The Limits of Agricultural Growth in the Nineteenth Century: A Case Study from the Mediterranean World

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ABSTRACT

This paper examines the incidence of environmental factors in the economic growth experienced by the Spanish agricultural sector during the 19th century. Using the principle of *Coevolution* between Nature and Society, this paper aims to verify a fundamental hypothesis which, in our view, suggest a new way of looking at the past of Mediterranean agriculture and its late incorporation into the more advanced agricultural world. The traditional view considers the low yield per hectare of the main cereals to be an indication of the relative backwardness of Southern Spanish agriculture, here the importance of environmental factors is asserted, at least until its complete transformation into an industrial-type agriculture, based on fossil fuels. Here, the relative backwardness will be explained not only by deficiencies in productivity, capital investment or diffusion of new technology, but principally by the *comparative ecological disadvantages* that areas such as Andalusia had in comparison with Northern Europe, if an agricultural growth based on cereals were to be chosen.

KEY WORDS

Economic growth, ecological limits, hydric deficit, nutrient requirement, rotation systems, ‘organic’ agroecosystems.

In this paper, I shall set out the significant results obtained in a research project[1] currently under way, which examines the incidence of environmental factors in the economic growth experienced by the Spanish agricultural sector during the 19th century. Whilst the traditional view considers the low yield per hectare of the main cereals – in comparison with countries such as Holland, England or

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Belgium – to be an indication of the relative backwardness of Southern Spanish agriculture, here the importance of environmental factors is asserted in explanation of this and other phenomena typical of the sector, at least until its complete transformation into an industrial-type agriculture based on fossil fuels. Far from suggesting environmental determinism, our argument derives from the principle of an interaction between Nature and Society, which we shall term *co-evolution*.[2] This involves considering, from a methodological point of view, our study subject (the agricultural sector) as subject to a double limitation; the first being ecological, in that physical/biological cycles sometimes impose strict limits on the development of productive activity, and the second being social, as every *agro-ecosystem*[3] is the result of human manipulation of a previously existing ecosystem and, to this extent, is a socially and historically constructed space which may modify the originally existing ecological conditions. Relative backwardness may be explained not only by deficiencies in productivity, capital investment or the diffusion of new technology, but also, and principally, by the *comparative ecological disadvantages* that areas such as southern Spain had in comparison with Northern Europe if agricultural growth based on cereals were to be chosen.

The research we present here thus starts from a recognition of the specific soil and climatic conditions of southern Spain – an area typical of the Mediterranean influence in the country – and their specific effects on farm production (ecological consideration of society). But it also considers the social effect on the environment, which is the difference between our analysis and any determinist approach; this effect is apparent in the different incidence that soil and climatic limitations have in the context of societies with different socio-ecological systems of organisation. In societies still based on solar energy with hardly any external energy inputs (*organic* economies, according to Wrigley [4]), such characteristics establish fairly harsh and spatially localised limitations. On the other hand, in societies based on fossil energy, with the possibility of considerable external inputs, environmental limitations tend to become *less localised* or *less dependent* on the physical situation of production, and generally give the false impression that the productive activity is independent of nature. Within this framework, the yields of a certain farm or the productivity of a factory depend more on the amount of energy and materials used – independently of where they come from – than on the particular area in which they are situated.

In the first part of this paper, we shall describe the socio-ecological conditions of farming production in the province of Granada, this being an area which is representative of the environmental peculiarities of southern Spain, prior to the liberal reforms at the beginning of the 19th century. In the second part, we shall define the farming growth model practised until the *fin de siècle* crisis. In the last part, the case study will provide us with a certain basis for assessing the social and ecological consequences of this model.

THE FARMING SYSTEM AT THE END OF THE OLD REGIME.

The farming system at the end of the 18th century was essentially solar, the whole cycle working mainly through energy from the sun. The capture of this energy and its conversion through photosynthesis into food or secondary energy was only possible with the help of biological converters (plants), which required a certain amount of land exposed to solar radiation for this purpose.[5] In contrast to present-day agriculture which, thanks to fossil fuels, can even function without soil and in artificially created climatic conditions, traditional agriculture depended almost totally on climatic oscillations and, in general, on its immediate environmental surroundings. As is well known, Mediterranean ecosystems produce low amounts of biomass. The rainfall regime reduces the primary production of the land and its carrying capacity.[6] Nevertheless this fact has never been taken into account by economic historians in their arguments to explain low agricultural yield per hectare: a good example of isolation between natural and social scientists.

Average Precipitation (mm)	486
Average Temperature (°C)	16.9
Relative Humidity (%)	59
Wind Speed (km/h)	9
Insolation (hours/month)	223
Potential Evapotranspiration	
< 800mm (km^2)	843
800–1100mm (km^2)	11,628
> 1100mm (km^2)	60
Humidity Index	
< 0.35 (km^2)	599
0.35–1.00 (km^2)	11,081
> 1.00 (km^2)	851
Risk of Frosts	
in > 5 months (km^2)	8,504
in 2–5 months (km^2)	3,329
in < 2 months (km^2)	698

TABLE 1. Hydroclimatic features of the province of Granada.

Source: Agencia de Medio Ambiente (1987,48) [Andalusian Agency of Environment].

The efficiency of cultivated plants in trapping solar energy in Mediterranean agro-ecosystems was limited by the rainfall and the amount of nutrients (fertiliser) that could be obtained from livestock. Total energy capture was restricted by the amount of land available for human alimentation, grazing or animal fodder. The adverse environmental conditions made it necessary to dedicate a particular part of the land to agricultural crops, another to grazing for livestock and finally, another to woodland; these spaces had to be maintained in equilibrium as regards their surface area, as each one satisfied demands essential in the functioning of the system. The flows of energy and nutrients were basically circular, and their supply was mainly to be found in the immediately surrounding area. This was logical in a world where commercial trading was still unusual and communications between different regions difficult, impeding the possibility of obtaining anything that one's own land could not produce enough of. The peasants thus depended essentially on a rational exploitation of their natural resources; their subsistence was based more on products collected or harvested by them than on those obtained through the market.[7]

	Santa Fe				**Montefrío**				**Ciudad Real**			
Month	**R**	**PET**	**-**	**+**	**R**	**PET**	**-**	**+**	**R**	**PET**	**-**	**+**
Jan	45	19		26	87	17		70	29	13		16
Feb	40	21		19	86	20		66	39	25		14
Mar	32	37	5		78	34		44	47	51	4	
Apr	38	52	14		55	48		7	43	77	34	
May	28	88	60		43	79	36		41	120	79	
Jun	17	114	97		26	110	84		28	156	128	
Jul	2	150	148		2	145	143		3	172	169	
Aug	3	141	138		6	138	132		5	150	145	
Sep	22	102	80		29	98	69		28	82	54	
Oct	41	63	22		58	59	1		43	43		
Nov	26	33	7		72	30		42	45	18		27
Dec	55	21		34	91	18		73	40	12		28
Year	**350**	**842**	**571**	**79**	**633**	**796**	**465**	**302**	**391**	**919**	**613**	**85**

TABLE 2. Humidity Balances (mm) in two areas representative of the Province of Granada and the average humidity regime of Xeric edafoclimate (Ciudad Real)

R: Rainfall; PET: Potential Evapotranspiration

Source: Gascó and Gascó (1999, 93) and *Caracterización agroclimática de la provincia de Granada* [Agroclimatic Characterisation of the Province of Granada] (1989).

The case of the province of Granada is a good example of this. It belongs to so-called ‘Dry Spain’, characterised by similar climatic conditions: high sunshine, low and irregular distribution of rainfall, and a long dry period during the summer with high temperatures. From the point of view of soil, Granada province belongs to the ‘Xeric’ humidity regime that covers over 74 per cent of the area of Spain. Table 2 compares two villages of Granada with Ciudad Real, which correponds to the average humidity regime of the Xeric edafoclimate. As can be seen, Granada is quite representative of the dominant dry Spanish regions.

The Granada climate imposes fairly strict limitations on activities where water is an essential factor. The most decisive factor is rainfall, and its spatial distribution is fairly heterogeneous. However, scarcity of rainfall is the norm in the intramountain depressions and also on the coast, these two areas being where the majority of agriculture is situated. The depressions of Granada, Guadix and Baza, representing the lowest rainfall in the province, receive only slightly over 400 mm. It is therefore not surprising that the average provincial rainfall (see Table 1) is less than 500 mm. In addition to the overall scarcity of rain, the specific monthly rainfall regime must be considered, for its incidence in farming activities is critical. The whole of the province is in general characterised by having a fairly long dry season (a number of months with water deficits), the peak of which is reached in July and August. In the *Caracterización agroclimática de la provincia de Granada* (1989), it is maintained that the dry season generally lasts four months at 50 of the 103 existing meteorological stations; at 30, it was over four and a half months; at 18 it was three and a half months; and at only five stations, all corresponding to high mountain areas, it was a mere three months. The areas with greatest agricultural potential tend to have the most severe dry seasons. The hydric balance, having taken into account the potential evapotranspiration, indicates that the whole of the province is water-deficient. This negative hydric balance makes the low values of the run-off indices comprehensible and is in turn reflected by the amount of water that ends up circulating in rivers, streams, watercourses or gullies. This averages around 26 per cent, in comparison with the national average of 34 per cent. Of the 16 meteorological stations considered in the *Caracterización agroclimática* ... to define the humidity regimen, only one of them, in Soportújar, can be classified as ME (humid Mediterranean). The rest correspond to Me (dry Mediterranean), with annual humidity indices averaging just over 50 per cent.

The combination of temperature and rainfall typical of the province establishes restrictive conditions not only on the availability of water but also on the type of vegetation. The acutely seasonal nature of the rainfall means that the dry period coincides with the hottest months – those in which evapotranspiration is at its highest – meaning that hydric deficits are of considerable relevance (see Table 2). These circumstances, in which the vegetation lives practically at the limits of survival, determine the types of crop possible – especially when the frequency of frosts also establishes limits in winter, despite the theoretical abundance of rainfall. Frosts and a summer water deficit thus characterise the main agroclimatic conditions of the province of Granada. Scarcity of rainfall and low temperatures make it essential to practise unirrigated agriculture in which winter cereals, pulses for human consumption and highly drought-resistant bush and tree crops, such as vines, olives and almonds, predominate. Indeed, these make up the typical Mediterranean trilogy which characterised and, to a large extent, continues to characterise the province of Granada.

Only two districts, the Valle de Lecrín and the Coast, enjoyed adequate temperatures for developing crops with large markets, such as sugar cane or cotton, citrus or other fruit trees and other subtropical products; but even here, there was still insufficient rainfall. Similarly, in the other districts in the province, where hot summers, in contrast to harsh winters, allowed a wide range of products to be cultivated for domestic consumption or export (non-citrus fruits, vegetables, fodder, industrial plants such as sugar beet, flax or hemp, summer cereals, etc.), the low resistance of these crops to the summer drought made them unviable. These limitations could be overcome to some extent by undertaking hydraulic works and irrigating previously unirrigated land. This helped to transform one restrictive factor, and meant that the aridity and high temperatures could become a comparative advantage because of the possibility of cultivating plants that were difficult to grow in other more humid latitudes.

The humidity regime was thus a limiting factor of the first order in the productivity of vegetal biomass of the agroecosystems of Granada and of southern Spain in general. In the absence of energy and nutrient inputs in farm production, the explanation for the differences that can be observed in the yields per cultivated hectare of cereals with respect to other areas of the country and other more humid countries in Northern Europe, can be found almost entirely in the scarcity of rainfall and in its intra- and interannual regime. Wheat yields in countries such as Denmark, Holland, Belgium or England were between three and four times higher than those obtained from the unirrigated land of southern Spain that was preferentially allocated to cereal crops. Even in the 1960s, according to data from the FAO,[8] when the use of chemical fertilisers had started to become generalised, the relative difference had not changed substantially in spite of a considerable increase in yields per hectare.[9] This statement can be indirectly substantiated by establishing the water balance corresponding to wheat production in near average agroclimatic conditions for the province. In order to do this, we used the village of Santa Fe, which is close to a complete meteorological station (Granada airport) and which therefore can provide us with data on all necessary variables to construct a Blanney-Criddle water balance. This village is located in the middle of the province, next to Granada city, on a large plain at the foot of the Sierra Nevada Mountains.

The water balance was measured for the most common rotation on unirrigated land in Santa Fe, *al tercio* (wheat–*erail* [fallow]–*barbecho blanco* [fallow after ploughing up]). The data shows that the crop suffered water stress from April

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Rainfall	26	55	45	40	32	38	28	17	280
Etc*	6	12	17	21	103	148	185	35	527
ETc adj†	6	12	17	21	103	66	28	17	270
Reserve Var.	20	43	28	10	72	29			
Reserves	20	63	90	100	29				
Excess				9					9
Deficit						82	157	18	257

TABLE 3. Water balance for wheat. Agroclimatic conditions in Santa Fe, Granada (data refers to the crop cycle, expressed in mm)

* Crop evapotranspiration under standard conditions/Crop water requirement

† Actual crop evapotranspiration

Wheat cycle in Santa Fe – measured from November to June.

onwards, which includes the most critical period of development as regards final yield (flowering and grain ripening). Having taken this fact into account, relative yield was calculated to have been around 60 per cent of the maximum yield obtainable if no hydric limitations had existed. The balance corresponding to the fallow and fallow ploughing years show that no significant effect of accumulation of water reserves would have existed to alleviate the spring deficit indicated. This could only have affected the first months of development, when the water needs of wheat were covered sufficiently. In any event, the balance also shows that from March to November no surplus water existed and that in the months May, June, July and August there was a considerable deficit. This means that without any water correction (irrigation), it was not possible to cultivate spring or summer cycle plants. The environmental conditions of the area only permitted winter crops, and even these suffered the added limitation of water scarcity in the critical periods of development.

The same agroclimatic limitations bring with them other negative consequences for the traditional crop systems as well as to the limited potential physical yield in a plot of land sown with a crop such as wheat. Given the meagre amount of biomass produced per hectare, the success of the harvest in each plot *required* the subsidiary use of other equivalent plots of land lying fallow, producing fodder, grazing, etc., so that the real amount of land necessary for actual production was several times the size of the plot itself. Indeed, the hostile ecological conditions made it advisable to grow crops in winter, or at least during the spring, thus making the most of the rainfall of those seasons in the growth of the plants. A second harvest was therefore discounted even when the land was under irrigation. The high insolation and scarcity of rainfall reduced the organic matter in the soil, making it practically impossible to grow crops every year without a fallow period or without the application of considerable amounts of fertilisers. This made crop rotation necessary in many cases: one year of harvest should be followed by another in which the land was left fallow without any attention (*descanso*) and/or left fallow after being ploughed (*barbecho*), in order to recuperate the nutrients exported in the previous harvest. Under these conditions of low biomass productivity, the capacity to maintain abundant livestock and produce more natural fertiliser was limited: the Mediterranean's open woodlands, and even its pastures could not compete with the meadows of 'Rainy Europe'.[10] Moreover, pasture plants had to compete for soil nutrients with crops destined for human consumption or cereal-fodder, thus leading to a reduction in the quantity of manure. It was a kind of vicious circle. The only way of maintaining annual crops without a break was through the cultivation of bushes or trees, especially olives, vines and almonds.

At the end of the 18th century, various crop rotations were practised over the immense majority of unirrigated cultivated land in southern Spain, and the intensity of these depended on the availability of fertilisers. Table 4 summarises the nutrient balances corresponding to olive groves and the three most general types of cereals. The yields, which had not changed significantly since 1750 except in the case of olives, and other physical data on the systems mentioned, are taken from property and tax register sources from the mid-19th century. The most widespread rotation was the 'one third' rotation, in which winter wheat was the main crop, followed by one fallow year (*descanso*) and a third and last of ploughed fallow (*barbecho*). The nutrient extractions in the wheat year substantially exceeded inputs – by almost three times – meaning that without further inputs of manure beyond those provided by gathering the livestock together on the land in order to fertilise it (*redileo*), the land could not be sown in the following two years (the balance only recovered after three). It is worth noting the importance that non-symbiotic fixation of nitrogen must have had in the recovery of fertility. Very little is known about the type of plants that grew in the year of rest, but there seem to be indications of the presence of pulses (e.g. sainfoin), which would have increased the symbiotic fixation capacity.

Table 4 next shows the same system but at a slightly more developed stage, typical of the large farms of southern Spain which had a lot of working animals and could allow themselves the luxury of adding some manure. The difference between this and the previous system was that pulses (broad beans or chick peas) were sown in a part of the ploughed fallow land, leading to the name 'sown fallow land' (*barbecho semillado*). The balance shows the positive effect produced by the pulses, which generated a surplus of nitrogen, leading in turn to an increase in wheat yield from 11 to 16 hl/ha. However, the input of manure was essential

Rotation System	**Output**			**Input**			**Balance**		
	N_2	P_2O_5	K_2O	N_2	P_2O_5	K_2O	N_2	P_2O_5	K_2O
'one third'	40.6	10.4	15.4	41.9	1.6	2.4	1.3	-8.8	-13.0
'one third with sown fallow land'	64.6	17.6	32.6	118.5	5.2	7.8	53.9	-12.4	-24.8
'Ruedos' * (wheat/broad beans)	105.5	30.8	46.6	212.1	24.4	42.6	109.6	-6.4	-4.0
Olive groves	14.3	2.9	12.4	12.0			-4.3	-2.9	-12.4

TABLE 4. Summarised Nutrient Balances (in kg/ha) of various rotation systems (Granada agroclimatic conditions).

* *Ruedos* are the areas immediately surrounding the villages which were easier to fertilise with manure and urban waste due to their accessibility.

Source: M. González de Molina, 2001, 97–101. Average yields obtained from 'Cartillas Evaluatorias' of various villages in the province of Granada. The nutrient value of each crop was obtained from Soroa (1947), before the new Green Revolution seeds were introduced.

for these pulses to grow, not so much because of the existing nitrogen deficit as the deficits in phosphorus and potassium; and fallow land continued to play an essential role in replacing nutrients. The balance suggests that where there was sufficient livestock, ploughed fallow land was sown (*barbecho semillado*), and the size of this sown area depended on the amount of manure available. In this system, the pulses were planted with a view to meeting the food requirements of the working animals, against the background of a sharp rise in the demand for cereals for human consumption and a shortfall in grazing land and fodder crops (as we shall see below), rather than as a result of their utility as plants for improving the wheat yield.

The third row of Table 4 reflects the most intensive rotation. This was used on the unirrigated land of the South, in the area surrounding the more populated centres (*ruedos*) where it was relatively cheap and easy to transport and apply manure produced in stables or generated from urban waste. The most common succession was broad beans in the first year and wheat in the second, although in other places the lack of cereal-fodder had established a winter cycle of three years in which broad beans were succeeded by wheat and the last year was dedicated to barley. The yields were fairly high (17 hl/ha of wheat, a similar amount for broad beans and around 20 hl/ha of barley) in comparison with those achieved in the previous rotations, but they were still a long way from those achieved in Denmark, Belgium, England and Holland, proving the limitation caused by the lack of rainfall and the specific regime of Mediterranean humidity. The balance shows a situation of relative equilibrium in phosphorus and potassium, but a considerable surplus of nitrogen, which in the long run must have affected the fertility of the soil. In any event, the broad beans, together with the manure, fulfilled their fundamental task and allowed the fallow year to be eliminated. In this regard, a rotation such as that defined in the so-called *agricultural revolution* was technically possible, although with a proportionally lower yield than in the wetter countries of northern Europe – but it required a great deal of manure and, consequently, more livestock. The data available on the number of animals in the mid-18th century (see Table 7) reveals that it was simply impossible to produce enough manure to generalise this system (between 3.5 and 4 tonnes/ha were required annually, whilst only 2.8 tonnes/ha of fresh manure were produced, including every kind of livestock and without taking into account losses). As stated above, the limited capacity of pastures restricted the possibility of increasing the number of livestock. *This means that the unavailability of external nutrients was the principal limiting factor for traditional organic agriculture, and this limitation was further aggravated by the relative scarcity of water*.

Finally, Table 4 also represents the nutrient balance of one hectare dedicated to olives, in which the difference in needs between cereals and olives can clearly be observed: the latter required three times less nitrogen and phosphorus, and 20 per cent less potassium. The deficit appearing in the balance is low enough to estimate that symbiotic fixation, or fixation by the free organisms, was enough to replace it, especially when the plantation was fairly widely-spaced (between 56 and 60 trees per hectare). Furthermore, the grass was usually used for grazing (*redileo*) with a consequent manure input, meaning that the nutrient input must have been a little higher.[11] Apart from this, manure was only applied if a tree was diseased. This means that under conditions of a structural lack of nutrients, olive groves (together with vineyards) were the only alternative permitting an annual crop without a fallow year and without having to resort to the application of fertilisers obtained from outside the farm. However, their yields were fairly irregular due to their high sensitivity to the rain between October and March of the previous year.[12]

It can thus be seen that the agriculture of Granada at the time was subject to a fundamental ecological limitation: due to its lack of humidity and, as a result, its incapacity to produce vegetal biomass, more land was required for agricultural, livestock and forestry activities than in the humid areas of the north of the peninsula and northern Europe. This meant that agricultural use was to a large extent incompatible with livestock or forestry use of the same plot of land. Under the existing agroclimatic conditions, it was practically impossible to adopt crop systems and rotations such as those, for instance, which characterised the famous English agricultural revolution. Quite apart from the differences between English and southern Spanish soils, nitrogen constituted a limiting factor for *all* traditional agriculture,[13] and in the case of Granada, the lack of water was an additional limiting factor which led to an even greater scarcity of nutrients. Where this limitation was overcome – in the rare cases of irrigated land in the quoted province – the rotations and yields were similar to British ones.

Table 5 compares the productivity of the agro-ecosystems described above with those in the county of Norfolk (UK) in the mid 19th century, using the agricultural revolution as a reference point. The values are averages for both regions and are ordered from highest to lowest intensity and from highest to lowest significance in terms of land area. As can be seen, the differences are quite considerable, both in the production of dry matter and in kilocalories per hectare, reflecting the differences in humidity regimes and accessibility to organic fertilisation. The 'one third' rotation system, which was the most common in the province of Granada, required four times more land than that of the British county to produce the same amount of dry matter per hectare. Furthermore, in Granada, the capacity to sustain livestock was almost three times lower. In Norfolk. the number of livestock units per cultivated hectare was 1.8, whereas in the province of Granada, it was 0.48.[14]

Crop system	**Dry matter kg/year**	**Thousands of kcal/year**	**Equivalent surface required by the 'one third' system**
'One third'	745	2,489	1
'One third' with sown fallow	1,222	3,864	1.6
'Ruedos'	2,649	10,264	3.5
Occasional irrigation	2,074	6,623	2.8
Constant irrigation	4,795	19,164	6.4
Norfolk system	2,936	—	3.9

TABLE 5. Yields per hectare in various crop systems and their comparison the Norfolk Systems, 1830–1850

Source: The calorific values of each product were taken from Naredo and Campos (1980, annex); the dry matter content from Soroa (1947) and the production and gross field area for each system was taken from the average of various 'Cartillas Evaluatorias' in the middle of the 1850s. The data relating to Norfolk System was obtained from Overton (1991, 296–306).

Given the considerable land requirements of cerals, it is difficult to understand why such an enormous proportion of land in Spain has always been devoted to these crops, especially since the Liberal Revolution. Prior to that date, cereal production was already perhaps slightly excessive, in spite of it only just providing for the needs of domestic consumption on the Peninsula.[15] This was due to the lack of commercial trading and its peripheral concentration around the large rural towns. The very high cost of inland transport in the country made merchandise – including grain – so expensive that trade was discouraged and it only took place at times of particular need or bad harvests.

This meant that every village or district had to dedicate a large amount of land to growing cereals, as the working animals and the farm labourers themselves depended on barley and wheat for their main source of energy. The traditional farming system could not have functioned without cereals. The primary production of the Mediterranean open woodland and other land reserved for grazing was insufficient to permit any significant increase in livestock. The need for new land to feed a higher population and, at the same time more and better grazing for livestock to work the land and transport the produce elsewhere, led to the cultivation of previously unused land and, when this was not possible, the dedication of part of the farmed land to growing cereal-fodder such as barley. This vicious circle led to yet a further increase in the amount of land dedicated to cereals. However, this territorial expansion was constrained by the fact that a very significant proportion of productive land was subject to a legal common land regime, which prohibited cultivation. The tension between the increase in the demand for cereals – in which population growth constituted an important factor – and the institutional limitations mentioned, caused a rise in cereal prices recorded during the second half of the 18th century, which in turn naturally stimulated a new wave of cereal cultivation. But all this changed with the agrarian transformations established by the Spanish Liberal Revolution, which extended private property rights over all the lands, and made the market, guided by abstract monetary values, the principal distributor of goods and services. This caused a split between the ecological and economic valuation of nature which was to have serious consequences, as we shall see below.

THE FARMING SYSTEM IN THE 19TH CENTURY

The importance of political and economic factors in the fortunes of Spanish agriculture is undeniable, although their environmental repercussions – i.e. their consequences in terms of *future development expectations* – have rarely been evaluated. In this sense, the evolution of the Spanish agrarian sector during the 19th century can only be fully understood by considering the inter-relationship (or co-evolution) between the limiting factors characteristic of each agro-ecosystem on the one hand, and the economic policies and commercial dynamics of the sector on the other.

The institutional obstacles to the expansion of agriculture and the commercial distribution of its products were overcome by the implementation of a set of agrarian measures (enclosures, sale of church lands, disentailment, free trading in grain, etc.) which accompanied the Liberal Revolutions. Three changes of particular significance arose out of these measures: a) the commercialisation of the property market and other natural resources; b) the collapse of the integrated traditional system of mixing agriculture with livestock farming and forestry; and c) the predominant use of the land by agriculture over and above everything else, *agriculturalisation*. The main agent in this triple process was the expansion of cereals. Cereal production occupied first place, ahead of any other land uses, due to the fact that grain was a product of mass consumption and therefore easy to sell on the market with good returns. Protectionist measures in the domestic grain market, such as those adopted in Spain from August 1820, contributed to this. Not only the politicians and thinkers of the time, concerned about the grain deficit that was apparent in the domestic market, but also the big agrarian interests, who obtained more stable profits from growing cereals than from other alternatives for which there was not such a reliable demand, used their influence in this matter. Below, we shall analyse the role of domestic consumption and the discoordination of the agrarian products market in the generalisation of the so-called *cereal system*.

Perhaps increasing grain production was the most ‘rational’ alternative from the point of view of the market and of the large agrarian interests of the time, but it is doubtful whether it was in the ecological, or even general economic interest. The social costs were quite considerable, although these have only been evaluated in terms of the concentration of property ownership, the strengthening of the system of large estates and the exclusion of peasants from the land. But it would be interesting to evaluate the lack of job expectations in the cereal industry which required little labour and which, at the same time, used up a lot of useful land (olives provided more than double the number of days’ work in comparison with the cereal system run on the ‘one third’ rotation basis, which was the most general). With regard to ecological costs, a rigorous in-depth study has still to be carried out, but there are some indications that these were considerable. Firstly, the expansion of cereals led to the ploughing up of woodlands and pastures and their conversion into cultivated land. In Catalonia, wich has similiar soil and climate to Granada, cultivated land increased by 63 per cent between 1790 and 1885 – from 700,000 ha to 1,142,000 ha, which presumably occurred at the cost of forest and grazing land.[16] In the case of Eastern Andalusia, Granada included, there is no lack of isolated evidence to show the disappearance of considerable stretches of forest land because of changes in use implemented by their new owners, following the privatisation of municipal and ecclesiastical property.[17]

In recent research on our particular study area, it is maintained that the increase in cultivated land between 1750 and 1860 in the province of Granada was only 3 per cent.[18] But our data (see Table 8) indicates a substantial increase in cultivated land, of 7.1 per cent, in only fifteen years from 1885 to 1900. The most significant expansion of cultivated land began after the middle of the 19th century. Between 1886 and 1931, the cultivated area in Eastern Andalusia grew by 40 per cent, undoubtedly at the cost of much forested and grazing land.[19] The ecological costs of this expansion in Almería, close to Granada and also in the Andalusian province, have been studied recently by García Latorre and others.[20] This work confirms our impression: deforestation, agricultural expansion and erosion were the main results of increasing population and mining activity.

This modest increase in cultivated land at the beginning of the 19th century was due to the low dynamism of the Eastern Andalusian population, which was shaped by the different population densities recorded in Andalusia and Catalonia at the time. If we bear in mind that manual labour constituted the main requisite in any process of ploughing and productive intensification, and that no significant increases in productivity had yet been achieved, it is easy to understand why Catalonian agriculture expanded rapidly as a result of the greater availability of labour, whilst Eastern Andalusia – 'the empty country' according to Jovellanos – took much longer to reach similar levels. In 1860, there was an average of one labourer per 2.9 ha in Catalonia, whereas the proportion in Eastern Andalusia was one per 4.6 ha – almost double the area. In fact, the significant expansion of cultivated land began later, at the middle of the 19th century, when mortality began to be reduced, resulting in the 'demographic transition'.

The reduction in grazing and woodlands as these gave way to agriculture and the establishment of enclosures (which introduced the sale of grazing rights on stubble and fallow fields into the economic market) must have led in turn to a fall in livestock numbers. As is well known, there is no agreement on this point in Spanish historiography, partly because of the non-existence of aggregate livestock farming censuses until 1865.[21] Until the data contained in the Land and Tax Register of the Marqués de Ensenada has been studied in sufficient detail, we can only offer indications. Meanwhile, a significant reduction in the number of animals in the province of Granada has been found, of around 24 per cent between 1752 and 1865, which percentage cannot entirely be due to the inherent defects in the census of the latter year.[22] The composition of livestock in both periods confirms that far from working animals diminishing in number they increased significantly, especially mules; it was cattle and particularly sheep, goats and pigs which decreased significantly in numbers (see Figure 1). The live weight figures were quite similar until 1868, but decreased significantly according to this data until 1900, in association with the more rapid growth of cultivated land. Whatever the degree of representativeness of this partial data, it does seem clear that livestock did not increase to the extent that cultivated land did, and this led to predictable consequences. Given the impossibility of fertilising all the cultivated land with manure, it became more difficult to generalise, or even to significantly increase, the amount of more intensively cultivated unirrigated land with fewer fallow periods. In this regard, the scarce evidence available on cereal yields during the 19th century in Eastern Andalusia indicates a certain stagnancy, which phenomenon can be generalised to the majority of Spanish Mediterranean cereal farming.[23] In terms of ecological economics we would say that the process of *agriculturalisation*, stimulated and aggravated by the predominance of cereals, must have caused a loss of *productive capacity* in the agro-ecosystems, as a great deal of fertile land was required to obtain a certain quantity of cereal.

The data relating to the province of Granada, which we have chosen as our case study, confirms this impression, and is even more conclusive with regard to the effects resulting from the expansion of the cereal system. The calculations carried out are based on tax sources and corrections made by scholars of the time and relate to the decade of the 1880s, just when the fall in cereal prices began, thus giving us a clear picture of agriculture in Granada immediately prior to the *fin de siècle* crisis. This data is complemented by the Agrarian Statistics compiled several years later in 1900 by the Ministry of Agriculture: both reveal the tendencies to be expected, with no great discrepancies arising between them.

Table 6 shows the land requirements in Granada for production of grain, destined for the most part to feeding its population and working animals. These requirements are calculated on the basis of average yields provided by the agrarian statistics and corrected by us with the help of land and tax register and notarial documentation. The data on average consumption per head was taken

Crop	**Production (hl)**	**Required area (ha)**	**Unirrigated area (ha)**	**Irrigated area (ha)**
Wheat	1,074,674	255,064	160,179	43,786
Barley	431,644	85,757	85,757	
Broad beans	69,243	12,364		12,364
Rye	106,457	29,709	29,709	
Maize	148,106	8,391		8,391
Chickpeas	5,649	1,158	1,158	
Total	**1835,771**	**392,443**	**276,803**	**64,541**

TABLE 6. Land requirements for grain production in Granada 1879 in unirrigated 'one third' rotation.

Source: Morell y Terry (1888) and author's data.

from Morell y Terry (1888) and completed, with regard to animal feed, using the work of the Junta Consultiva Agronómica (Agronomic Consultative Committee) carried out at the end of the 19th century. The results reveal very similar figures for the cultivated surface area to those in 1885 (see Table 8) and show that agriculture in Granada at the time was mainly oriented towards satisfying the demand for food from its population rather than its livestock, with the result that livestock growth remained limited. Table 7 reconstructs the total agricultural production from the whole province on the basis of the agrarian statistics of 1900. In this table, macronutrient requirements are also expressed. The total net

Crop	**Production (tonnes)**	**Requirements (kg)**		
		N	**P**	**K**
Wheat	79,416	1,652	627	413
Barley	30,452	457	176	97
Rye	812	14	6	4
Maize	9,095	145	53	33
Broad Beans	14,305	580	166	171
Chick Peas	4,011	127	37	54
Haricot Beans	2,373	98	22	33
Yeros *	1,236	54	12	10
Lentils	1,107	42	5	8
Olives	19,322	87	21	183
Grapes	11,210	19	17	56
Sugarbeet	253,879	406	203	990
Sugar Cane	189,315	151	113	303
Potatoes †	37,160	126	59	215
Almonds †	112	4	2	1
Oranges †	986	3	3	3
Total	**654,791**	**3,965**	**1,522**	**2,574**

TABLE 7. Nutrient requirements of net agricultural production in Province of Granada, 1900.

* Leguminous animal feed

† This data corresponds to 1902

Source: *Estadísticas históricas de la producción agraria* (1991) [Historical Statistics of agricultural Production] and Soroa (1947) for the needs of each crop.

production (without straw or harvest remains, which the statistics do not include) was 654,795 tonnes, almost two tonnes per hectare, and half a tonne of dry matter, undoubtedly due to the incidence of the land in which it was viable to practise annual crops. All this required a minimum of 11 kg of nitrogen, 4.2 kg of phosphorus and 7.1 kg of potassium per hectare, still without taking into account the consumption of straw and harvest remains.

We then examined the evolution of livestock recorded from the middle of the 18th century, for which we have reliable data (see Figure 1). As can be seen, livestock numbers decreased slightly until the mid-19th century, thereafter falling moderately. In general terms, we could say that at the end of that century, livestock numbers had fallen by 35 per cent compared with 1749, which brought about a reduction in the availability of manure of a little over 11 per cent. Over this period, a fundamental change had occurred in the composition of livestock:

Surface	**1885**	**1900**	**Variation (%)**
Cereals and Pulses	278,709	309,960	11.2
Sown Area		145,932	
Fallow		164,028	
Vineyards	25,376	6,995	-72.4
Olive Grove	25,600	33,290	30.0
Fruit Trees	42	616	1366.9
Roots, Tubers, Bulbs Crops	2,330	2,493	7.0
Horticultural Plants	3,520	2,232	-36.6
Industrial Plants	1,785	7,253	306.3
Artificial Pastures	1,706	403	-76.3
Unirrigated Land	254,278	257,781	45.8
Irrigated Land	72,232	105,371	1.3
Cultivated Land	339,068	263,152	7.1
Open Woodland & Pastures	881.332	857,248	-2.7
Agrarian Land	1220,400	1220,400	

TABLE 8. Distribution of agricultural land in hectares, Province of Granada, 1885–1900.

Source: *Estadísticas históricas de la producción agraria* (1991) [Historical Statistics of agricultural Production]; Morell y Terry (1888, 144) and own data

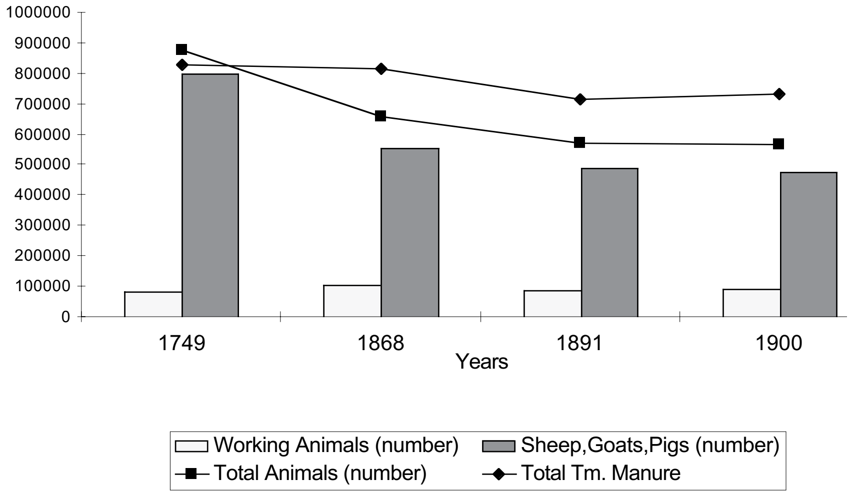

FIGURE 1. Evoluton of livestock, 1749–1900

Source: for 1749 Urdiales (1998); for 1868 Morell y Terry (1888) and for 1891 Jiménez Blanco (1986). The manure production per head was taken from Ventué y Peralta (1885)

income-producing livestock (sheep, goats and pigs) had fallen by 40.5 per cent, whilst working animals had increased by 14 per cent. Two factors undoubtedly contributed to the relative decline of income-producing livestock: on the one hand the extension of enclosures, the elimination of some common rights, and the privatisation of a great deal of the grazing rights over pastures and stubble fields, and on the other, the very expansion of cultivated land which replaced some of the traditional grazing land.

Among the working animals, a considerable substitution of cattle by mules took place and there was also a decline in donkey numbers. The number of working cattle fell by 45 per cent and of donkeys by 25 per cent. The growing difficulty in finding common grazing land to feed oxen undoubtedly contributed to this situation, more than any advantages which mules may have had in terms of traction. In any event, this substitution was yet another stimulus (or perhaps a reflection of the beginning of the *agriculturalisation* process) for the expansion of cereals, as barley and cereal straw in general was the basic fodder for this kind of livestock. Overall, the changes in the livestock only improved the traction capacity per cultivated hectare very slightly, as the increase recorded in the

Year	Number of animals	Equiv. no. in horses	H.P.	H.P./ha
1749	81,848	49,329	34,591	0.11
1868	104,071	72,537	50,785	0.15
1891	85,462	69,489	48,678	0.14
1900	93,658	71,237	49,891	0.13

TABLE 9. Evolution of the traction capacity of working and its relationship with cultivated land.

Source: same as Figure 1. The conversion indices are taken from Naredo and Campos (1980), and the surface area from Ferrer (1998) and from Table 7. H.P = horse-power.

number of head was due more than anything to the new needs generated by the increase in cultivated land (see Table 9) and the relative increase in commercial traffic for which this type of animal was used as a means of transport. In any event, the reduction in livestock did not reduce their feeding needs to any significant extent, as working animals had higher requirements. These were not satisfied by grazing uncultivated land but by the harvests from cultivated land which provided them with the grain and straw that was the basis of their alimentation.

These changes did not improve the fertilising capacity of the livestock, rather the contrary. In Table 10, we have calculated the average production of manure for all livestock (though for income-producing livestock this could often only be profitably used by specifically gathering the herds together on the land for this purpose [*redileo*] or from temporary stabling) and its content in macronutrients. The results are revealing. In total, there was a relatively significant fall in the fertilisation capacity of the farming system in general, which must have limited the expansion of more intensive crop rotations. The relationship between nutrient inputs and outputs in the case of wheat, which was the most common crop, reveal a considerable deficit which made the practice of fallow periods necessary and limited the application of the little manure available to the most intensive areas of cultivation. It is thus confirmed that the excessive extension of cereal production led to a reduction in the possibilities for intensifying agriculture on unirrigated land. This led to an increase in the areas cultivated on the basis of the 'one third' rotation with sown fallow periods and those areas immediately adjacent to the towns (*ruedos*) where it was possible to establish a combination of cereals and pulses, and limited a more intensive orientation towards irrigated land.

	1749	**1868**	**1891**	**1900**
Manure	829,364	815,655	714,166	734,515
N Content	4,478	4,404	3,856	3,966
P Content	2,571	2,528	2,214	2,277
K Content	4,561	4,486	3,927	4,044
Tonnes/ha	2.8	2.4	2.1	2.0
N/ha in kg	14.9	13.1	11.3	10.9
P/ha in kg	8.6	7.5	6.5	6.2
K/ha in kg	15.2	13.3	11.6	11.1
Deficit	-10.8	-12.6	-14.4	-14.8

TABLE 10. Estimated manure production and its macronutrient content (in tonnes)

Source: Soroa (1947) and author's data. The deficit is the result of the balance for wheat with the imput of macronutrients per hectare. Calculated for each year in the table.

The wheat expansion would not have been possible without the import of animal feed from other areas of Andalusia. We have calculated the cultivated land requirements, only taking into account the needs of working animals, which had a basic diet of cereal fodder, straw and some pulses.[24] The results are conclusive: the wheat industry generated a significant deficit in barley and other fodder grains which in 1891 (a year for which we have reliable data on the movement of grain in the province) was 309,139 hl and in 1900 was over 500,000 hl. This meant the import of the equivalent, in terms of land with average yields, of 20,473 ha and 36,414 ha respectively. If we bear in mind that the areas from which barley was brought in corresponded to the Andalusian countryside of Jaén, Seville and Córdoba, where the usual crop rotation was on the 'one third' basis, the *real amount of land necessary* to maintain cereal agriculture in Granada was 400,487 ha at the first date and 472,394 ha in 1900, 30 per cent more than the existing cultivated land of the time. Satisfaction of both the food needs of the population and those generated by the livestock was hindered by the soil and climatic conditions and the amount of animals. Competition between food and livestock was biased in favour of the former, due to the higher monetary profits arising from wheat compared with other types of grain. In contrast to what happened in other countries in 'Rainy Europe', the number of working animals was determined during these years by the need for traction rather than fertilisation.

It is worth asking whether there were other alternatives. The Catalonian experience, for instance, shows that within environmental limits not so very different from those in Eastern Andalusia, more efficient alternatives to the cereal system did exist: vines, olives and almond trees. Catalonian agriculture increased the commercial specialisation that had been defined since the end of the 18th century. Although cereal farming was already clearly predominant, from the end of the 18th century there was a tendency to specialise in vines (25 per cent of cultivated land in 1790) and olive groves (8.5 per cent). At this time, around a million hectolitres of grape juice was exported in the form of wine or brandy. But perhaps the most interesting fact is that a complementary system had been established between the various Catalonian areas: whereas the mountainous regions farmed mainly livestock, those in the west sold cereals and those in the south and east traded their excess wine and brandy in both domestic and foreign markets. 'Their purchasing power in turn stimulated the activity of other agrarian sectors along with the rural textile industry which had simultaneously been rapidly developing in central Catalonia'.[25] This means that at the beginning of the 19th century there was an internal market of certain importance and, above all, more than a third of the cultivated land had lost its dependence on cereals, something which Eastern Andalusia was only to achieve at the end of the 19th century, at the height of the *fin de siècle* crisis.

If we take into account that Eastern Andalusia as a whole was a little drier and warmer than Catalonia, it is not easy to understand why a more intensive specialisation in bush or tree crops did not take place. Table 11 sets out the *net profit* (income from sale of the harvest and residues or subproducts, less farming costs) of each crop in the mid-19th century, at the height of the expansion in cereals. Apart from the areas with enough water to irrigate during the dry season (constant irrigation, thus permitting second harvests), it was irrigated olive groves that provided the greatest profits. Even in unirrigated areas, this crop undoubtedly had the highest economic yield per hectare, except for cereal production in the areas immediately adjacent to the towns (*ruedos*). Table 12 compares the cultivation of cereals on the 'one third' rotation basis with olives (both unirrigated) at the date mentioned. The conclusion is clear: olives offered comparative advantages in that they were apparently more profitable, provided more jobs and required less animals, they required almost three times less nitrogen and owing to this, harvests were produced annually with no need for the land to rest. However, olives had not even reached 20 per cent of the cultivated area in Eastern Andalusia by 1900, when the cereal crisis was at its height. In the province of Granada, the surface area of olive groves in the 1880s satisfied internal demand and generated a small excess for sale.

The reasons for this paradox are numerous, but here we shall set out only a few, in particular, the continuing importance of domestic consumption by the peasant population during most of the 19th century, and the high degree of self-sufficiency in rural communities. This situation was partly a result of the low

Crop	Irrigated land	Unirrigated land
Constant irrigation †	144.7	—
Occasional irrigation †	54.4	—
‘Ruedos’	—	88.6
‘One third’ cereals	—	21.7
Olives	134.2	50.5
Vines	99.7	15.0
Donkeys	18.3	17.2
Cattle	16.0	9.2
Sheep	1.0	0.7

TABLE 11. Net profit* of the main crops in the mid-19th Century, 1852–1859 (in Pesetas/ha).

* Net profit = Income less expenses of the crops.

† In both systems, cereals are the central crop of the different rotations.

Source: Various ‘Cartillas Evaluatorias’ from several villages in the province, corrected with profit and loss accounts and extracted from the *postmortem* inventories of the time.

	Wheat	Oil
Production (hl)	8	1.98
Price (Pesetas)	16.0	69.6
Gross income (Pesetas)	128.0	137.8
Crop expenses (Pesetas)	106.4	87.3
Annual net profit (Pesetas)	21.7	50.5
Labour (no. of 8-hour days)	5.7	24.0
Yoke labour (Idem)	6.3	3.5
Total annual labour (Idem)	12.0	27.5

TABLE 12. Comparison of cereal crops in the ‘cne third’ rotation system with olive groves,both unirrigated (1850)

Source: Various ‘Cartillas Evaluatorias’ from several villages in the province, corrected with accounts of the *postmontem* inventory of the time.

degree of trade in the rural economy and deficient communications, which delayed a more consistent organisation of the internal market for farm products.[26] A good deal of the wheat and other grain harvests were consumed on the farm itself or, at most, within the rural locality. If we bear in mind that to meet the requirements of one person, 2.6 hl (200 kg) were needed per year, carbohydrate food had to occupy a quarter of a hectare of cultivated land every year, i.e. three quarters of a hectare in total, as the 'one third' rotation was the most common. On the other hand, in order to meet the demand for olive oil (six litres for human consumption and two for lighting), only 404 square metres per person was required. Thus, wheat for food required 18.6 times more land than oil. The reasons for the low export demand for oil are to be found in the low quality of the Granada and Eastern Andalusian oils of that time.[27]

Some time earlier, Eastern Andalusia had experienced a process similar to that in Catalonia but this had collapsed with the loss of the colonial markets. At the beginning of the 19th century, there no longer existed a complementary farming system in the different areas, based on each region's previous specialisation and within an organised domestic market, except in some markets on the coast where communications were good. No doubt the unbalanced property and farming structure and the results which the Liberal Agrarian Reform had for the peasantry in its initial stages did not stimulate the creation of an organised market, favouring instead domestic consumption, local or regional self-sufficiency and a low capacity of demand. Similarly, perhaps a less protectionist policy might have facilitated a certain territorial specialisation and reduced domestic consumption. In the same way, a more determined fiscal policy would have increased the capacity to spend on infrastructure and communications and would have co-ordinated the Andalusian market sooner, permitting internal specialisation better adapted to the soil and climatic conditions of each agro-ecosystem. The frequency is notable with which the land and tax register sources describe practically identical crop distributions for each village, in which the size and dedication of each farm is only intended to provide for its own needs. Within the technological parameters and those of the market itself in the 19th century, it might have been possible for a specialisation to occur that reserved the mountainous areas for livestock and forestry – which in turn would have preserved a significant part of the woodlands, kept the hilly areas for vines and olives, and left the flat open areas of higher natural productivity for the production of cereals.

Such was one alternative suited to the soil and climatic conditions of Eastern Andalusia. However, there was another alternative. This consisted of modifying the humidity regime in the country by technological means and applying the amount of water necessary to change the hydric balance from negative to positive for many months of the year. This would avoid the need for fallow land, would allow more intensive rotations and even the possibility of sowing the same crops every year – i.e. those with the highest demand or which produced the highest profits – and all of this with average yields more or less homologous with those recorded in the countries of northern Europe. In order for this to be possible, a considerable proportion of unirrigated land had to be put under irrigation. Yet in the field of hydraulic works, Andalusia often inexplicably occupied a secondary place despite its water resources, with fairly modest irrigated areas in relative terms. According to the Report of the *Junta Consultiva Agronómica* (1904), the amount of land under irrigation was 192,062 hectares, or little more than 5 per cent of cultivated land. More than 70 per cent belonged to the province of Granada, and these schemes suffered serious deficiencies in the regularity of their flows, due to the very low water levels reached by the rivers and irrigation channels in summer. However, we shall not deal with the reasons for this here.

In the kind of agriculture we have analysed, in which it still was not possible to import fertilisers from elsewhere, apart from Peruvian guano and, only much later, chemical fertilisers, the dedication of important portions of land to ‘manufacture’ manure by providing grazing for animals, or to provide fuel and work tools by conserving woodlands, limited the possibilities for the expansion of agriculture; agriculture required more land than in ‘rainy’ Europe because of the structural deficiencies already metioned. The growth of agricultural production was therefore limited to the availability of land, and in this context, the only possibility of increasing it lay in improving yields per unit of surface area. In order to do so, we have argued that water and organic fertilisers constituted the main limiting factors for 19th century Eastern Andalusian agriculture. At the same time, the viability of cereal crops depended on state intervention through tough protection of the domestic market, i.e. it depended on economic policy decisions that were subject to the fragility of the relationships of political power, and to the setbacks that the unstoppable process of international integration could cause in the agricultural product markets. It was the latter which ruined the traditional model of growth. The collapse in cereal prices – especially for wheat – which was the manifestation of the *Fin de Siècle* agrarian crisis made the disadvantages of the system clear and, above all, revealed the ecological and social limits on which it was based.

NOTES

[1] Financed by the Dirección General de Investigación del Ministerio de Educación y Ciencia.
[2] Norgaard, 1994; Deléage, 1993.
[3] Altieri, 1995; Gliessman,1997.
[4] Wrigley, 1988.
[5] Pfister, 1990; Sieferle, 1990 and 2001.
[6] McNeill, 1992.
[7] González de Molina, 2001.

[8] FAO, 1965.
[9] Simpson, 1996.
[10] Jiménez Blanco, 1986, 267.
[11] *Redileo* was the system used to fertilise land with the manure left by animals specifically gathered together on the land for a certain period of time for this purpose.
[12] Naredo, 1983, 197.
[13] Chorley, 1981; Overton, 1991; Ellis and Wang, 1997.
[14] The conversion of livestock units was made on the basis of proportion of different types of livestock used by M. Overton (1991, 302) and the number of animals in Table 12 corresponding to the province of Granada in 1868.
[15] García Sanz, 1986.
[16] Pujol, 1995, 406 and 429.
[17] López Estudillo, 1992.
[18] Ferrer, 1998.
[19] Cobo et al., 1992.
[20] García Latorre, et al., 2001.
[21] García Sanz, 1994.
[22] Urdiales, 1998.
[23] Garrabou, Pascual, Pujol and Saguer, 1995.
[24] The needs were calculated for each working animal according to the data contained in the *Cartillas Evaluatorias* of the various villages in the 1850s. The estimation of the area required was made by dividing the barley needs by the average yield in 1900 (15.1 hl/ha) and multiplying by 21, which was the relationship between cultivated and fallow land existing in the cereal system in that year. See Table 7.
[25] Pujol, 1995, 406.
[26] The sharp oscillations in cereal prices and other basic agricultural products in the province of Granada and Andalusia in general is a recurring theme in economic literature of the time (see for instance, Morell y Terry, 1888, 55 and 56) and was the subject since the beginning of the 19th century of parliamentary debates which gave rise to the Decree of 13th June 1813 and the Decree of Direct Contribution of September of the same year (see *Defects of the Direct Contribution implemented by the 'Cortes Extraordinarias' [Extraordinary Parliamentary Sessions] on 13th September 1813*. Madrid: Imprenta Ibarra, 1814).
[27] Zambrana, 1987.

REFERENCES

Agencia de Medio Ambiente, 1987. *Informe general del Medio Ambiente en Andalucía*. Sevilla: Agencia de Medio Ambiente.

Altieri, M.A. 1995. *Agroecology: the Science of Sustainable Agriculture*. Boulder, Co: Westview Press, Third Edition

Chorley, G. 1981. 'The agricultural revolution in Northern Europe, 1750–1880: nitrogen, legumes and crop productivity'. *Economic History Review*, 34: 71–93.

Cobo, F., Cruz, S. and González de Molina, M. 1992. 'Privatización del monte y protesta campesina en Andalucía Oriental (1836–1920)'. *Agricultura y Sociedad*, 65: 65–100.

Deléage, J.P. 1993. *Historia de la Ecología. Una ciencia del hombre y la naturaleza.* Barcelona: Icaria.

Ellis, E and Wang, S. 1997). 'Sustainable traditional Agriculture in the Tai Lake Region of China'. *Agriculture, Ecosystems and Environment*, 61: 177–193.

Food and Agricultural Organisation, 1965. *Yearbooks of Food and Agricultural Statistics*. Rome: FAO.

Ferrer Rodriguez, A. 1998. 'La producción agraria' in M. Titos Martínez (ed.), *Historia Económica de Granada*. Granada: Cámara de Comercio.

Garcia Sanz, A. 1986. 'Crisis de la agricultura tradicional y Revolución Liberal (1800–1850)', in A. Garcia Sanz and R. Garrabou (eds), *Historia Agraria de España Contemporánea*. Barcelona: Crítica, 7–102.

García Sanz, A. 1994. 'La ganadería española entre 1750 y 1865: los efectos de la Reforma Agraria Liberal'. *Agricultura y Sociedad*. 72: 81–120.

García Latorre, J., García Latorre, J. and Sánchez Picón, A., 2001. 'The man-made desert: effects of economic and demographic growth on the ecosystems of arid Southeastern Spain', *Environmental History*, 6 (1): 75–94.

Garrabou, R., Pascual, P. and Saguer, E.. 1995. 'Potencialidad productiva y rendimientos cerealícolas en la agricultura catalana contemporánea'. *Noticiario de Historia Agraria*. 10: 89–130.

Gascó Montes, J. and Gascó Guerrero, A. 1999. 'Adaptación de los cultivos y las labores al régimen de humedad de los suelos en la agricultura tradicional', in R. Garrabou and J. Naredo (eds), *El agua en los sistemas agrarios. Una perspectiva histórica.* Madrid: Visor, 1999, 85–94.

Gliessman, S. 1997. *Agroecology. Ecological Processes in Sutainable Agriculture.* Chelsea, MI: Ann Arbor Press.

González de Molina, M. 2001. 'El modelo de crecimiento agrario del siglo XIX y sus límites ambientales', in M. González de Molina and J. Martínez Alier (eds.), *Naturaleza trasnformada. Estudios de Historia Ambiental en España.* Barcelona: Icaria, 87–125.

Jimenez Blanco, J. 1986. *La producción agraria en Andalucía Oriental, 1874–1914.* Madrid: Editorial de la Universidad Complutense.

López Estudillo, A. 1992. 'Los montes públicos y las diversas vías de su provatización'. *Agricultura y Sociedad.* 65: 65–100.

McNeill, J. 1992. *The Mountains of the Mediterranean World. An Environmental History*. Cambridge: Cambridge University Press.

Ministerio de Agricultura, Pesca y Alimentacion, 1989. *Caracterización agroclimática de la provincia de Granada.* Madrid: MAPA.

Ministerio de Agricultura, Pesca y Alimentacion, 1991. *Estadísticas históricas de la producción agraria española, 1859–1835.* Madrid: MAPA. Compiled by Study Group of Rural History (GEHR)

Morell y Terry, L. 1888. *Estudio sobre las causas de la decadencia de la agricultura de la provincia de Granada y medios para regenerarla.* Granada: Iimprenta Indalecio Ventura.

Naredo, J. and Campos, P. 1980. 'La energía en los sitemas agrarios'. *Agricultura y Sociedad*, 15: 17–115.

Norgaard, R. 1994. *Development Betrayed. The End of Progress and Coevolutionary Revisioning the Future*. London: Routledge.

Overton, M. 1991. 'The determinants of crop yields in early modern England', in B. Campbell and M. Overton (eds), *Land, Labour and Livestock. Historical Studies in European Agricultural productivity*. Manchester: Manchester University Press.

Pfister, C. 1990. 'The early loss of ecological stability in an agrarian region', in P. Brimblecombe and C. Pfister (eds), *The Silent Countdown. Essays in European Environmental History*. Berlin: Springer-Verlag, 37–55.

Pujol, P. 1995. 'Especialización y cambio técnico en la agricultura catalana: hipótesis explicativas'. In J. Morilla Critz (ed.), *California y el Mediterráneo: Estudios de Historia de dos agriculturas competidoras.* Madrid: MAPA., 403–423.

Sieferle, P 1990. 'The energy system. A basis concept of environmental history', in P. Brimblecombe and C. Pfister (eds),*The Silent Countdown. Essays in European Environmental History*. Berlin: Springer-Verlag,

Sieferle, P. 2001. '¿Qué es la Historia Ecológica?'. In M. González de Molina and Martínez Alier (eds), *Naturaleza trasnfoormada. Estudios de Historia Ambiental en España*. Barcelona: Icaria, 31–54

Simpson, J. 1996. 'Cultivo de trigo y cambio técnico en España, 1900–1936'. *Noticiario de Historia Agraria*, 11: 39–56.

Soroa, J. 1947. *Prontuario del agricultor y del ganadero (agenda agrícola reformada)*. Madrid: Editorial Dossat.

Urdiales, M. 1998. 'La producción ganadera'. In M. Titos Martínez (ed.), *Historia Económica de Granada*. Granada: Cámara de Comercio.

Ventue y Peralta, B. 1885. *Cambio y mejoramiento del cultivo en la Vega y demás territorios de la provincia de Granada*. Granada: Imprenta de I. Ventura Sabatel.

Wrigley, E. 1988. *Continuity, Chance and Change. The Character of the Industrial Revolution in England.* Cambridge: Cambridge University Press.

Zambrana Pineda, J. 1987. *Crisis y modernización del olivar*. Madrid: MAPA.