Agricliometrics V | Universidad de la República (Uruguay) | 7-8 December 2023
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Ghost pastures in Uruguay, 1870-1930

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When a country imports an agricultural product it is effectively using foreign land resources embodied in that commodity. South America has long been a provider of 'ghost acres' for industrialising economies through crop and livestock exports, leading to wide-ranging environmental degradation in the region. And yet we know almost nothing about the extent of ghost pastures grazed by livestock to supply foreign markets, because the literature measures only the cropland embodied in trade. We examine the case of Uruguay, the country with the most cattle per person in the world, during the First Globalization, when it exported c.10% of globally traded beef and wool. This paper offers the first estimates for pastureland embodied in Uruguayan exports, considering changes in breed, diet, and age of animals between 1870-1930. We find that p1astures embodied in exports expanded by 0.85% each year to occupy 40% of Uruguay's total land. The efficiency gains produced by biological innovation (each animal needed less land) resulted in *more* land being used in total: a pastoral variation on Jevons' paradox.

Human life, wellbeing, and economic development have always been tied to land and the material resources it provides. Whilst competition for land has been pervasive throughout history, the scale of the struggle became global over the last two centuries, with unprecedented environmental and economic consequences. Industrialization, whether in nineteenth-century Europe or in twentieth-century East Asia, required increasingly large volumes of raw materials and foodstuffs brought from near and far. A vast expansion of international trade since the mid-19th century opened the floodgates to 'outsourcing' land use, whereby industrializing and industrialized nations gained access to new frontiers through the importation of land-based commodities. When a country imports an agricultural product it is effectively using the foreign land resources embodied in that commodity. A large literature in environmental history and ecological economics (among other sub-fields) has attempted to quantify the scale and the effects of this 'land outsourcing' in the global periphery. Today, over a third of global cropland is estimated to be 'traded' in this way, but we know surprisingly little about the part played by grass in the global struggle for land in the past and the present.

In this paper we estimate the hectares of grassland embodied in Uruguay's beef and wool exports during the First Globalization (1870-1930). Uruguay is an exceptionally good case study to test a method for estimating the land embodied in pasture-based cattle and sheep farming in historical perspective. The country with most cattle per person in the world, then and now, Uruguay's pasture-based livestock farming was crucial for the national economy (c.80% of exports, c.40% of GDP) and played an oversized role in international markets: a country of about 1.5 million people was home to 8 million cattle and 20 million sheep and contributed c.12% of globally traded beef and c.6% of wool.[1] In a context of high international prices for these commodities, the agricultural export economy made Uruguay comparatively prosperous: by 1900 average incomes were similar to France's or Canada's (and three times higher than in

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[1] María Inés Moraes, 'El capitalismo pastor. Dinámica tecnológica e institucional de la ganadería uruguaya entre 1870-1930,' *Historia Agraria* 29 (2003); Emiliano Travieso, 'Soils, scale or elites? Biological innovation in Uruguayan ranching, 1880-1913,' *Economic History Review* 76, 2 (2023).

Mediterranean Europe), and sustained an early attempt at a welfare state and progressive legislation (including the 8-hour workday, divorce law, and separation of state and church) in the era known as 'first *batllismo*'.[2] It was a 'peculiar welfare state, standing on hooves, grass, and mud.'[3] What were the environmental costs of this prosperity? The land embodied in livestock exports can tell part of the story. Whereas in other countries cattle and sheep grazed on marginal areas, in Uruguay they occupied 90% of the agricultural land and contributed to far-reaching grassland degradation.[4] Here we estimate how much of that land was used to satisfy foreign demand, or, to paraphrase Pomeranz, how large were Uruguay's ghost pastures.

After this introduction, Section 1 reviews the comparative empirical literature on land embodied in agricultural trade, considering also the part 'ghost acres' play in narratives about industrialization and the Great Divergence. Section 2 describes our estimation method and our data sources. Section 3 presents our main results, and Section 4 discusses them in relation to Uruguayan economic history and wider debates. The conclusion argues for the importance of considering pastures when estimating and discussing 'ghost acres' and their environmental impacts.

1. Literature: ghost acres and land footprint

Pre-industrial economies were fundamentally constrained by the availability of agricultural land, which was the ultimate basis for the production of food, clothing, and energy. As shown extensively by E.A. Wrigley, economic activity in these 'organic economies' was fundamentally a zero-sum game: there was a limited supply of land which could be used either to produce energy (fuelwood or fodder for animal muscle power) or food for humans.[5] This land constraint was overcome, at least in its starkest form, by coal-powered steam technology during the first industrial revolution, which developed in Britain in the late-eighteenth and early-nineteenth centuries, spread to north-western Europe, and eventually reached many other countries.[6] But Britain (and then Europe) also found substantial ecological relief by importing agricultural commodities from across the ocean. Kenneth Pomeranz famously argued that having access to the 'ghost acres' in the Americas was crucial for industrialization to begin in Britain rather than China, and thus contributes to explain the 'Great Divergence': the processing leading to a large gap in living standards between some Western societies and most of the rest of the world.[7] In other words, the emergence and consolidation of modern economic growth was facilitated by

[2] For a recent analysis of Uruguay's politics during *batllismo* see Gerardo Caetano, *La república batllista* (Montevideo, 2013); for an overview of Uruguay's economy, see Luis Bértola, 'Primer Batllismo: reflexiones sobre el crecimiento, la crisis y la guerra,' in *Ensayos de Historia Económica. Uruguay y la región en el mundo (1870-1990)* (Montevideo, 2000).
[3] Alberto Methol Ferré, *El Uruguay como problema en la cuenca del Plata entre Argentina y Brasil* (Montevideo, 1967).
[4] Daniel Panario and Mario Bidegain, 'Climate change effects on grasslands in Uruguay,' *Climate Research* (1997).
[5] E. A. Wrigley, *Energy and the English Industrial Revolution* (Cambridge, 2010).
[6] For an overview of the part played by coal in the origins of British industrialization, see Robert C. Allen, *The British industrial revolution in global perspective*, New approaches to economic and social history (Cambridge, 2009).
[7] Kenneth Pomeranz, *The Great Divergence: China, Europe, and the making of the modern world economy* (Princeton, 2000): 264-97. For a global overview of the Great Divergence, see Robert C. Allen, *Global Economic History: A Very Short Introduction* (Oxford, 2011).

horizontal expansion (tapping into agrarian frontiers elsewhere) as well as by vertical expansion (accessing subsoil fossil fuel reserves).[8]

But exactly how large were these 'ghost acres' which helped core economies overcome their land constraints via international trade during and since the 19th century? Economic historians usually focus on the land savings in importing countries, measuring for example the opportunity cost in terms of cropland of producing an imported agricultural commodity in Britain, or, if the crop could not be grown there, the average land cost among producing countries.[9] The procedure is, therefore, to take the volume of imports of a crop (in primary equivalent in case the imported commodity has already been processed) and multiply by a coefficient reflecting the land productivity of that crop in the importing country, or using a global mean coefficient, regardless of where the products are actually coming from. This makes sense from the perspective of discussing the contribution of land outsourcing via trade to the development of core economies, but it does not inform us about the environmental impact for exporting countries in the global periphery.

On the other hand, ecological economists, social ecologists, and environmental historians often prefer to focus on the 'land footprint': the extent of land actually 'externalized' (embodied in exports) given productivity levels in exporting countries. This emphasis resonates with a different analytical tradition to the 'great divergence' narrative popular among economic historians. Instead, scholars in these fields see global economic development under the lens of 'unequal ecological exchange': the theory that the enrichment of the West was founded on the degradation of landscapes in much of the rest of the world through an 'environmental load displacement.'[10] Some of the empirical studies in these fields do attempt to include the land used in traded animal products, but they only cover the recent past and only count the land required by the crop products embodied in livestock commodities.[11] That is to say: if a cow is fed using grain fodder, then that is counted in the land embodied in beef exports, but the grass it ate is not counted. Therefore, in both the historical and the ecological literatures, estimates of 'land footprint' or 'ghost acres' do not include pastures used to produce meat.[12] This is surprising because animal protein imports remain central for industrializing economies in Asia today and most land embodied in South American exports today is pastureland. From a

[8] Rolf Peter Sieferle, *The Subterranean Forest: energy systems and the Industrial Revolution* (Cambridge, 2001); Edward Barbier, *Scarcity and Frontiers: How Economies Have Developed Through Natural Resource Exploitation* (Cambridge, 2011).

[9] Dimitrios Theodoridis, Paul Warde, and Astrid Kander, 'Trade and overcoming land constraints in British industrialization: an empirical assessment,' *Journal of Global History* 13, 3 (2018); Dimitrios Theodoridis, 'Colonialism and Trade: Ecological Foundations of British Trade in the Nineteenth Century,' *The Journal of Interdisciplinary History* 53, 1 (2022).

[10] This is a very rich scholarly tradition which we cannot do justice to here. See, for an influential example, Alf Hornborg, 'Footprints in the cotton fields: the Industrial Revolution as time–space appropriation and environmental load displacement,' *Ecological economics* 59, 1 (2006), and, for an overview, Alf Hornborg, John Robert McNeill, and Juan Martínez Alier, *Rethinking environmental history: world-system history and global environmental change* (2007).

[11] There are very many case studies in the ecological economics literature. For an overview of the methods, see Martin Bruckner, Günther Fischer, Sylvia Tramberend, and Stefan Giljum, 'Measuring telecouplings in the global land system: A review and comparative evaluation of land footprint accounting methods,' *Ecological Economics* 114 (2015). An important analysis at a global scale is Thomas Kastner, Karl-Heinz Erb, and Helmut Haberl, 'Rapid growth in agricultural trade: effects on global area efficiency and the role of management,' *Environmental Research Letters* 9, 3 (2014).

[12] Theodoridis includes pastureland savings through wool imports to Britain in his latest study, but not meat; see Theodoridis, 'Colonialism and Trade'.

historical standpoint, beef and wool were crucial for European economic development in the First Globalization and key exports for several countries in the global periphery.

Scholars argue against including pastures in calculations of land embodied in agricultural trade for two main reasons. First, that the variation in global pastureland use is so large that it complicates calculations: the quality, productivity, levels of human intervention, and productive strategies of livestock farming are immensely varied and so methodological assumptions quickly become unrealistic. And second, it is claimed that pastures occupy marginal areas often not suitable for crop agriculture and so are less costly from the point of view of food security in exporting peripheral economies, and thus should have less impact in terms of land degradation.[13] But this is not true in much of Latin America, and certainly not in Uruguay, either a century ago or today.

We aim to contribute to this literature through a specific case study. Beyond the relevance of our findings for advancing the understanding of Uruguayan economic and environmental history, we contribute methodologically by showing a relatively minimalistic way (in terms of the data requirements) of estimating land embodied in beef exports in historical perspective.

2. Method and data

To estimate cropland embodied in trade it is enough to have a single factor as a coefficient: the land required to produce a certain volume of that crop, either in the importing country ('land relief') or in the exporting country ('land footprint'). But pastureland is different for several reasons. Firstly, because there are more factors involved: the rate of grass growth, the feed requirements of animals, and the pasture usage rate (how much of grass available is effectively eaten). Secondly, because in the case of beef cattle, the productive process spans multiple years: if an animal is slaughtered and its meat exported in year *t*, how should we allocate the grass it ate *t-1*? Thirdly, livestock are multi-purpose: they result in the joint output of several primary commodities, and so it becomes necessary to allocate the land requirements between products. Fourthly, in some agricultural economies, such as Uruguay, rely on mixed grazing: cattle and sheep (or other animals) share the same pastures. Finally, the diet of animals often involves grass as well as grain fodder, although this was not the case in Uruguay in this period.

For our estimation of the land footprint of beef and wool exports in Uruguay between 1870 and 1930 we work backwards from the export figures taking these issues into account. We rely on primary sources and on the specialist historiography for some of the coefficients required, and on present-day agronomic studies for others (Figure 1, Table 1). To account for the multi-year raising of beef cattle, we consider two methods: (a) all of the pastureland required by the animal during its life is allocated to the year when the meat is exported (we call this the 'slaughter-year method'); (b) we project backwards the grass eaten by each cohort over their lifetime, in a matrix that reconstructs the age and dietary requirements of each generation in every year ('cohort method'). It should be noted that in this first estimation we consider cattle hides to be entirely a sub-product of beef, and so we do not allocate land specifically to cattle hide exports; this requires some qualification especially in the first decades of the period under study, which we will develop in a later version of the paper.

[13] Kastner, Erb, and Haberl, 'Rapid growth', Supporting information, p.10.

Table 1. Sources and procedures for each variable [14]

Variable	*Sources*	*Procedure*
Cattle initial weight after lactation	Armstrong et al (2021)	We input initial weight after lactation following Armstrong et al (2021) studies on present-day herds in open-air grazing: 83 kg for creole cattle and 102 kg for crossbred cattle. Lactating period is fixed at 0.29 years for all animals.
Grass growth	Crempien [1983] (2008) and Pereira Machín et al. (2011)	Based on both sources, we take a mean of 4,000 kg/ha of dry matter growth.
Cattle breeds	Travieso (2023)	Travieso (2023) gives % of cattle improved through crossbreeding in 1870, 1880, 1890, 1908, and 1930. We use linear interpolation to get a yearly series of shares of creole and improved cattle.
Pasture usage rate	Crempien [1983] (2008) and Pereira Machín et al. (2011)	We take the average % of pasture usage rate between the two sources (60%)
Daily weight gain and feed requirement	Armstrong et al (2021)	We input daily weight gain by breed following Armstrong et al (2021) studies on present-day herds in open-air grazing: 0.272 kg for creole cattle and 0.308 kg for crossbred cattle.
Age at slaughter	Herrera y Obes (1885) Plan Agropecuario (1947)	For 1870-1900 we use Herrera y Obes estimates (creole cattle 6 years; crossbred cattle 4.5 years). For 1913-1930: Plan Agropecuario (1947: 165) reports an average slaughter age of 4.5 years between 1913 and 1930. For 1900-1913: linear interpolation between the 1899 and 1914 figures.
Weight loss in transport to plant	Castro and Robaina (2003)	We assume 5% weight loss in transport to the slaughterhouse.
Weight at slaughter	Moraes (2001)	Yearly series already provided by Bértola et al. (1998) from different primary and secondary sources.
Cattle sold for slaughter	Bértola et al. (1998)	Yearly series already provided by Bértola et al. (1998)
Share of beef output cattle	Bértola et al. (1998)	Bértola et al. disaggregate the output of the beef industry by destination (domestic market or exports). We apply the same proportion to the number of cattle slaughtered.
Number of sheep	Narbondo (2022); Censo General Agropecuario (1900, 1908, 1916, 1924, 1930)	For 1870-1899 we use Narbondo's (2022) estimates. For 1900-1930 we use linear interpolations between years with census data.
Sheep feed requirement relative to cattle	Álvarez (2014)	Following the Livestock Unit coefficients for Uruguay recommended by Álvarez (2014: 140-141) for this period: 5 sheep ~ 1 cow.
% of sheep sheared	Censo General Agropecuario (1937, 1946, 1951)	Based on the average of these census' reports, we assume 85% of sheep were sheared each year.
Wool export volumes	Millot and Bertino (1996); BROU (1933)	Yearly volumes reported.
Total pastureland	Álvarez (2014)	Linear interpolation between the benchmarks gathered by Álvarez (2014) from different primary and secondary sources.

Source: own elaboration, see Figure 1 for the use of each variable in our estimations.

[14] See References section at the end of this draft for full bibliographic data.

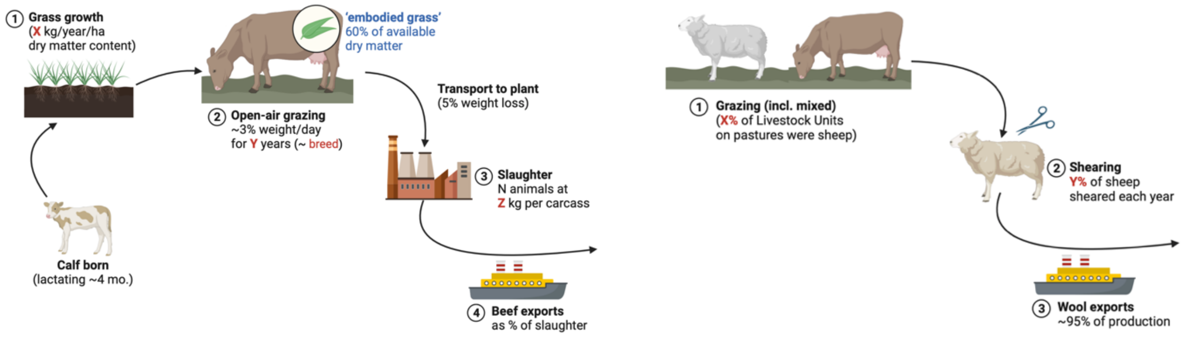

Figure 1. Production cycle of beef (left) and wool (right) in Uruguay (1870-1930) and the coefficients we use to estimate pastureland requirements.

The process described in Figure 1 does not explicitly depict live cattle (*ganado en pie*) exported to be slaughtered elsewhere, which in this period meant almost always in southern Brazil. Live exports accounted for about 12% of the total market of 'finished' cattle sold in the period 1870-1930.[15] These animals are included in our total estimates, so the grass eaten by 'on the hoof' exports is part of our ghost pastures. At present, however, we treat their feed requirements exactly as if they had been slaughtered in Uruguay. This should be improved upon because cattle exported overland to Brazil were qualitatively different from most animals slaughtered in Uruguay: less likely to be genetically improved and older. In a future version of this paper, we will offer a specific set of estimates for 'on the hoof' ghost pastures throughout this period.

3. Results

The land footprint of Uruguayan livestock exports increased substantially during the First Globalization: from about 4 million hectares (or 25% of the country's agricultural land) to almost 7 million hectares (over 40% of agricultural land). Unlike other temperate economies in this period (Argentina, Canada, Australia, New Zealand, and the United States), Uruguay had no open frontier. Instead, the land demands of the export economy had to be met through land-use change: the surface covered by managed pastures expanded at a cumulative rate of 0.3% per annum, led by pastures supporting export production which grew almost three times faster (at 0.85% per year).

Figure 2 shows the evolution of pastureland embodied in wool and beef exports. The variation between the two series shown is due only to changes in how we account to land embodied in beef. The 'slaughter year method' series shows a sharper volatility, because it is very sensitive to years when culling rates were exceptionally high (due for example to draughts, as we will discuss below). The 'cohort method' results in a smoother trend which is, we believe, a better guide to changes on the ground, as it more accurately reflects the actual extent of pasture being used every year by cattle which would eventually be slaughtered.

[15] Our calculations from Bértola et al., *El PBI de Uruguay*.

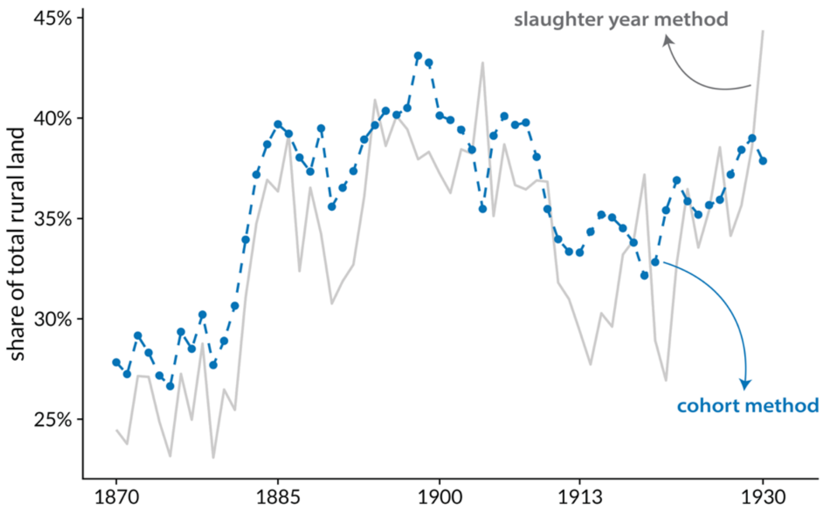

Figure 2. Footprint of Uruguay's wool and beef exports as share of total agricultural land
Source: our calculations; see Table 1 for sources and Figure 1 for the method.

This growth was mainly driven by the land footprint of beef cattle, which doubled in the period (Figure 3). The footprint of wool exports remained higher throughout (albeit its growth was slower) and it was less volatile, simply because when exporting wool the animals remain alive, and so there is no stock variation as a result of exports like in the case of beef cattle. Because many Uruguayan producers practiced mixed grazing (sheep and cattle grazing together), falls in wool ghost pastures and increases in beef ghost pastures (as in the 1910s and the early 1920s) or vice versa (as in the 1890s) could often reflect changing herd balances within estates, rather than a wholesale conversion of areas from sheep country to cow country.

Figure 3. Footprint of Uruguay's wool and beef exports (in million hectares).
Source: our calculations; see Table 1 for sources and Figure 1 for the method.

4. Discussion

What has been the land footprint of historical livestock exports in South America? Our results show that for the case of Uruguay, a leading global livestock producer during and since the First Globalization, over a third of all land was occupied by pastures to produce wool and beef. Anthropogenic pressure on land increased significantly, despite notable efficiency gains, in a pastoral version of Jevons' paradox: new cattle breeds were more effective at transforming grass into protein, but there were many more cows than before. Moreover, our estimates show that producers responded to climate variation by altering the balance between cattle and sheep, with important consequences for Uruguay's ghost pastures.

4.1. Jevons in the ranch

In the late-nineteenth and early-twentieth century, Uruguayan producers increasingly adopted crossbreeding, improving local animals—the Uruguayan Creole Cattle—with specialist beef breeds from the United Kingdom, mainly Hereford and Shorthorn (Figure 4).[16] These improved animals were more efficient at converting grass into protein, which resulted in efficiency gains both from an economic and an environmental standpoint. Crossbred cattle (*mestizos*) could reach their target weight faster, which *ceteris paribus* should have resulted in land savings, freeing up some of Uruguay's 'ghost pastures.' Nevertheless, increased efficiency led to *more* land being used to produce beef exports. This is known in the literature as the 'rebound effect' or Jevons' paradox: efficiency gains lead to higher absolute levels of resource exploitation.[17]

Figure 4. Uruguayan Creole Cattle (left) and Uruguayan Hereford cattle (right).
Source: authors' photo of *criollo* reserve herd (2022) and Uruguay Hereford Society.

Figure 5 shows how Jevons' paradox operated on Uruguay's grasslands during the First Globalization. The average time spent by each animal on pasture fell notably, as increasingly crossbred herds needed less grass per head to reach their slaughter weight. At the same time, and because land could be used more efficiently, the total number of cattle bred for export in Uruguay increased. As a result, the footprint of livestock exports became substantially larger due to cattle crossbreeding, driving anthropogenic pressure on Uruguay's land.

[16] For two analyses of this process of innovation adoption, see Moraes, 'Capitalismo pastor' and Travieso, 'Soils'.
[17] Named after William Jevons' *The Coal Question* (1865) where he argued that 'It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth.'

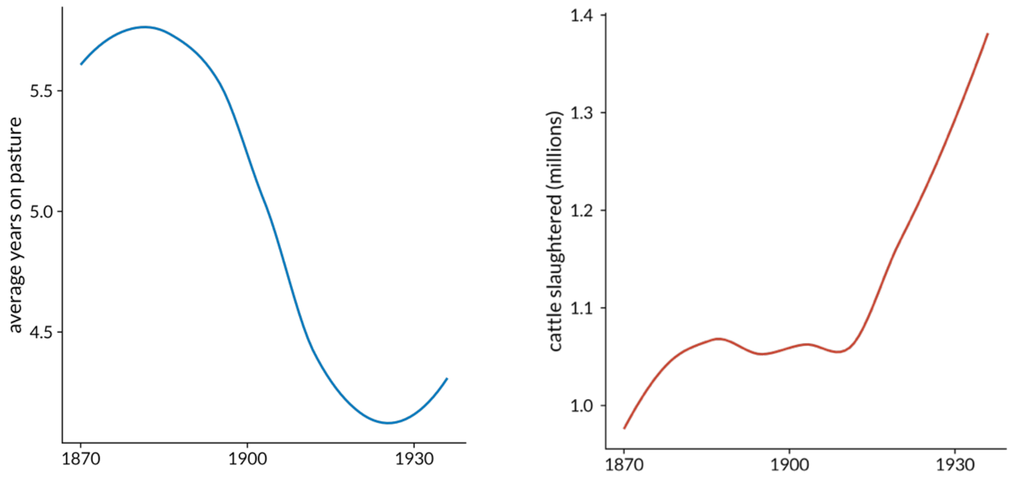

Figure 5. Average years of pasture (left) and total cattle slaughtered (right).
Source: our calculations; see Table 1 for sources.

4.2. Rainfall and mixed grazing

Moraes estimated that total factor productivity in Uruguayan pastoral agriculture between 1870 and 1913 grew considerably faster than in Argentina, Canada or the United States, and argued that the technical innovations which made that possible started with the large-scale adoption of Merino sheep in the 1860s and, in particular, the development of mixed grazing (i.e. cows and sheep being raised together on the same plots of land).[18] Because sheep and cattle get along well on the grazing range (sheep give way to cows), have different foraging preferences (short and long grasses respectively), and do not mind eating near the other species' dung, they are often thought as complementary in mixed grazing systems.[19]

But there are limits to that complementarity, because both species ultimately consume the same finite (albeit renewable) resource, and trade-offs do emerge in environmental settings which, like large parts of Uruguay, can profitably accommodate both species. Increased animal competition for resources within the estancias (especially forage but also drinking water and preferred spots to rest) was intensified in the winter, when grass growth is noticeably slower and overgrazing significantly reduces forage availability. A committee of experts appointed by the Uruguayan Rural Association in response to a government request concluded that it was the effect such competition had on pastures, and not any sort of diseases transmitted from sheep to cattle or within cattle herds themselves, which was to blame for a reduction in the stock of cattle across most of the Uruguayan countryside.[20]

Our results show that the variations of beef ghost pastures and wool ghost pastures often mirror each other, and that they show the responsiveness of local producers to changes in climate through time. Figure 6 compares the variation in yearly rainfall with the extent of grassland embodied in beef and wool exports between 1883 (the first year for which we have rainfall observations) and 1930. Temperate-zone cows (*Bos taurus*) tolerate excess rain much better than dry spells, sheep are very resilient to droughts, and so the distribution of land embodied in Uruguay's pastoral exports moved in favour of beef after rainy years, and in favour of wool in drier times.

[18] Moraes, 'Capitalismo pastor', 19.
[19] Clive Phillips, *Cattle Behaviour and Welfare* (Oxford, 2002): 103-04.
[20] Biblioteca Nacional (Montevideo), *Revista de la Asociación Rural*, n.51, 15 January 1875, 706-708.

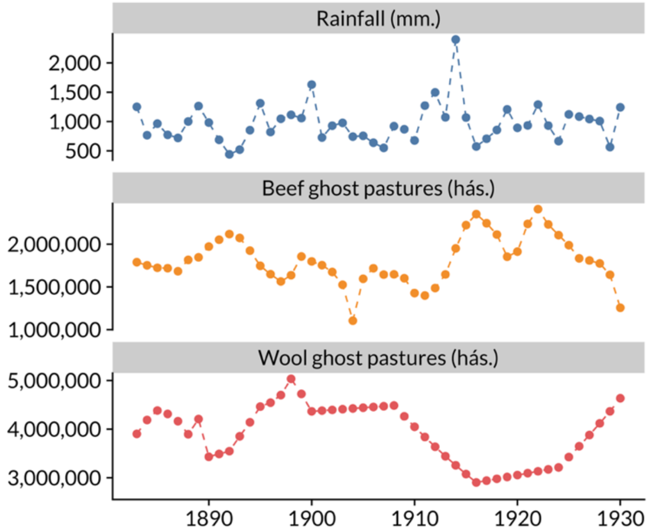

Figure 6. Yearly rainfall and pastureland embodied in Uruguay's beef and wool exports, 1882-1930.
Source: rainfall data from Morandi (1940); land embodied from our own calculations (see Table 1 for sources and Figure 1 for procedure).

Almost fifty years ago, in their seminal *Historia Rural del Uruguay Moderno*, Barrán and Nahum highlighted the importance of working on the history of climate in Uruguay to understand long-term development.[21] The historical relationship between rainfall and land use in export agriculture is a crucial part of that history which remains to be written.

5. Conclusion

Pastures have been a key part of the struggle for land in global economic history, and so historical estimates of land embodied in agricultural trade should include them. We examine the case of Uruguay, a leading livestock exporter, and propose a method for estimating the pastureland embodied in beef and wool exports during the First Globalization (c.1870-1930). We find that Uruguay's *belle époque* prosperity was tied to externalizing up to 40% of its land. Biological innovation in the form of cattle crossbreeding encouraged efficiency gains and land savings, but also allowed stocking densities to increase, leading to more (not fewer) 'ghost pastures.' Running all these cattle and sheep to satisfy foreign demand had profound environmental impacts.

Over the last two decades, economic historians have made substantial contributions to our understanding of long-term Uruguayan development focusing on the relationships between institutions, growth, and inequality. By comparison to these themes, the ecological implications of different development models have been overlooked.[22] Counting 'ghost pastures' offers an

[21] José Pedro Barrán and Benjamín Nahum, *Historia Rural del Uruguay Moderno Tomo V: La prosperidad frágil, 1905-1914* (Montevideo, 1977): 146.
[22] Two recent exceptions are Silvana Sandonato and Henry Willebald, 'Natural Capital, Domestic Product and Proximate Causes of Economic Growth: Uruguay in the Long Run, 1870–2014,' *Sustainability* 10, 3 (2018);

entry point to the study of the environmental costs of Uruguayan economic development in the long-run. In our future research, we will consider the impact of livestock agriculture in terms of greenhouse gas emissions and land cover. We will also extend our estimates until the present and use what we have learnt to calculate ghost pastures elsewhere in South America.

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