (1874)

were used in urban centres (more if only the share of adult horses is calculated).[3] This amount of horses clearly should be deducted from the total horse stock when we estimate the number of horses used for draught power in agriculture. The local investigations of 1916 usefully divided the horses into two different uses: workhorses, and riding horses and carriage horses. On average 1916-1918 the workhorses amounted to 53% and the riding and carriage horses 4% of total horses.

The procedure for reaching an estimate of agricultural workhorses has been the following:

1. Start with the total number of horses
2. Deduct young horses below 3 years. This figure is generally recorded in statistics and the share is around 15-16%.
3. Deduct horses used in the cities, for transportation and industry. In 1901 this was 4.4%.
4. Deduct riding horses and carriage horses in the countryside. Only part of the 4% that were categorized as riding and carriage horses were used in the cities. Some indication of the proportion of heavy workhorses and light riding horses among the city horses is provided for a few cities in the local investigations. In Malmö 61% were heavy workhorses, but in Filipstad and Luleå there were only working horses. We thus assume that some 3% of the total were riding horses and carriage horses in the countryside.[4]
5. Deduct horses used for military purposes. They were around 2%.[5]
6. Deduct horses in the countryside that were mainly used for transportation and industry. The number of horses used for personal transportation during skjutsväsendet was only around 1 000 - 3 000 horses, thus less than 1% of the total. However the total use of horse and oxen time for transportation and industry (work other than agricultural work) has been estimated to be 10% of adult working horses.[6]

20% of the horses aged over three years were deducted on the basis that they were used for non-agricultural work.

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[3] BiSOS series Q, Agriculture, 1901.
[4] BiSOS series Q, Agriculture, 1901.
[5] Kocken, 'Krigshästen från äldsta tider'; Ribbing, 'Hästen i vår nuvarande armé'; Furugren, 'Arbetshästen och svensk hästavel.
[6] Krantz, *Transporter och kommunikationer.*

Oxen and cows

Oxen and to some degree cows were used as draught animals in Swedish agriculture. The cow was the poor man's ox, especially preferred by poor crofters, since it could be used both for milk and for draught power, although the latter could be detrimental to the former. Often two cows were used in a pair, or one ox went in pair with one cow. The habit of using cows as draught animals increased along with the number of landless and land poor people over the course of the nineteenth century.

Oxen were not used as draught animals for their entire lives. This means that the total amount of oxen in the statistics must be reduced to account for those not actually working. In fact, in calculating oxen as 'horse equivalents' one must also remember that they were used differentially and thus consumed different amounts of fodder dependent on age.[7] One cost advantage with the ox compared to the horse was that the ox had its highest sales value when fattened for slaughter. In especially oxen rich parts of Sweden like Småland a special trade with oxen developed, with far- reaching specialization, where some farms took care of the breeding, others took care of the training, others used the draught oxen, and yet other farms with rich fodder availability took care of the final fattening, and then the oxen were sent for slaughtering. On basis of the cycles in this trade we can say that below three years of age the ox was not yet tamed and ready for work. Then the ox worked for roughly four years and then was put to final fattening for one and a half years and then eventually slaughtered.[8] On the basis of this information it seems reasonable to assume that 50% of all oxen (including the calves) were used for work. In other parts of the country with less specialization and fattening options it is however likely that the oxen worked longer before eventually being slaughtered, so a more reasonable assumption is that 60% of oxen all ages worked. Out of the adult oxen population, which is provided in the statistics, we have assumed that 80% of them worked in agriculture. For Swedish cows we assume the same proportion used for draft purpose as in Germany (see below).

[7] Collins, 'The farm horse economy', pp.89-91.
[8] Sigvardsson, *Oxen,* p 22; Peterson, 'Häst eller oxe', pp.46-7.

Germany

Year	*Horses*	*Oxen & Cows*	*Horse Equivalent*
1815	1656	1924	2945
1840	1796	2143	3232
1850	1868	2095	3272
1860	2193	2178	3652
1870	2319	2122	3741
1880	2187	2080	3581
1890	2522	2164	3972
1900	2895	1970	4215
1913	3145	2210	4626

Horses

Surveys of horse numbers in the German states occurred intermittently from the 1810s onward. Nearly every state produced comprehensive surveys in the early 1860s, and from 1873 truly national surveys of livestock were conducted.[9] These took place in 1883, 1892, 1900, and with increasingly regularity until becoming annual after 1912. It should also be noted that data on donkeys and mules also survives, but these were too insignificant in number to be included in the analysis. All of the national surveys from 1873 provide data on horses either used 'predominately in agriculture', or from the 1890s, explicitly those used for the preparation of the soil.[10] In the case of the first category, statisticians acknowledged that this could only be an estimate of actual use, but they expressed the hope that the time spent by these horses doing non-agricultural tasks was balanced out by non-agricultural horses that do occasional agricultural work.[11] After 1873 the time series is based on this data with interpolations for the missing years. The entire time series relates to the territory of the German Reich to within its 1873 borders (i.e., including Alsace-Lorraine).

Before 1873 no direct data on horses working in agriculture exists, and estimates must be made of both the total number of horses, and then the numbers of these employed in

[9] *Statistik des deutschen Reiches*, Bd.VIII (1874)
[10] *Statistisches Jahrbuch des deutschen Reiches* (1881, 1883, 1884, 1887, 1893, 1894, 1898, 1899, 1900, 1902, 1904, 1905, 1907, 1915)
[11] *Statistik des deutschen Reiches*, Bd.VIII (1874), p.105.

agriculture. Contemporary statisticians noted problems with inconsistencies in the counting of livestock between surveys in different states and at different times, concerning, for example, whether very young animals were included, and what time of year the survey was taken in (winter surveys will produce a minimum for all species, and all national surveys were taken in December or early January). However, the spread of local surveys provides almost complete national coverage for the years around 1861, and have been homogenized into one data set placed in that year. Decadal, and sometimes more frequent, surveys of total horse numbers survive for all large German states beginning in the 1810s. These show a consistent upward trend with only a small standard deviation, and so a national trend has been back-projected from 1861 taking the arithmetic mean of the proportional change of horse numbers in these states (largely provinces of Prussia, Baden, Württemberg and Bavaria) between the 1810s and 1861.[12] This implies a rise in horse numbers of some 35% between 1815 and 1861. In 1873, 70% of all horses (including foals) were employed in agriculture; a very similar figure to the 69% found in the 1890s, although there was a slight dip in the intervening years. It has been assumed that this proportion remained constant over the nineteenth century, which implies in turn that over 80% of German horses over the age of three were used in agriculture. It is unlikely that this figure could have been very much higher, even in Napoleonic times.[13]

Oxen and cows

Oxen numbers were recorded on a national basis from the survey of 1873 onward, and were also included in surveys of livestock by individual states reaching back to the 1810s (see above). However, there is far greater variation in local trend than is the case with horses, and lack of consistency in the years in when data was collected does not allow the back projection of a national trend with frequent benchmark dates. However, data from all major states in the 1810s has been aggregated into two regions, a 'northern' and 'southern', where the constituent units had similar oxen-holding characteristics. These two regions had similar oxen population sizes in 1873. A lineal trend was then back-projected between 1873 and the 1815 for each region, including those areas lacking data in the earlier period, and combined

[12] *Statistik des deutschen Reiches*, Bd.VIII (1874), p.128, passim.
[13] *Statistik des deutschen Reiches*, Bd.VIII (1874), p.128, passim; *Statistisches Jahrbuch des deutschen Reiches* (1881, 1887, 1899).

into a national trend. It appears that the oxen population at these two dates was very nearly identical, although this is a product of quite divergent trends with numbers falling in northern Germany and increasing in the south.

In 1873 statisticians tackling the problem of how to categorise their use assumed that all oxen over the age of two were used for draught purposes. This assumption is undoubtedly an exaggeration. Indeed, it was noted at the time that there was some variation in the proportion of oxen recorded as having been used for draught in the previous year. In the very small state of Brunswick, only 66% of oxen were used for draught purposes; in Baden, 83%. Here it has been assumed that 80% of oxen and steers over two years old were used for draught purposes.[14]

Cows had a fairly prominent role as draught animals in some regions, largely those with high numbers of smallholdings and industrial activity. In evaluating their power input, contemporary statisticians valued a cow at one third of an ox, taking into account size, speed and duration of work provided.[15] The number of cows used for cultivation was recorded explicitly in 1873 and can be calculated indirectly from data provided in the 1890s. The proportion of total cows so employed was very stable between these two dates, shifting from 10.6% to 10.2%. It is assumed that before 1873 this proportion is constant (which possibly overstates their use, as smallholdings proliferated with partible inheritance in some regions of western Germany), and that after 1895 the proportion of total cattle numbers made up by cows used for draught power declined at the same rate as the proportion of total cattle numbers made up by oxen used for draught power (thus falling to 8.7% by 1914).[16]

[14] *Statistik des deutschen Reiches*, Bd.VIII (1874), pp.104-5.
[15] *Statistik des deutschen Reiches*, Bd.VIII (1874), p.106; Thaer, *The principles of agriculture,* pp.67-8.
[16] *Statistik des deutschen Reiches*, Bd.VIII (1874), p.128, passim; *Statistisches Jahrbuch des deutschen Reiches* (1899, 1905, 1915).

England and Wales

Year	*Horses*	*Oxen*	*Horse Equivalent*
1815	700	78	700
1840	720	0	720
1850	812	0	812
1860	807	0	807
1870	802	0	802
1880	840	0	840
1890	892	0	892
1900	925	0	925
1913	808	0	808

Horses

From 1870 the annual Agricultural Statistics recorded numbers of on-farm horses used for agricultural purposes. Before this date, only some local surveys of total horse numbers in 1854, along with incomplete tax data from the 1810 and 20s, is available. Scrutiny of this data suggests that Collins' estimate of 700 000 horses being used in husbandry in 1810 is accurate. Some 847 000 horses and mules were taxed for use in husbandry in *Great Britain* in 1821, and Scotland took up perhaps 14% of this total. Assessors did however note in 1819 that distinguishing horses in husbandry was difficult and that many were used for multiple tasks. Scaling up data on total horse numbers from thirteen counties for 1854 and assuming the proportion of the total employed in agriculture is the same as that estimated by Thompson for 1870 suggests that some 812 000 horses were employed in agriculture in England and Wales in that year. Intervening years before 1870 have been interpolated from these estimates. [17]

Oxen

[17] Thompson 'Nineteenth-century horse sense'; Mingay, ed., *agrarian history*, p.1066; Collins, ed., *agrarian history*, pp.1779-1806; Collins, 'Power', p.210; *Parliamentary Papers* 1805.LX, pp.721-2; 1816.I, pp.453-4; 1819.XV, pp.423-5; 1821.XVI, pp.323, 335; 1869.LXII, pp.52-60; 1870.LXVIII, pp.60-64; 1871, LXIX, pp.60-68; Mitchell, *International historical*, p.365.

A few oxen were employed for draught power in the early nineteenth century, and debate persisted as to the relative merits of oxen and horses as providers of draught power. Burke records oxen as being the main providers of draught power in four western English counties early in the century, in an area that in the late 1860s held a tenth of the stock of English agricultural horses. Horses soon superseded these oxen. A survey of contemporary literature (especially the Reports to the Board of Agriculture) suggests that otherwise oxen input to total draught muscle power was almost negligible. It has been estimated that in the early nineteenth century oxen used for draught power numbered one-tenth of the number of horses used in agriculture.[18]

Netherlands

Year	*Horses*
1815	142
1840	N/a
1850	161
1860	153
1870	168
1880	172
1890	163
1900	164
1913	180

Numbers of horses in the Netherlands are recorded intermittently from 1816, although a broadly-based survey also exists for 1807. Official head counts of horses do not properly specify use, but agricultural reports define as working horses all those aged over 3 years excluding the stallions and breeding mares etc. As non-agricultural horses were taxed, the agricultural proportion can be deduced from this data, although this does not allow us to

[18] See Burke, *British husbandry*, p.; Marshall, *Rural economy*, pp.116, 238-9, 288, 293; for one example of the usage of oxen for ploughing and the debates on this subject, see Young, *General view of the agriculture of Oxfordshire*, pp.229, 287-90.

distinguish stallions and breeding mares. As with other countries' data, these are included in our figure. Numbers of stallions were relatively small and it is clear that many mares were used for work, although they would not have had the same power input as non-breeding horses. In the Napoleonic period, some 72% of all horses were working in agriculture, some 70% at mid-century but falling to 55% by 1913.[19] Overall this is undoubtedly a slight underestimate of animals used for draught power as oxen were certainly employed, primarily in the east of the country. There numbers were however small and no sure data exists on the totals. They have not been included in our data.

France

Year	*Horses*	*Oxen*	*Donkeys*	*Mules*	*Horse Equivalents*
1815	1560	1702	312	275	3078
1840	1778	1550	326	294	3218
1850	1816	1584	363	320	3317
1860	1715	1535	304	252	3096
1870	1499	1486	300	264	2857
1880	1431	1436	286	252	2740
1890	1322	1387	264	233	2571
1900	1539	1342	308	271	2811
1913	1708	535	288	154	2316

Horses, donkeys and mules

French agricultural statistics provide regular surveys of all livestock from 1867 onward. Before this date surveys were taken in the late 1830s, 1851 and 1862.[20] Early in the century, total horse numbers have been taken from Montalivent, who made estimates in 1812. Some

[19] Although underestimating numbers, a survey of 1807 found only 18 850 oxen against 141 844 'agrarian horses'. Diederiks, 'Horses in the Netherlands', pp.135-6; Ben Gales, Personal Communication from Unpublished Paper on Dutch draught animal use.

[20] Gayot, *Atlas statistique*; Royer, *Notes économiques*; *Parliamentary papers*, 1866.LXX, p.241; Toutain, *Le produit de l'agriculture française*, p.154.

of these surveys (1851 and 1890) also provided estimates of horses employed for draught power in agriculture, when the proportion of total adult horses employed in agriculture was 72% and 53% respectively. In the 1840s, Mounier considered around two-thirds of horses reaching working age (over three) to have been used for husbandry. For the earliest dates, numerous agronomists provided estimates of the numbers of horses working in agriculture in the eighteenth and early nineteenth century, although the principles underlying these estimates are not always clear. To estimate the proportion of total horses that were used in agriculture, we have used the estimate of Lavoisier (1791) despite its early date, on the assumption that numbers remained relatively static over the Revolutionary period. Lavoisier made an estimate of the horses employed to cultivate in certain acreages in different regions of France and scaled these up to a national estimate on the basis of land surveys. This gives an estimate of 76% of adult horses being used in agriculture (assuming that, as in 1840, around 13% of the horse population were foals), a figure consistent with what might be expected from later trends, as well as comparable estimates for other nations.[21] For intervening years the trends in the proportion of total horses working in agriculture has been linearly interpolated. Between 1890 and 1914 the proportion of total adult horses in agriculture is assumed to have remained static.

The number of donkeys *in toto*, and mules employed in agriculture, is recorded in surveys of 1840, 1862 and 1914.[22] It has been assumed that 80% of donkeys were used for draught power in agriculture. As the figure for the total number of donkeys approximates steadily to around 25% of the number of horses employed in agriculture, donkey numbers for intervening years have been calculated on this basis. For years where no data for mules is available, it has been calculated that total mule numbers are equivalent to 22% of the number of horses working in agriculture, the proportion found in years with comparable data; and that 80% of those mules are employed for draught power. This presumes that nearly all adult mules and donkeys were employed in some way in agriculture, though many in the south would have also been used for transport.

Oxen

[21] Monier, *De l'agriculture en France*, p.354; Lavoisier, *Statistique agricole*,, p.132.
[22] See note 19.

Oxen numbers were recorded in the surveys noted above, and previous estimates of oxen working in agriculture have been provided by J.-C. Toutain for 1850, 1890 and 1913.[23] These appear to be reliable and have been followed here. For intervening benchmark dates numbers have simply been linearly interpolated. For the start of the nineteenth century, we have employed estimates collected by Chaptal on the basis of local statistical surveys.[24] Although his figure for working oxen is significantly lower than that provided by other agronomists of the revolutionary period, it is far more in line with all later estimates and on what seems likely on the basis of cross-national comparison.

Italy

Year	*Horses*	*Oxen*	*Mules*	*Donkeys*	*Horse Equivalents*
1860	401	1351	236	472	1399
1870	384	1376	226	452	1377
1880	453	1452	267	666	1592
1890	480	1660	282	564	1693
1900	516	1762	303	607	1810
1913	669	2038	393	787	2237

Horses, mules and donkeys

National statistics provide figures for total numbers of horses, mules and donkeys from 1861 onwards. These have been adjusted by deducting 15% for foals, and a further 20% for horses used in non-agricultural purposes. It has further been assumed that 80% of donkeys and mules are used for draught power in agriculture.

Oxen and cows

[23] See note 19.
[24] Chaptal, *De l'industrie française.*

The numbers of oxen have been calculated on the basis of national statistics from 1930 that record 29% of all 'bovine animals' were employed for draught power. Each bovine animal is treated as two-thirds of an ox for 'horse equivalent' and energy calculations. This rests on the assumption that roughly half of draught cattle are oxen, and half are cows, and that a cow is equivalent to a third of an ox. The beasts were both extensively used and might be yoked together.[25]

Spain

Year	*Horses*	*Oxen*	*Mules*	*Donkeys*	*Horse Equivalents*
1870	435	928	861	1038	2055
1880	360	886	792	958	1866
1890	284	843	767	878	1719
1900	322	801	741	798	1686
1913	378	847	709	694	1696

Horses, mules and donkeys

National statistics provide figures for total numbers of horses from surveys conducted in 1865, 1880, 1890, 1900, and 1910. A deduction of 15% from the number of was made to account for foals, although in the statistics collected this proportion has varied historically between 21% and 10%. It is assumed that 85% of the adult horses are used for agricultural draught work, thus a little higher proportion than in Sweden and Germany. Survey data from 1863 suggest that in total around 80 000 horses and mules were used in the professional transport sector, and 50 000 donkeys. Data on mules and donkeys was collected in 1865 and 1910, with intervening benchmark years linearly interpolated. It is assumed that 80% of mules and donkeys are used for draught power.[26]

Oxen and cows

[25] Malanima, P., *Energy Consumption*; Colman, *The agriculture and rural economy*, p.273; Pallavicini, *Del cavallo in Italia*, pp.30-45.
[26] Barciela López, et al 'Sector Agrario y Pesca', Cuadro 4.25; Gomez Mendoza, 'The role of horse'.

Data was collected from the national statistical surveys mentioned above. These figures assume that 40% of all bovine animals were employed for draught power. This is based on the actual number of working animals as a proportion of all bovines recorded in 1965. As with Italy, each bovine animal is treated as two-thirds of an ox for 'horse equivalent' and energy calculations. This rests on the assumption that roughly half of draught cattle are oxen, and half are cows, and that a cow is equivalent to a third of an ox.

Part Two. Animal weights and energy consumption

The method of calculating draught animals in terms of horse-equivalents is rather crude, although employed by German statisticians in the nineteenth century. One ox equals two-thirds of a horse, one donkey is one-half of an ox, and one cow is one-third of an ox.[27] Animals are of the same size and power in different countries and do not change over time. This is certainly a simplification. We know for instance that England and Wales had relatively large working horses. Sidney in 1875 writes: 'It is in England that the cart-horse like every other kind of live stock valuable in agriculture, has attained the greatest average perfection, because the principles of breeding have been more carefully considered by our farmers than in any other country, and also because it is the country where, as compared with the rest of Europe the roads are good, the farmers are rich and the landowners lead the way in every stock-breeding improvement.' A similar testimony was given by a Pehrson, a Swede, about the same time.[28] Thus it may be that England actually had larger access to muscle power than the sheer numbers indicate. But it is also likely that other countries caught up with them over time due to imports of cold blooded working stallions and cross-breeding with their domestic smaller working horses. In south-western France and Spain, the asses were very tall compared to the British donkey, reaching a height of 14 hands (140 cm). The draught mules in Britain and Spain could reach a height of 16-17 hands and be very strong.[29] In southern Europe and the Mediterranean region the donkey and mule were favoured above the horse for agricultural work, and often were harnessed together with an ox. In these regions mules and donkeys may generally have been larger than their northern

[27] *Statistik des deutschen Reiches*, VIII, (1874), p.105.
[28] Sidney, T*he book of the horse*, p 276; Pehrsson, *Om hästkulturen*, p 38.
[29] Sidney, T*he book of the horse*, pp 285-286; Lefour, *Le cheval,* p.166.

European counterparts that were not much used for draught power.[30] These kinds of problem call for an attempt to modify our results by taking actual fodder inputs to oxen, horses, mules and donkeys into account, and furthermore accounting for change over time and variation in space.

From the human perspective draught animals can be regarded as living machines that convert chemical energy into motive energy. The chemical energy is the energy of the fodder they consume.[31] All fodder consumed by the animal, as well as the energy needed for rest, is from the human perspective a necessary cost for the draught work of the animal. The fodder consumed in a workday is dependent on the size of the animal and how hard they worked. Fodder requirements for a day at rest are simply dependent on the size of the animal. To calculate the primary energy of the fodder consumed by draught animals there is thus a need for information on the numbers of draught animals, how many days they worked during one year and how much they ate when they worked and when they rested. It is very difficult to find reliable information on the number of workdays, so we refrain from taking number of workdays into account. Instead we apply the simple formula for primary energy consumption by draught animals of equation (1):

$$E_i = H_{t_t} * Hf_t + C_t * Cf_t + D_t * Df_t$$

Where:

(1)

E_t = primary energy of the fodder intake by draught animals (in year t)

H = number of horses and mules

C = number of cattle (oxen and sometimes also cows)

D = number of donkeys

Hf = average fodder intake by the horses

Cf = average fodder intake by the oxen

Df = average fodder intake by the donkeys

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[30] Clutton-Brock, *Horse*, p 155.
[31] Malanima, *Energia e crescita*, pp.71-89.

In order to aggregate all the fodder by animals it is necessary to have some way of estimating the energy content of the fodder. This is provided by agronomy handbooks and can be expressed in terms of fodder units. The fodder unit equals the digestible energy content of 1 kg barley.[32] One kilogram of barley contains 2 800 Kcal useful energy and approximately 3 000 Kcal digestible energy. This means that we can go from fodder units to calories, and we choose the digestible energy content, i. e. 3 000 Kcal per fodder unit. Animals of different size require different amounts of fodder units. Swedish agronomist Hansson provides feed recommendations for oxen and horses weighing 500 kg, which are summarized in table B.1:[33]

Table B.1: Fodder units per day for oxen and horses (500 kg beasts)

	Ox (Fodder units per day)	Horse (Fodder units per day)
Subsistence feed	3.3	4.5
Easy work	6.0	6-7
Average work	7.0	7-8.5
Hard work	8.0	8.5-10.0
Very hard work	9.0	10+

We assume, as did several nineteenth century agronomists, that fodder requirements increase proportionally to weight of the animals, and that for simplicity they work averagely hard all days of the year, which gives us the basis for our modelling shown in Table B.2.[34] In reality of course the animals rested, the number of rest days may have differed among our countries, and in addition the animals may have worked harder in some countries than in others during days they actually worked. Unfortunately we have nothing to back up such conjectures with, and we have not attempted to model this.

[32] Hansson, *Husdjurens utfodring*, pp. 25, 43.
[33] Hansson, *Husdjurens utfodring*, p.235; Larsson, *Husdjurslära*, p 42. 30% of the gross energy in the fodder is not digestible; it simply passes through the body. The remaining 70% is called digestible energy. 61% of the gross energy is useful energy and 9% ends up as urine and methane. 1 kcal = 4190 joule.
[34] Hansson, *Husdjurens utfodring*, pp.25, 43; Petit, *Nutrition et Production*, pp.182, 246; Oldenburg, *Anleitung zur Pferdezucht*, p.129; Nobis, *Was hat der Landwirth zu beobachten*, p.39.

Table B.2 Fodder units per day in relation to size of the animal

Weight	Ox per working day	*Horse per working day*
270 kg	3.8	4.2
300 kg	4.2	4.7
350 kg	4.9	5.4
375 kg	5.2	5.8
400 kg	5.6	6.2
450 kg	6.3	7.0
500 kg	7.0	7.8
550 kg	7.7	8.4
600 kg		9
700 kg		10.9
750 kg		11.6
800 kg		12.5

It has not been possible to find much information on fodder for donkeys or mules. We have thus simply assumed that mules consume as much fodder as their relatives the horses in those countries, and that one donkey consumes three-quarters of the fodder for one horse in southern Europe.

In order to estimate the actual amount of fodder units consumed by the draught animals of each country we need some information about the average size of the beasts and of the size development over time. We have not, however attempted to account for further influences, such as the maintenance of 'training horses' that were not fully employed in commercial agriculture until a relatively advanced age, or the lesser work performed by pregnant mares.[35] Below, we discuss the sources from each country that have formed the basis for our modelling of size development. These comprise a mixture of occasional estimates of weight of horses, statistical data on animal size collected by government surveys, and fodder inputs either described or recommended by agronomists, or recorded by some transport companies. It should be stressed that information is scarce and that our estimates must remain conjectural.

[35] Collins, 'Power availability', p.217; also Thaer, *The principles of agriculture*, pp.78-9.

England and Wales

The cold-blooded English horses were of four primary types: the London Dray-horse (used solely in breweries and thus not treated here), the Shire horse, the Clydesdale and the Suffolk Punch. The bulkiest and heaviest was the Shire, standing at least 16 hands high (160 cm) and found in the shires where the strongest class of plough horses were required.[36] By the twentieth century the Shires were the most widespread draft horses of England, and could occasionally weigh as much as 1000 kg in 1915.[37] The Clydesdale is of Scotch and Dutch origin and stallions could weigh nearly a ton, but was still only 16 hands 1 inch high (163 cm). The average weight of Clydesdales that were exported to the United States was 900 kg.[38] The Suffolk Punch reached from 15 hands 3 inches to 16 hands, and was excellent for plough teams, but less suitable for transport or drawing timber. It was not all that heavy; and according to the American Suffolk Horse Association it should weigh 680-725 kg. Occasionally the Suffolk Punch could reach well over three quarters of a ton.[39] The Suffolk Punch was more widely employed during the nineteenth century than later.

By the early twentieth century English horses varied in size from about 500 kg to enormous beasts of a tonne that were generally used in urban breweries. Heavy agricultural horses weighed about 850 kg, lighter ones generally about 700 kg. According to authorities of the 1910s, size increases had been quite dramatic since about 1880, when stud-books had first been kept and horse breeding societies founded, but the power output had increased even more than the weight because of physiological changes. Chivers estimated that around 70% of agricultural horses were heavy horses in the early twentieth century, suggesting that the average weight for an adult draught horse was around 800 kg.[40] Judging by the fodder inputs gathered by Burke from a little less than a century earlier, agricultural draught horses weighed 5-600 kg, though colliery and dray horses could be much larger.[41]

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[36] Sidney, *The book of the horse,* p.268; see also Collins, 'Power availability', p.216; Philip-Fox, *Horses in Harness*, p.154.
[37] Hart, *Heavy horses*, pp.38, 43.
[38] Sidney, *The book of the horse,* p.269; Philip-Fox, *Horses in Harness*, p.154.
[39] Sidney, *The book of the horse*, p 270; Philip-Fox, *Horses in Harness* , p.152; Hart, *Heavy horses*, p 5.
[40] Collins, 'Power availability', pp.216-7; Lewis, 'Irish horse breeding', p.37.
[41] Burke, *British husbandry*, pp.127, 139-142.

Germany

There were several kinds of cold-blooded workhorses in Germany,[42] out of which the Rheinisch-deutsche was the heaviest and tallest at around 170 cm. It could be used for work at the age 3 and was worn out at the age 14, resembling the Percheron and the Ardenner; others, such as the Schleswiger or Norische were smaller, lighter, or both.[43] Several agronomists provided details of the fodder intake of horses from the late eighteenth century onward, and it appears that the race of horse was never a strong consideration in this literature, or at least was not considered worthy of comment. These figures suggest weights of 5-600 kg for most of the century.[44] National statistics provide slaughter weights of horses from 1906, when live weights appear to be only a little over 400 kg, though probably for aged stock.[45] There is rather more direct data in the case of oxen. Slaughter weights of adult male cattle are provided by a number of sources across the century, and from 1883 there is comprehensive statistical data that was collected at state (*Land)* and national level, when the national average for oxen and steers over two years of age was 466 kg. This figure varied from as little as 369 kg in Westphalia to 625 kg in Berlin (the latter doubtless largely consisting of cattle fattened for consumption).[46]

France

The Percheron was to become the most prominent domestic cold-blooded breed of horse in France, though in practice many cross- and local hybrids predominated. Boulonnais, Poitevin, Breton and Comtois were specified in Lefour's work of 1872; the famous Ardenner tended to be used for transportation.[47] The Percheron originated in the provinces Beauce and Perche and was first mentioned in the early nineteenth century, after which it steadily gained in popularity. The demand grew faster than the supply and in response to demand

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[42] Papavassiliou, *Liebenswerte Riesen:*.
[43] Kruger, *Unser Pferd*, pp.52-7.
[44] Hartmann, *Die Pferde*, pp.248-9; Thaer, *The principles of agriculture,* pp.80-1; Reider, *Lehrbuch der deutschen Landwirtschaft*, pp.281-3; Oldenburg, *Anleitung zur Pferdezucht*,, p.129; Nobis, *Was hat der Landwirth zu beobachten,* pp.42-5; Löbe**,** *Anleitung zum rationellen betriebe der Pferdezucht*, pp.49-53.
[45] *Statistisches Jahrbuch des deutschen Reiches* (1927), p.66.
[46] Busch, *Die Leistungssteigerung der deutschen Landwirtschaft*, p.41; Schremmer, 'Faktoren' , p.52; *Statistisches Jahrbuch des deutschen Reiches,* 1889, p.21.
[47] Lefour, *Le cheval,* p.87.

some smaller horses from Brittany were crossed with these and sold as Percheron horses. As a consequence the quality of the horse deteriorated and exports had almost ceased in the 1870s, to recover thereafter.[48] By 1936 Pecherons in the United States, that imported considerable numbers from both the continent and Britain, could reach 16-17 hands for mares, and 16.5 -17 hands for stallions. Stallions weighed 900-1000 kg.[49] However, for the period under consideration agricultural horses were clearly much smaller than this. Both the extensive figures on weight and fodder intake provided by Parisian transport companies for their horses in the 1870s, and agronomist works up to as late as the 1890s, suggest weights ranging from 420 kg to 560 kg.[50] Estimates of horse weight provided by Lavalard for the 1870s and early 1880s are only a little over 400 kg, but this is blamed on there being very many young animals after losses in the Franco-Prussian war.[51] As early as the 1840s extensive estimates were made of cattle weight, the averages being 413 kg (gross) and 245 kg (net), but regional variations were large, with more than double the weight in some regions as compared to others. In Eure-et-Loire net weight was 324 kg, in Cantal 320 kg, in Nord 318 kg and in Loire 315 kg. In the southern provinces cattle were very small indeed: Corsica 112 kg, Finistère 136 kg, Ille-et-Vilaine 147 kg; but also in Marne only 160 kg.[52]

Sweden

The breeding of horses and cattle, where domestic breeds were crossed with foreign kinds, became common during the nineteenth century in Sweden, which increased the size of the animals. The normal Swedish rural horse in the early nineteenth century was around 150 cm tall. The earliest breeding by means of imported stallions mainly benefited the army; the agricultural horses remained largely unaffected. Only from the mid-nineteenth century did demand for stronger working horses in agriculture grow leading to the import of heavy cold-blooded horses. The Norwegian horse, the Scottish Clydesdale, the English Shire, the French Percheron and the Austrian Pinzgauern were tried, but these initial cross-breeding

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48 Pehrsson, *Om hästkulturen,* p.16.
49 Philip-Fox, *Horses in Harness,* p.152.
50 Colman, *The agriculture and rural economy*, p.277; Lefour, *Le cheval*., p.114; Bixio, *De l'alimentation*; Lavalard, *Le cheval*, pp.201-64; Petit, *Nutrition et Production*, pp.246-8; Bouchet, *Le Cheval a Paris de*, pp.204-13.
51 Lavalard, *Le cheval,* Vol 2, pp.28, 225.
52 Royer, *Notes économiques*, pp.90-1. Ratios between gross and net (or live and dead weight) appear to have varied quite considerably in Europe. In England the standard was 14:8, but according to some authors might be 2:1. Turner et al, *Farm production*, p.181; Kjelleström, *Vad är oxen värd?,* p 11: Average animals leave 46-48% of their live weight, half-fattened animals leave 48-52% of live weight as slaughter weight and fully fattened animals leave 52-60%.

attempts were generally not very successful.[53] Most successful was cross-breading with the Norwegian horse, which developed into a new kind: The North Swedish horse, named in 1901. Breeding of Clydesdales continued for a while but never became widespread. Only with the import of the first Belgian Ardenner horse in the 1870s did a really successful cross-breading start, which eventually made the Swedish Ardenner horse the dominant rural horse in most of Sweden. Around the turn of the century larger Ardenner horses were imported and affected the size development of Swedish agricultural horses: the average height was 165 cm in the 1920s, and they were substantially broader and stronger than the original Swedish agricultural horses. Horse breeding was mainly designed to provide strong working horses. Cattle-breeding was devoted to increased beef and milk production. Cattle or horses are not likely to have grown stronger and bigger during the first half of the nineteenth century, when the horse was still smaller than an ox.[54] It seems reasonable in the Swedish case to believe that the size figures given Hansson´s book on fodder recommendation for 1920s were relevant then, and that means that we assume an average size for horses of 550 kg in 1913 and 500 kg for oxen. Additional support for this assumption is provided by Johansson's statement that the average body weight for fully-grown Ayrshire cows was 587 kg.[55]

The Netherlands

The Netherlands was very early in developing heavy cold-blooded horses, one of which was the Frisian. In the eighteenth century average height was around 150 cm, which probably rose during the late eighteenth and early nineteenth century boom years in agriculture. Later, the Frisian horse lost market share, largely to cross-breeding and some imports. Although a specific breed and although they lost market share, the size evolution of Frisians is probably representative for the whole, and it is not clear that they developed much in height over the duration of the period under consideration.[56] However, the body mass of agricultural horses is likely to have increased to some degree as in the other countries.

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[53] Dyrendahl, *Från arbetshäst till sport-och rekreationshäst*; Furugren, *Arbetshästen och svensk hästavel.*

[54] Support for the idea that cattle, especially in the south, grew bigger from the mid 1850s is given by the price of milk and beef in relation to the price of cows, which clearly shows that the cows became more expensive in relation to beef or milk. This indicates more productive animals in terms of meat and milk, and thus larger animals. See Kander *Economic growth* , p.177; Furugren, *Arbetshästen och svensk hästavel*, p.132.

[55] Johansson, *De svenska nötkreatursrasernas.*

[56] Ben Gales, Personal Communication based on Unpublished Paper.

Portugal[57]

Slaughter weights from Portuguese cities around 1900 give the following figures for weights in kilograms:

Horses	Mules	Donkeys	Bovines
267	264	136	298

For cattle, data stretches somewhat further back in time:

	Porto	Lisboa
1870-1874		221,5
1875-1879		223,9
1880-1884		233,8
1885-1889	223,1	242,2
1890-1894	234,1	249,3
1895-1899	233,3	248,9
1900-1904	240,3	255
1905-1909	242,8	252,4

Net weights varied between half and two-thirds of live weight.[58] In Lisbon there was an increase in slaughter weight by 15 % over 30 years, and perhaps as much as 50% over the century.

European comparisons

We do not have sufficient data to justify very complicated and detailed modelling. However, there appears to have been a relative ranking of horses. Based on data on height – though this very obviously does not allow a simple translation into weight - and breed, we have assumed that the Netherlands and England had horses of equivalent size. France and Germany appear to have had beasts of similar sizes, following similar trends over time. Southern German horses were probably small; equally southern French horses (which

[57] Andrade, 'Notas históricas'; Vareta, 'A acção municipal'.
[58] See note 24.

became a larger proportion of the national herd over time) were also smaller than their northern counterparts. Sweden began with rather smaller horses in the early nineteenth century but caught up with north-west Europe later. Portugal, Spain and Italy were undoubtedly at a lower level, but we can make little more than educated guesses. Data is rather better for oxen, where France, Germany and Sweden appear to have had very similar sized animals; again, the Mediterranean and Iberian breeds were rather smaller. We have attempted to stay close to the actual weights provided in the text above for specific countries and dates, but have rounded these off for simplicity. It is impossible of course to make such estimates with great exactitude for particular years. To calculate the rest of our benchmarks, we simply use linear interpolation.

Table B.3 Assumed average weights of animals

	Ox			Horse			Donkey
	1815	*1870*	*1914*	*1815*	*1870*	*1914*	
England	na	na	Na	500	700	800	na
Holland	na	na	Na	500	700	800	na
France	400	450	500	450	500	550	na
Germany	400	450	500	450	500	550	na
Sweden	400	450	500	400	450	550	na
Portugal	300	350	400	350	400	500	350
Spain	300	350	400	350	400	500	350
Italy	300	350	400	350	400	500	350

References

Statistical sources

Barciela López, C., Giráldez Rivero, J., Grupo De Estudios De Historia Rural, López Ortiz, I., 'Sector Agrario y Pesca', *Estadísticas Históricas de España, siglos XIX-XX*, forthcoming, Cuadro 4.18;

BiSOS (Bidrag till Sveriges Officiella Statistik) (Supplement to Swedish Public Statistics) series Q, Agriculture, 1901.

Rey, G., and Vitali, O., (eds.); *Conti (I) economici dell'Italia* 1, (Roma-Bari, 1991).

King, G., 'The LCC Burns Journal', in Laslett, P., (ed.), *The earliest classics. Works by J.Graunt and G.King,* (1973), p.200.

Ministério das Obras Públicas, Comércio e Indústria- Recenseamento geral dos gados no Continente em Portugal, 1870, Imprensa Nacional 1875.

Netherlands Central Statistics Bureau (CBS), *Tweehonderd jaar statistiek in tijdreeksen, 1800–1999* (Amsterdam, 1999).

Parliamentary papers Vols. LXII, LXVIII, LXIX.

Relatório do Ministério dos Negócios do reino apresentdo às Câmaras legislativas em 30 de Junho de 1852, Dec. 29. -for 1851

Schön, L. *Historiska nationalräkenskaper för Sverige. Jordbruk och binäringar 1800–1980*. (Lund, 1995)

Statistik des deustchen Reiches, Bd.VIII (1874)

Statistisches Jahrbuch des deutschen Reiches (1881, 1883, 1884, 1887, 1893, 1894, 1898, 1899, 1900, 1902, 1904, 1905, 1907, 1927)

Literature

Andrade, Amâncio, 'Notas históricas de interesse pecuário', *Separata do Boletim Pecuário*, 6. (1938).

Bixio, M., *De l'alimentation des chevaux dans les grandes écuries industrielles, 5 ans d'expérience sur une cavalerie de 10.000 chevaux* (Paris, 1878).

Bouchet, G., *Le Cheval a Paris de 1850 á 1914* (Paris, 1993).

Brown, S., 'On the statistical progress of the Kingdom of Italy', *Journal of the statistical society of London*, 29/2 (1866).

Burke, J.F., *British husbandry; exhibiting the farming practice in various parts of the United Kingdom. Volume 1* (London, 1834).

Busch, W., *Die Leistungssteigerung der deutschen Landwirtschaft seit 1800* (Berlin, 1941).

Campbell, B.M.S., *English seigniorial agriculture* (Cambridge, 2002).

Chaptal, J., *De l'industrie française* (Paris, 1819).

Clout, H.D., *The land of France 1815-1914,* (London, 1983).

Clutton-Brock, J., *Horse power: a history of the horse and the donkey in human societies*, (London, 1992).

Collins, E.J.T., 'The farm horse economy of England and Wales in the Early Tractor Age', in Thompson, F.M.L., *Horses in European economic history. A preliminary canter* (Reading, 1983), pp.73-100.

Collins, E.J.T., 'Power availability and agricultural productivity in England and Wales, 1840-1939', in Bavel, B. van, & Thoen, E., eds, *Land productivity and agro-systems in the North Sea area, Middle Ages – 20th century. Elements for comparison* (Turnhout, 1999), pp.209-225

Collins, E.J.T., ed., *The agrarian history of England and Wales. Vol VII, 1850-1914*, (Cambridge, 2001)

Colman, H., *The agriculture and rural economy of France, Belgium, Holland and Switzerland; from personal observation* (London, 1848).

Diederiks, H., 'Horses in the Netherlands at the beginning of the Nineteenth century', in Thompson, F.M.L., *Horses in European economic history. A preliminary canter* (Reading, 1983), pp.132-142.

Dovring, F., 'The transformation of European agriculture', in Habbakuk, H.J., & Postan, M.M., eds, *The Cambridge economic history of Europe, Vol. VI.II. The industrial revolution and after* (Cambridge, 1965), pp.604-72.

Dyrendahl, S., *Från arbetshäst till sport-och rekreationshäst*, Kungliga Skogs- och Lantbruksakademiens tidskrift, Supplement 20 (1988).

Furugren, B. 'Arbetshästen och svensk hästavel', in Liljewall, B., and Myrdal, J., (eds), *Arbetshästen under 200 år* (Lund, 1997).

Gayot, E., *Atlas statistique de la production des chevaux en France. Documents pour servir a l'histoire naturelle-agricole des races chevalines du pays* (Paris, 1851)

Gomez Mendoza, A., 'The role of horses in a backward economy: Spain in the nineteenth century', in Thompson, F.M.L., *Horses in European economic history. A preliminary canter* (Reading, 1983), pp.143-155.

Grant, O., 'Productivity in German agriculture: estimates of agricultural productivity from regional accounts for 21 German regions: 1880/4, 1893/7 and 1905/9', University of Oxford Discussion Papers in Economic and Social History, 47 (2002).

Hannerberg, D. *Svenskt agrarsamhällen under 1200 år* (Stockholm 1971).

Hansson, N., *Husdjurens utfodring. Dess teoretiska grunder och ekonomiska genomförande*, (Stockholm, 1928).

Hart, E. *Heavy horses - an anthology* (Gloucester, 1994).

Hartmann, G., *Die Pferde und Maulthierzucht* (Stuttgart, 1777).

Helling, G., 'Zur Entwicklung der Produktivität in der deutschen Landwirtschaft im 19. Jahrhundert', *Jahrbuch für Wirtschaftsgeschichte* 1 (1966), pp.129-141.

Holgersson, B. 'Cultivated Land in Sweden and growth 1840-1939', *Economy and History*, XVII (1974), pp.20-51.

Johansson, K.-I., 'De svenska nötkreatursrasernas kroppsutveckling och produktion', *Meddelande Ulltuna* 38, (Uppsala, 1928).

Justino, D., *A formação do espaço económico nacional. Portugal 1810-1913. Vol I* . Quadro 2.1, (1988) p.57.

Kander, A., 'Energy consumption and Forestry in Sweden 1800-1990, - Implications for CO2 emissions. Licentiate thesis, 1998, pp 121-123.

Kander, A., *Economic growth, energy consumption and CO_2 emissions in Sweden 1800-2000* (Lund, 2003).

Kjelleström, J., *Vad är oxen värd? Och vad kostar köttet?* (1896).

Kocken, T., 'Krigshästen från äldsta tider', in Trägårdh, C., et al (eds), *Hästen i Sverige*, (Stockholm, 1939)

Krantz., O., *Historiska Nationalräkenskaper för Sverige: Transporter och kommunikationer, 1800-1980*, Studentlitteratur, (Lund, 1986).

Kruger, W., *Unser Pferd und seine Vorfahren* (Berlin, 1939).

Larsson, S., *Husdjurslära. Del 2: Husdjurens utfodring och vård*, (Stockholm, 1945).

Lavalard, E., *Le cheval dan ses rapports avec l'economie rurale et les industries de transport. Vol.1* (Paris, 1888).

Lavoisier, *Statistique agricole et projets réformes* (Paris, [1791])

Lefour, Inspectuer de l'agriculture, *Le cheval, l'ane at le mullet. Extérieur, races, élevage, entretien, utilisation, equitation, etc.* (Paris, 1872).

Lengerke, A. von, *Landwirtschaftliche Statistik der deutschen Bundesstaaten* (Braunschweig, 1840),

Levy-Lebouyer, M., and Bourguignon, F., *The French economy in the nineteenth century. An essay in econometric analysis* (Cambridge, 1990).

Lewis, C.A., 'Irish horse breeding and the Irish draught horse, 1917-1978', *Agricultural History Review,* 31 (1983), pp.37-49.

Löbe, W**.,** *Anleitung zum rationellen betriebe der Pferdezucht und Pferdehaltung* (Berlin, 1862).

Malanima, P., *Energia e crescita nell'Europa preindustriale* (Rome, 1996).

Malanima, P., *L'economia italiana dalla crescita medievale alla crescita contemporanea* (Bologna, 2002)

Malanima, P., *Energy Consumption in Italy in the 19th and 20th Centuries. A Statistical Outline* (Naples, 2006).

Marshall, W., *Rural economy of the west of England. Volume 1* (London, 1970 [1796]).

Mingay, G.E., ed., *The agrarian history of England and Wales. Vol VI*: *1750-1850,* (Cambridge, 1989).

Mitchell, B.R., *International historical statistics: Europe 1750-1988* (London, 1988).

Monier, M.L., *De l'agriculture en France d'après les document officials* (Paris, 1846)

Nobis, R., *Was hat der Landwirth zu beobachten und zu thun, um seine Pferde, Rinder, Schafe und Schweine gegen Krankheit zu schützen?* (Danzig, 1861).

Oldenburg, F., *Anleitung zur Pferdezucht im landwirtschaftlichen Betriebe* (Berlin, 1901).

Pallavicini, A., *Del cavallo in Italia* (Napoli, 1867).

Papavassiliou, F. *Liebenswerte Riesen: die schönen Kaltblutpferde Europas*, (Wiesbaden, 1988).

Pehrsson, O., *Om hästkulturen I Normandiet jemte några anteckningar under en resa på kontinenten och i England*, (Lund, 1873).

Peterson, G. 'Häst eller oxe', in Liljewall, B., and Myrdal, J., (eds), *Arbetshästen under 200 år*, (Srockholm, 1997).

Petit, P., *Nutrition et Production des animaux boeuf, cheval, mouton, porc* (Paris, 1892).

Philip-Fox, C., *Horses in Harness* (Greendale, 1987).

Prados de la Escosura, L. *El progreso económico de España 1850-2000* (Madrid, 2003).

Reider, Jacob Ernst von, *Lehrbuch der deutschen Landwirtschaft nach eigenem Systeme* (Leipzig, 1933 [1819]).

Ribbing, O. 'Hästen i vår nuvarande armé', in Furugren, B., (ed.), *Hästen i Sverige*, (1997 [1939]).

Royer, C.E., *Notes économiques sur l'administration des richesses et al statistique agricole de la France* (Paris, 1843).

Schön, L., *En modern svensk ekonomisk historia* (Stockholm, 2001) fig 1.2 p. 14.

Schremmer, E., 'Faktoren, die den Fortschritt in der deutschen Landwirtschaft im 19. Jahrhunder bestimmten', *Zeitschrift für Agrargeschichte and Agrarsoziologie* 36 (1988).

Sidney, S., T*he book of the horse: saddle and harness, British and foreign* (London, 1875).

Sigvardsson, S., *Oxen* (Västorp, 1991).

Smits, P., Horlings, E., & van Zanden, J.L., *Dutch GNP and its Components, 1800-1913* (Groningen Growth and Development Centre, 2000)

Thaer, A.D., *The principles of agriculture,* trans. Shaw, W., & Johnson, C.W., (London, 1844 [1810-2]).

Thompson, F.M.L., 'Nineteenth-century horse sense', *Economic History Review* 29 (1976), pp.60-81.

Toutain, J.-C., *Le produit de l'agriculture française de 1700 à 1958: I. Estimation du produit au XVIIIe siècle* (Paris, 1961).

Toutain, J.-C., *La population de la France de 1700 à 1959* (Paris, 1963)

Turner, M., Beckett, J., & Afton, B., *Farm production in England 1700-1914* (Oxford, 2001).

Turner, M., 'Agriculture, 1860-1914', in Floud, R., and Johnson, P. (eds), *The Cambridge Economic History of Modern Britain: Vol II, Economic Maturity, 1860-1939* (Cambridge, 2004), pp. 133-60.

Vareta, B., *A acção municipal na questão das subsistências* (Porto, 1910).

Young, A., *General view of the agriculture of Oxfordshire* (London, 1813).

Wrigley, E.A., *Continuity, chance and change. The character of the industrial revolution in England* (Cambridge, 1988).

Wrigley, E.A., 'Energy availability and agricultural productivity', in Campbell, B.M.S. & Overton, M., *Land, labour and livestock* (1991), pp.323-39.

Wrigley, E.A., *Poverty, progress and population* (Cambridge, 2004).

Zanden, J.L. van, 'The first green revolution: the growth of production and productivity in European agriculture, 1870-1914', *Economic History Review,* XLIV (1991), pp.