ANIMAL POWER IN EUROPEAN AGRICULTURE IN THE 20C.

Agriculture in industrialised countries is a prolific user of energy, and nowadays almost wholly dependent on mechanical power and the internal combustion engine the chief energy source.. Until recently, though, animals were the chief source of motive power in European farming, supplying in 1930 about 95 per cent, in 1949 85 percent, and in 1980 only about one- third of the continent's draught needs. At this late stage, animals were still in common use on small farms in parts of southern and eastern Europe. Currently, in Romania, over 4 million farms are worked by animals, while in 2008 nearly half a million horses were still to be found, albeit now fast diminishing on Polish farms. (see **Table 1**).

Table 1 Draught availability in European agriculture 1930, 1948/49 (in millions of draught power units)

	1930			1948/49		
	Tractors	Draught Animals	%	Tractors	Draught Animals	%
Europe (excl UK)	0.7	21.3	95.4	3.0	17.9	85.6
UK	0.1	0.8	90.0	1.7	0.5	22.7
USSR	0.4	24.8	98.4	3.0	11.1	78.7
North America	6.1	17.4	73.4	17.2	8.4	32.8
Latin America	0.1	37.6	99.7	0.4	45.2	99.1
Near East	-	7.8	100.0	0.1	9.2	98.9
Oceania	0.2	1.3	86.7	0.6	1.0	62.5
Far East	-	89.5	89.5	0.1	90.0	99.9
Africa	0.1	13.4	99.3	0.3	17.1	98.3
Total	7.7	214.2	96.5	31.4	199.2	86.3

Draught power units are denominated as follows: tractors=6, horses/mules=1, buffaloes =0.9, draught cattle=0.5 units

The history of farm traction in the twentieth century has succeeded in attracting very little scholarly attention given the importance of the agriculture in the economy at large. The key question is why in 1950, half a century after the unveiling of the first light--weight tractor, and a century after the launch of the steam-plough, all but a small share of all the farm work was performed by animals. To answer it requires an understanding of the role of animals in farm production, and their performance. This paper examines the size and composition of the working herd, and relative importance and geographical distribution of the several draught species; and energy availability, use and efficiency..

Draught animals on European farms currently number fewer than two million head, compared with an estimated 44 millions at their historic peak in the 1930s, and including the USSR, 69 millions. Horses were the largest single class of work animal, forming together with mules, asses, and donkeys - about two-thirds of the total workforce, with oxen, cows and buffaloes comprising the remaining third. The size and composition of the European draught herd in 1933-5 is analysed in **Table 2** below.

Table 2 Numbers and ranking order of draught species 1933-35 (in millions of head)

	Europe	**%**	**USSR**	**%**	**Total**	**%**
Horses	22.760	51.7	16.579	66.8	39.339	57.2
Mules asses	5.190	11.8	.657	2.6	5.847	8.5
Draught oxen	5.805	13.2	2.449	9.9	8.254	12.0
Draught cows	10.000	22.7	5000	20.1	15.000	21.8
Buffaloes	.236	0.5	.152	0.6	.388	.6
TOTAL	43.990		24.837		68.828	

Apart from sharply alternating downturns and recoveries in and after the two world wars, the working herd underwent only minor changes in size and structure over the course of the first half of the 20c. Trends in the more advanced countries, however, differed somewhat from those in the less so. In the former, herds peaked just prior to or soon after the First World War. The decline thereafter, up to 1945, was modest by post-World War 2 standards, and due less to the inroads of tractors as to falling demand for horses in the towns, and to a lesser extent in agriculture, due to a reduction in tillage. Apart from Britain, where numbers rose quickly following the opening of the Fordson plant in 1933, and the USSR where they were a main-plank of the collectivisation programme, already numbering 150,000 by the mid-30s, tractors were of little importance in the inter-war years, and suffered sharply falling sales in the depression, especially in eastern and central Europe where, as an economy measure, animals replaced tractors, a rare example of technical inversion.

In contrast, in the agrarian countries, animal numbers were little changed or actually increased, in response to population pressure and land reform. In Denmark, Greece, Ireland, Latvia, Lithuania, Norway, Rumania and Yugoslavia, horses in 1939 were more numerous than in 1925, and in the Balkans continued to expand until the mid - 1950s and after. Indeed, only in the next decade was the hegemony of draught animals seriously challenged over much of southern and eastern Europe.

In 1939, tractors totalled less than 330,000 overall. In 1935, the combined fleets of the five leading industrialised countries were many times larger those of the rest of Europe put together, barring Italy where, as an enabling factor in the wheat self-sufficiency programme, mechanisation made impressive strides in the thirties. The mid-20c was a critical watershed in the sourcing of farm power. Where in 1950, some 830,000 tractors had supplied one –seventh of total horse-power, by 1980 ten times number supplied over two-thirds. In Britain, the horse population plummeted from 545,000 in 1945 to barely 20,000 by 1960. Likewise in the original member countries of the European Union (EU 6), mechanical traction units rose 12-fold between 1950 and 1970, while animal traction units fell by three-quarters, thereby reversing their relative positions inside two decades.

Mechanisation in eastern and southern Europe on the other hand, lagged 15-20 years behind their northern neighbours. In 1980, tractors contributed 85 per cent of total available draught in the enlarged European Union, as against less than 60 percent in the less advanced regions. By 1990, the European fleet stood at more than 10 millions, while draught horses had shrunk to 5-6 millions, or one-quarter their 1948 level. In fact, in north-west Europe tractor numbers had by now peaked, though average h.p. per tractor continued to rise, in the EU9 by 32 per cent between 1950 and 1980. .

Animals continued to play a useful if limited role. In 1980, horses still numbered more than 300,000 in France, Germany, Poland, Rumania, and Yugoslavia, and assest more than 100,000 in Greece, Portugal and Spain, and over 300,000 in Bulgaria. In Poland, horses remained the chief source of draught on small and medium-sized farms, while in the Iberian peninsula oxen could be seen ploughing on small farms in Andalusia and central and northern Portugal. In the early stages of f the transition, animals and tractors worked side by side, with the former often doing the majority of the work. Enormous differences in tractor usage existed between regions : in Italy, for example, in 1955, only 6 per cent of farms in mountainous districts possessed a tractor, compared with 68 per cent in the plains. The contributions of animals and tractors to total energy supplies between the late 1930s and 1980, and in the EU(6) in 1950 and 1970, are analysed in **Tables 3 and 4 below.**

Table 3 Power availability in Europe: pre-war, and 1947 -1960 (in millions of h.p.)

	Animal Units	Mechanical Units	Total units	%animal	%mechanical
Pre-war	122	5	127	96.1	3.9
1947	114	13	127	89.8	10.2
1950	113	22	135	83.8	16.2

1955	100	46	146	68.5	31.5
1960	89	76	165	53.9	46.1

Source Development of Farm Mechanization and Consumption and Prices of Motor Fuels in Member countries (OECD Paris, 1963), p.17.

Table 4 Animal and mechanical traction units in the European Union (6), 1950,1970 (in millions of units).

	1950	%	1970	%	change%
Animal Traction Units	6438	85.7	1501	10.5	-76.7
Mechanical Traction Units	1070	14.3	12730	89.5	+ 189.7
TOTAL UNITS	7508		14231		+89.5

Traction units: horses =1.0. mules asses 0.7, draught oxen 0.5, draught cows 0.2, draught bovines gender unspecified 0.3, tractors 7.0

Long term trends in animal and tractor numbers over the period 1910-1990 are summarised, as far as the statistics allow, in Table 5. A major shortcoming is lack of data for draught cattle from the mid-1940s when the International Institute of Agriculture discontinued its excellent l digest of agricultural statistics. The FAO Yearbook provides ingle listings for horses, asses and mules, but not cattle or buffaloes, nor information as to age, gender or deployment. **Table 5** show the peak in the animal population in the 1930s, dramatic rise in tractor numbers from 1950 slowing after 1980, and equally dramatic decline in horse numbers in the 40s and 50s.

Table 5 Trends in draught animal and tractor populations in Europe (excl the USSR), 1910-1990 (in millions of head).

	Tractors	Horses	Mules/ Assess	Draught Oxen	Draught Cows	Buffaloes
1910	< 200	18.76	4.26	-	-	-
1920-2	0.06	20.17	5.11	-	-	-
1933-5	0.20	22.76	5.19	5.81	c 10-15m	0.24

1938-9	0.34	22.18	6.35	-	-	-
1950	0.83	16.90	5.00			
1960	5.89	7.81	3.10			
1980	8.46	5.5.	1.90			
1990	10.38	4.20	1.43			

Source Annuaire Statistique Agricole, FAO Year Book, EurostatAg Stats

Geographical Distribution of Draught Animals by Species

The geographical distribution of the different species of draught animal can be plotted only very roughly. Where, for example, in England, the animal workforce was comprised exclusively of horses, in just one small district of Bulgaria, it consisted of 195 oxen, 25 draught cows, 630 horses, and 330 asses and mules Most ox-using farms kept one or two horses for general duties, and mixed teams were commonplace. A few generalisations can be made however. First, horses comprised 55-60 per cent of the combined herd, and were the more or less exclusive power source throughout most of northern Europe, in an arc roughly co-terminus with the Great European Plain. Here, horses had been displacing oxen since the Middle Ages, a process that was still incomplete in a parts of the Baltic in the 1930s. Second, horses formed a majority or significant minority of the workforce in a broad belt from central France to north Yugoslavia, and were important also in the 'maize belt, a region of high summer rainfall and mixed farming, running eastwards across the northern Mediterranean from northern Spain through the Po Valley to northern Greece.

Although horses were nowhere entirely absent, and were gradually gaining ground, over a large part of Continental Europe, cattle were the pre- dominant species. In the 1930s, vestiges of the once huge herds of draught cattle survived sporadically in the horse-using regions into the 20c. In the mid-1930s, 8000 oxen still existed in Sweden, over 20,000 in Belgium, and 31,400 in Latvia. England at this stage could boast only a single ox team, at Cirencester on the Cotswolds, and in the far north of Scotland and the Northern Isles, a smattering of working cows.

In the mid-1930s the ox population was of the order of 5.8 millions, and including the USSR, about 8 millions, or 12 percent of the Eropean herd. Contrary to popular belief the greater proportion of working cattle consisted not of oxen but of cows. Indeed, in their various states - in-milk and in-calf, dry and barren - cows were the backbone of

the farm power economy in central and southern Europe, and may have totalled as many as 15-.20 millions, three or four times the numbers of oxen.(Table 2)In Austria, for example, in 1935, draught cows predominated by more than 50 per cent, and in Czechoslovakia by 200 per cent. In the poorer parts of southern Germany all work was done by cows with almost no oxen. Their numerical superiority was most marked in France and Germany where, in 1950, they comprised 66.8 and 86.8 per cent respectively of all working cattle, and in 1960, 80.7 and 96.0 per cent. (Table 4). In Europe generally, most cows were worked at one time or another, at least occasionally..

Cow- ox ratios increased between 1920 and 1960, due partly to the increased keeping of male cattle for beef, and the fact that many small farmers could not afford to keep oxen solely for work, whereas cows could produce a calf a year plus milk in addition. Any reduction in milk yields was outweighed by cost-savings, cow draught being much cheaper than that of oxen or horses. **Table 6** shows the ratio of cows to oxen in 12 European countries c. 1935.

Table 6 Numbers and proportions of cows and oxen in 12 European countries c.1935 (in millions of head)

	Draught oxen	Draught Cows	% of cows in combined herd.
Austria	180	277	60.1
Czechoslovakia	307	899	74.9
France(1929)	964	1850	65.7
Germany	384	2478	86.4
Albania	183	140	43.3
Bulgaria	683	228	25.0
Greece	353	122	25.8
Romania	1035	1697	62.2
Yugoslavia	901	1864	67.4
Italy	897	355	28.3
Spain	299	406	57.5
USSR	2449	1903	43.7

Note Cows in Germany used for ‘ milk and draught’. In Bulgaria, for draught only.

With the exception of Ireland, where together with horses they were the chief work animals, the historic homelands of the lesser equides were the Mediterranean Basin and the Balkans. Smaller and less powerful than horses, mules, asses, and donkeys perfectly met the needs of small farmers in mountainous semi-arid regions for versatile, low-cost, multi-purpose animals, for farming and transport. Mules were well adapted for draught, although their role as universal carriers declined from the 1930s with the increase in metalled roads and growing numbers of motor vehicles. In France, asses and mules were increasingly confined to the mountain departments of the south and south east , and in Italy to the rough roads and small rocky fields inaccessible to wheeled transport. Up to the 1950s, asses were sti used extensively in Sicily, Campania, Calabria, and the Abruzzo. In all, mules and asses totalled about 6 millions in 1938-9, falling to about 3 millions in 1960, and to less than 1.5 millions in 1990.

Numbering in the mid-1930s about 230,000, water buffaloes were much valued for their milk, and for ploughing the alluvial coastal plains and river deltas of eastern Europe and the Balkans, notably in Rumania and Bulgaria, which then contained three - quarters of the European buffalo herd, with smaller concentrations in Spain and Italy.

Numbers and distributions by region (excluding northern Europe) of the six principle draught species in the 1930s,are analysed in **Table 7,** and by country in **Appendix Table 2 .**

Table 7 Numbers and regional distribution of draught species in Europe (excluding N Europe), 1933-5 (in millions of head and %).

Region	Horses	Draught Oxen	Draught Cows	Asses & Mules	Buffaloes
W.Central	6.742	1.843	6.375	0 .351	.004 5.312
Eastern	4.964	1.275	7.927	.344	.075 14.260
Southern	1.008	1.364	3.097	3.823	.015 9.307
Balkans	1.433	2.119	1.476	7.84	.169 5.980
TOTAL	14.147	6.601	18.875	4.970	.263 44.860
USSR	16.579	2.449	1.903	.657	.152 21.840

Regional distribution (%)

W Central	44.0	12.0	41.6	2.2	0
Eastern	34.8	8.9	55.6	.4	.1
Southern	10.8	14.7	33.3	41.1	.0
Balkans	23.9	35.4	24.4	13.1	2.8
TOTAL	**31.6**	**14.7**	**42.1**	**11.0**	**.6**

Power ratings and energy availability.

Power is defined as the time-rate at which work (measured in foot-pounds or their metric equivalent) is done and energy expended. The 'horse-power' (h.p.) was historically the standard measure of work output, equating to the puling capacity of a heavy horse. It is defined as the ability to lift 33,000 lbs (15,000 kg) one foot (0.35 metres) per minute for one hour. The energy ratings employed in the 1950s and 1960s to measure animal draught are those estimated by Hopfen and Biesalski for FAO, and by Eurostat for the European Union. These together with bodyweights and working speeds are shown in **Table 8.**

Table 8 Bodyweights, speeds, and notional power outputs of draught animals.

	Bodyweight (kg)	Speed m/sec	power capability (h.p.) FAO	EU6
Horse/light horse	**400-700**	**1.0**	**1.0**	**1.0**
Mule/ass	**200-400**		**0.7**	**0.7**
Donkey	**120-250**		**0.4**	
Draught ox	**400-600**		**0.4**	**0.2**
Buffalo			**0.9**	

Neither the scientific nor methodological basis for either ratings are anywhere precisely stated. One source of error is that because they appear to be based on the relatively higher northern European norms, energy availability in other regions, and in Europe overall, tends to be over-stated. Also, they appear to discount regional differences, and other factors such as size, age and gender, or the amount of time spent on non-agricultural work, such as transport, or as in the case of cows, in reproduction and calf rearing. Clearly, muscle power alone was not the sole nor even the most important determinant of energy use or availability.

The working capabilities of the different species will now be examined successively, beginning with the horse. Horses were specialist draught animals esteemed for their all-round capabilities, which combined strength with speed and endurance. A heavy horse in prime condition could weigh upwards of 1000 kg, and working moderately hard, generate in excess of 1..2 h.p. per hour over a 6-7 hour working day , 200-250 days per year. Enhancing performance was the ability to exert a pull of 40- 50 per cent or more of its own bodyweight in very short bursts, compared with the average 10-15 per cent . The largest and most powerful horses were sold into the towns at 5-6 year-old, fully trained, for commercial work, but were often bought back at 9-10 y.o. to spend their final years on farms whence they had originated.

However, contrary to popular belief, based probably on posed photographs of individual prize specimens or matched teams in prime condition, true heavy horses formed only a small part of the working herd , even in horse-countries, such as Britain and the Netherlands. Agricultural horses were in reality of far less awesome proportions. In Britain even, 'light' horses' predominated in the west and north, while in France only 60 per cent of agricultural horses were classed as 'heavy'. In southern and eastern Europe, horses were insufficiently robust and probably too under-nourished for continuous heavy work, such as ploughing, and it was only in the inter-war period that serious efforts were made to breed larger and more powerful types. This was partly to meet the demands of dray masters in the towns, and partly a response to a marked deterioration in the working capabilities of the oxen, due it was claimed, to their dilution by crossing with imported dairy breeds to improve milk yield. In southern Europe, horses were employed mainly for transport, with the heavy work, including ploughing, done by cattle or mules.

Draught capability varied also with age and gender. Upwards of one-half of a normal plough team consisted of young horses in training, and veterans of 10-12 years or more, each less productive than 5-10 y.o geldings (neutered males).Likewise mares in foal, often glossed over in farming textbooks, but in fact frequently outnumbering the males, many of which spent their most productive years in the towns.

Determining the 'real' size of the agricultural herd, meaning animals used exclusively for farm work, involves confronting the problem, inherent in the way in which most farm censuses were then conducted, of separating 'horses resident on farms' employed in agriculture, from those used for other purposes. In England c1910, at least one-quarter of horses on farms were non-agricultural, , and in suburban areas as many as one- half.

In short, the equine herd was far from heterogeneous, demographically or physically, and potential draught output per head well short of the of James Watt's notional 'one horse-power). **Table 9** illustrates well the many and considerable variations in the horse-power (h.p.) outputs of the different classes of horse commonly found in Britain in the early 20c

Table 9 Weight, work capability. and usage of various classes of British horses c.1920.

	weight (kg)	work output (h.p.)
Heavy horse (town work)	900-1050	1.2.
Medium heavy (agricultural)	750-900	1.0
Light medium (light agricultural)	600-750	0.7
Light (carts)	500-600	0.6

Mature horse	(5-12y.o.)	1.0 traction units =1 h.p.
Maturing	(3-5 y.o.)	0.8
Horses in training	(2-3 y.o.)	0.6
Old horses	(+12 y.o.)	0.5-6
Mares in foal		0.4 (1st half only, then rested)

While horses held sway in northern Europe, cattle were much more in evidence in other regions (see Appendix Table 1). An especially large ox or bullock were reckoned able to exert almost as much pull as a good horse, but were slower, less active, and tired more quickly. Oxen functioned well in large teams, and could pull heavy dead-weight loads of stone or timber over long distances. Often, they were preferred to horses for ploughing, and kept specifically for that purpose. Bovines had the advantage of being multi-purpose, and cheap and easy to upkeep. Whereas horses were fed high - energy foods, oxen could do useful work on a low-energy high-cellulose diet of poor grass or hay, and crop residues such as turnip leaves and straw.

Though slow-moving when in harness, on the open range oxen could be very active, and difficult to herd. In Britain and France, specialist breeds were developed in the 18 and early 19c to meet the need for work animals which combined moderate draught, higher speeds and improved beefing qualities: in short, bovines with equine characteristics. In France, the demand was met by the Parthenay, a quick worker designed to be sold for fattening on grass farms in Normandy; the larger and more powerful Charlerois ; and the elegantly conformed Limousin, used on sugar-beet farms in Picardy and Champagne for ploughing and row- work, and fattened on mash and beet-

tops. The English equivalents were the quick-moving and much admired North Devon breed, popular on light turnip soils, and its rivals, the Sussex, Pembroke, and Hereford.

European cattle , though, were of very variable quality. In the east and south they tended to smaller framed and less powerful than in the west and north.. In the mountain areas of Romania, for example, they had the reputation of good milkers but poor workers, lacking staying power, and in the Old Kingdom, of being small and degenerate. The best workers were the rangy grey steppe cattle, with long lyre-like horns, as found in Transylvania. Of classic conformation - heavy shouldered, deep- chested, long-legged- from the late 19c they began to lose many of their draught properties as a result of crossing with western European breeds to improve milking performance. By 1926, grey cattle in Hungary comprised only 17 per cent of the national herd, compared with 80 per cent in 1884. A compelling reason for the institution of heavy horse breeding programmes after 1920 was the desire to compensate for the fading powers of the ox. Oxen were normally slaughtered at 6-7 y.o., when incremental growth was slowing and meat quality beginning to deteriorate: some though were kept working far longer, up to the age of 12 or beyond.

As already shown, cows were an integral part of the European draught economy, and in many regions more used than oxen. Table 8 shows the percentage of working cows in cattle herds in the mid-1930s to have ranged from 25 to 75 per cent, and in France and Germany to have risen to 80 per cent in the early post-war period.
Estimating the draught capability of working cows is problematic, as not only were they capable of less work than oxen by virtue of their smaller size, , but a high proportion of their energy was spent in reproduction, resulting in only a very modest contribution to work effort before and after calving.

Asses, mules and donkeys were an under-rated but in southern Europe at any rate, often an indispensable part of the energy reserve. Operationally, they were faster and more nimble than horses and cattle, able to negotiate difficult terrains, withstand extreme heat, and cheap to maintain. Oxen and horses were preferred for ploughing, but particular advantage of the smaller equides lay in their high energetic efficiency in relation to bodyweight, and the ability to carry heavy loads over long distances. Where oxen could exert a draught of between one-eighth and one- tenth their own weight for 5-6 hours, mules could exert between one-fifth and one-sixth, albeit for shorter periods, up to 3-3.5 hours. Best of all, a donkey could carry as much as one-quarter to one-third of its own weight over distances of up to 40km daily.

Mules bred for draught were heavier than those bred for pack work, and of similar stature to a light or medium -sized horse. All-round sturdiness, compact bodies, straight backs, and short muscular legs, were the hallmarks of the superior types of mule, as bred in specialist breeding districts, such as Poitou in eastern France. Donkeys were used primarily for transport, but could plough at a pinch. In Ireland, they did the carrying and the horses the ploughing, while in Spain mules did mainly farm work in

Winter and Spring and carting and carrying at other times of the year. A strong draught mule was reckoned to exert almost as much pull as an ox, though with less stamina,.

Water buffaloes were a distinct species of domesticated cattle, famed for strength and endurance, and so well adapted for ploughing the deep heavy soils of the marshy coastal plains and river deltas of the east and south, where speed was unimportant.

Energy efficiency

The analysis so far implies that the net stock of animal energy available for work was much smaller than generally assumed and the proportion of it utilised far less than theoretically available. In the bio-physical world, all energy flows are regulated by the Laws of Thermodynamics. This is to say that 'heat engines', animal and mechanical, are inherently inefficient, and at all points along the distribution chain, subject to transmission loss and dilution. In the case of horses, it is estimated that only 50 per cent of hay and 70 per cent of grass ingested are metabolised, and overall, less than 10 -20 per cent of energy consumed converted into work. Bovines are more efficient than equides because the former are better able to utilise, where bio-chemically the latter cannot, low- value less easily digested foodstuffs such as straw. As a consequence, doing moderate work, the energy needs of cattle are only about 60 per greater than is required for maintenance. Conversely, the horse's higher metabolic rate enables it to exert more power more quickly, and for short periods, exceptionally bursts of up to 60 per cent bodyweight. Mules, asses and donkeys are more physiologically efficient again, and on very low energy diets are capable of extraordinary feats .of work. Overall, weight for weight, and if appropriately fed, a horse is better adapted for heavy draught than other species of working livestock.

Energetically, motor tractors were many times more productive than animals, the typical 1950s machine being rated at 20-25 draw-bar h.p. They too though were inefficient, more so than horses or oxen. In the early 20c, the efficiency of stationery steam engines rated at 14- h.p. on the brake, , was 4-12 per cent, and of oil engines rated at 5.5 belt h..p. 18-20 per cent. Tractors at the 1921 trials averaged only 10 per cent, rising to 15 per cent in 1935, and 20 per cent in the 1950s. **Table 10**

Table 10 Mechanical power ratings in Great Britain

Stationary steam engine c.1900	14 h.p.(brake)
Oil engine c.1939	5.5 h.p.
Electric motor c.1939	4.0 h.p
Motor tractor c.1939	25 brake-h.p. (belt), 1h.p. (draw-bar)
Motor tractor c.1975	65 brake-h.p (belt), 40 (draw-bar)

Draught needs at the farm level were a function not of accumulated demand, month upon month, but of demand at the work peak, plus contingencies. Workloads at the height of the ploughing season, could be upwards of 50-80 per cent greater than in the slack season. Thus, all prime movers tended to be under-employed for a large part of the year, where in the high season they were fully stretched. Peasant farms in eastern Europe often had to hire in horses at busy times. In Britain, according to a 1930s survey, even on the best-managed farms, the horses were worked for only 175 days per year, and tractors for only 80-120 days, or on average, only 40 per cent of the 200 days normally available.

Thus in agriculture, in contrast to manufacturing, power forces of whatever source, would be under-utilised, due partly to seasonal factors, but also because of the limited demands made on the energy available. Exceptionally, an energy-using task such as deep ploughing might utilise 70-80 per cent of a horse's output capacity, compared with only 25 per cent fin rolling and harrowing, and 20-30 per cent overall. Because of their low velocity- 3-4 kph in the case of horses, oxen only 2-3kph, under- loading could not be offset by faster working speeds and higher work rates. Before 1950, most of the implements in use were designed for horses, resulting in tractors having to work at well below maximum speed, sometimes at walking pace.

Where the internal combustion engine was tireless, and in the higher latitudes or if fitted with lights, could work until well into the night, animals were subject to fatigue, which limited the horses to a 7-9 hour working day in summer and 6-7 hours in winter. Oxen tired sooner than horses, and so worked shorter- half or three-quarter- days, or three or four days a week, or for a few months only. Large teams of eight or ten, sparingly fed, and with a high proportion of very young and very old animals, and cows, in practice may have done very little work, especially in late winter and early spring when feed was scarce. Cows may have contributed very little to the team effort, as the energy available had to be divided between four jointly supplied outputs- meat, milk, reproduction, and work. Under-fed cattle were, almost as a matter of policy, worked only moderately hard, lest they lost weight and condition. This somewhat unflattering view of the ox's capabilities is leavened by the English experience in the early 19c, when specialist workers such as the Devon, could keep pace with horses on light land, and in

ploughing competitions sometimes finish ahead of them. One Sussex ox is reported as having run 4 miles (6km) around a local racecourse in just 16 minutes.

Tractors in the proto-mechanical age were systematically under-worked. Once described as 'a very powerful and untiring species of horse', in fact, tractors used only a fraction of the power available. Would-be purchasers may have been deterred by the tests carried out by the National Institute of Agricultural Engineering at Oxford in 1945, which demonstrated that due to transmission losses, tractors with an official draw-bar horse-power of 20, developed only 8 h.p. when ploughing to furrow. Tractors more so than horses were invariably under-loaded : pulling a plough at speed may have utilised 80 per cent of the full engine load, but a chain harrow only 15 per cent, and a heavy roller or harvest wagon, perhaps only 25 per cent. Power losses were incurred from wheel slip, constant rolling resistance, and the energy absorbed in moving the tractor itself. A puzzling feature was that less power was developed in top gear than in bottom. Horses were utilised more effectively than tractors. One British survey in the 1940s, found that horses supplied 40 per cent of the available power, but did 70 per cent of the actual work; another, that horses worked about 1500 hours (c. 170 days) per year, and tractors 600-800. Only at a late stage of mechanisation did tractors shoulder most of the work, and horses relegated to doing odd jobs around the farm, clearing up.

Farm size was a further complicating factor and source of inefficiency. Lenin, no less, had used the number of draught animals per household as a measure of peasant stratification in Pre-Revolutionary Russia. He showed that large farms usually had a surplus of draught, while very small farms often had no specialist work animals, and had either to hire them, or use cows instead. Doreen Warriner's classic study of European peasant farming set in the 1930s, observed that the numbers of work animals per hectare in the small farming regions of central and eastern Europe were typically as high or higher than in intensively farmed regions in western Europe. In Poland and Hungary, 'fantastic' numbers of horses relative to crop yields were kept by large farms, at the same time as small holdings were increasing due to population pressure and the re-distribution of land following the the break-up of large estates. Thus the situation where two-thirds of all cattle on small farms were used for work rather than producing saleable produce.

The imperfect distribution of energy relative to need was at the root of 'the farm problem' in inter-war Europe. The density of draught animals per hectare varied inversely with the size of holding, and was much larger on small than on large farms. In pre-collectivist Russia, horses were unprofitable in one-third of peasant households because crop areas were in most cases smaller than the eight hectares that a horse could plough. Moreover, size of farm apart, a team of at least two horses or three or more oxen was required to generate the 1.5-2.5 h.p. needed to cultivate medium soils. In England, in the 1930s, horse densities per farm averaged 4.5 in the 8-40 hectare size group, but only 2.1 in the 120-200 acre size group, a saving of more than 50 per cent in horse

inputs. After World War 2, farms with tractors often continued to keep large numbers of technically redundant draught animals As a result, tractors replaced fewer animals than the seven theoretically achievable, and by 1970, most farms in W .Europe of more than 10 hectares were hugely over- powered.

The paper concludes with a revised estimate of the power ratings of the principle species of draught animal. **Table 11**

Table 11 Revised and historic power ratings of the of the principle species of draught animals used in European agriculture in the early – mid 20c. (in h.p.).

	FAO Ratings	**EU9 Ratings**	**Revised Ratings**
	h.p.	h.p.	h.p.
Horses	1.0	1.0	0.5-0.6
Asses/ Mules	.7	.7	0.4-0.5
Draught oxen	.75	.5	0.4-0.5
Draught Cows	.2	.4	0.3
Buffaloes	-	-	0.5

The revised ratings for horses, asses and mules, shown in Table 10, are in both cases between one-third and one-half than the FAO and EU ratings. Applying the separate ratings to animal numbers in 1933-5, gives three values, each subject to a wide margin of error, for animal power availability at what was probably the historic peak of animal usage, a decade or so before the onset of the mechanical revolution of the second half of the 20c..(**Table 12**).

Table 12 Animal power availability in Europe c 1935 based on FAO, EU9 and the author's revised estimates of output ratings (million h.p.)

	Revised rating	**FAO rating**	**EU9 rating**
Horses	11.38-13.87	22.76	22.76
Mules/asses	2.08-2.60	3.63	3.63
Draught oxen	2.32-2.90	4.35	2.90
Draught cows	3.00- 4.50	2.00 -3.00	4.00-6.00
Buffaloes	.12	.12	.12
TOTAL (million h.p.)	**17.90-22.29**	**32.86- 33.86**	**33.41-34.1.**

As tractor power units then totalled only about 600,000 h.p., and steam plough power units about 80,000 h.p. mechanical traction posed no immediate threat to the dominant position occupied by animals. The main effects of my revision is to reduce power availability by about one-half, while at same time not seriously impinging on the standing of the horse.. Comprising rather less than one-half of the combined draught herd, horses supplied more than 60 per cent of the available power , and together with asses, mules and donkeys, nearly two-thirds.

The modern history of animal traction has still to be thoroughly researched. A highly complex topic, it is fertile territory for a multi-disciplinary approach, requiring a knowledge of animal physiology and bio-chemistry, animal nutrition, and mechanics, and practical agriculture, as well as agricultural history and econometric skills in constructing demographic models. A powerful case exists for close liaison between agricultural historians studying the transition from animal to mechanical power in the last

century, and agricultural development economists looking at energy systems in developing countries at the present day.

EJT COLLINS
10 September 2010