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Diffusion of Agricultural Science and Technologies. Innovation in Galicia (Spain), 1880-1940.

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Summary

The purpose of this paper is to outline the organization and implementation of the Spanish agrarian innovation system and technology consulting in the Atlantic region of Galicia between 1880 and 1936, and to examine the reception of technological innovation by farmers.

Increased productivity during this period reflects the spread of new techniques in what appeared to be a classical peasant economy. Changes in Galician agriculture occurred in a manner that was coherent with the context, defying some of the assumptions of the neoclassical model. We will focus on three innovations as examples of this: 1) changes in cattle breeding and the creation of the new Galician Red breed; 2) The widespread implementation of threshing machines in an agrarian economy built primarily around livestock, and 3) Galicia as the testing field for pioneering the introduction of hybrid maize in Europe in the 1920s and 1930s.

1) A new paradigm of technical change in a specific space and time

The scope of our enquiry involves Spain, in the Iberian Peninsula, during the period spanning from 1880 to the onset of the Spanish Civil War in 1936. With regard to innovation, classical historiography commonly associates Spain in those years with economic stagnation, backwardness, and a 'long *siesta*' in agriculture (Simpson, 1995; Sánchez-Albornoz, 1968; P. Vilar…). This approach was built around XIX & XX century conflicts involving revolutionary peasant day labourers and demands for agricultural reform (Malefakis, 1970) in a Southern European country identified with inefficiency and poor management. Here, we shall examine the other face of Spanish agriculture in the Northwest region of Galicia, an area dominated by small-scale farming, a northern Atlantic climate and specific crops. It has been identified as a peasant economy by anthropologists and in agrarian studies (R. Iturra, 1988) and is generally thought to have been as inefficient as large-scale farming was in Mediterranean Spain.

The period from 1880-1940 was one of accelerated technological change in agriculture, with important innovations linked to the second wave of industrialisation (W.W. Wade, 1981; FML Thompson, 1968; Feller, 1962; Collins, 1994; Van Zanden, 1997) and powerful scientific advances in agricultural chemistry and animal and vegetable genetics. These included the commercial development of mineral and chemical fertilisers, more efficient agricultural machinery and equipment with new designs and materials, new varieties of seed, new livestock breeds and improvements in crop rotation, cultivation systems and irrigation. All this occurred in the aftermath of agricultural crisis in Europe and offered new possibilities for increasing production and productivity, reducing costs, improving efficiency and increasing the competitive capacity of agriculture. The Atlantic European model grew out of the English mixed-farming model of the eighteenth-century, which had been depleted and defeated by competition from other parts of Europe that inundated markets with agricultural products and livestock.

In this context, given the new scientific complexity of chemical, genetic or biological progress, it was no longer possible to wait for the usual process of local imitation and word-of-mouth propaganda. Innovation and technology transfer had to reach farmers more efficiently and in ways that would be practical or practicable in various spheres of agriculture. The key words were applicability, adaptation, and implementation. Greater State intervention was a necessary and important outcome of the political and agronomic debates regarding the consequences of the agricultural crisis and specific policy attempts to overcome it. Agronomist G. Fernandez de la Rosa described the situation aptly in 1886: "*Do farmers or land workers in Spain have money for new initiatives? (…) What the State does not undertake, no one will for now*." (Pan-Montojo, 1994).

Until this point in time, the liberal State had left technological change in the hands of innovative landowners, but at this juncture the State took on a more proactive role. In the aftermath of economic and social crises, turn-of-the-century Europe became a space in which farmers and tenants demanded and obtained a new status as voters and political subjects. With universal male suffrage (in 1890 in Spain) and tenant demands for ownership of the land they cultivated, peasant farmers became the subject and object of public policy. They replaced idealised, forward-thinking landowners as the new targets for innovation. Accordingly, a State institution led by scientists and technical experts was envisioned and constructed to facilitate training, experimentation and demonstration. It sought to develop an apparatus that could expose farmers to innovations and to help them adapt to new technologies. Precedents in Germany and the United States dating from the mid-nineteenth century inspired the European phenomenon of creating State innovation systems for these purposes (Fumian, 1983; Fernández Prieto, 1992; Koning, 1995; Collins, 1997).

Here, it is important to distinguish the novelties that accompanied this era of technological change from those that triumphed in the second half of the twentieth century. Turn-of-the-century agriculture still required handling nature in a paradigm that could neither master nor disregard it. Innovations were closely linked to the social and physical context. Technological advances in these decades impacted five essential physical-biological processes: 1) energy use, through mechanisation; 2) bio-geochemical processes, related to fertilisation; 3) breeding practices, due to improved genetic material; 4) hydrologic uses, based on new pumps and irrigation systems; and 5) biotic regulation, thanks to new rotation schemes. At that time there was no technology for transporting or using large amounts of energy to re-create homogeneous environmental conditions, which occurred after 1945. The productivity of an agro-ecosystem was still determined by its own capacity to produce biomass (Gonzalez de Molina, 2001).

2) The magnitude of changes in Galician agriculture, 1900-1930

Agrarian historiography has recently re-examined Spanish agriculture during the late nineteenth and early twentieth centuries, and can now begin to offer a more nuanced picture that looks beyond 'stagnation' and 'backwardness'. A key reference work in this new phase is *El Pozo de todos los males* (Pujol, González de Molina, Fernández Prieto, Gallego and Garrabou, 2001) along with the works of Vicente Pinilla and Martínez Carrión. This update of the classical interpretation (Fernández Prieto, 1992; Soto, 2006) has found that Galician agriculture experienced significant intensification between the crisis of the late nineteenth century and the Spanish Civil War, rooted in changes that had begun earlier in the nineteenth century.

Galician agriculture, characterised by small-scale peasant farming with livestock specialisation in a Northern Atlantic climate, was unusual in the Spanish context. Contrary to the common characterisation of the Galician economy and especially agriculture as backward and resistant to change, our study suggests that between 1900 and 1936, *organic* Galician agriculture experienced considerable intensification and technological change that was institutionally fostered but socially driven by the farmers themselves.

The considerable economic growth in Galician agriculture between 1900 and 1930 was especially visible in the province of A Coruña, which we will use as our case study. During this period, the value of agricultural production almost tripled and the value of total agricultural production nearly quadrupled (Table 1). Growth in the value of production coincided with a slight decrease in cultivated surface and a lower active male population involved in agriculture.

Table 1. Coruña: agricultural changes, 1900-1933

	Unit	1900	1910	1922	1933
Crops	millions pts 1910	70	119	171	260
Agricultural production	millions pts 1910	122	190	269	354
Cultivated surface	thousands of has	259	241	242	231
Productive surface	thousands of has	774	774	774	774
Males active in agriculture	thousands	137	133	135	113

Source: Soto, 2006

This implied an even greater increase in land and labour productivity, particularly in relation to the rest of Spain (Table 2). In 1900, the province of A Coruña was below the national average in total land and labour productivity and only slightly above the national average productivity for cultivated land. By 1933, it was 57% and 68% above these averages, respectively, and cultivated land productivity was 4.5 times the Spanish average.

Table 2. Coruña and Spain: agricultural productivity, 1900-1933

	Unit	1900	1910	1922	1933
Coruña					
Productivity of cultivated land	pts./ha	269	493	707	1129
Total land productivity	pts./ha	157	246	348	457
Labour productivity	pts./ males active in agriculture	886	1437	2001	3134
Spain					
Productivity of cultivated land	pts./ha	193	200	240	241
Total land productivity	pts./ha	163	191	254	292
Labour productivity	pts./ males active in agriculture	977	1081	1484	1868

Source: Soto 2006 and GEHR 1983.

In contrast with the trend after 1939, institutional and market factors can explain these economically spectacular results to some extent. Peasant farmer access to full ownership of land was central to this process and encouraged the more effective farm management practices that had begun to take hold in the prior century. Also, the 1883 opening of a railway from Galicia to central Spain created market opportunities for livestock farming that replaced the unpredictable English market (Carmona, 1982). However, these alone would have been insufficient if other factors had not also heavily influenced economic results (Fernández Prieto, 1992 and 2007; Pan Montojo, 2005). There was a significant place for technological change among small-scale peasant land owners, who adopted the innovations most suited to their intensification processes. Together, the State and rural society took advantage of new technologies.

The data eloquently reflect the sustained agricultural transformation that occurred between 1900 and 1930, with notable increases in land and labour productivity. Here, we examine only the data for the north-western province of A Coruña, but the trend was similar throughout Galicia (Pujol et al., 2001) which in turn resembled other European regions with comparable agriculture. Here we shall seek to identify some of the mechanisms behind agrarian technological change, with special attention to the institutional initiatives that facilitated agricultural transformation and the social and productive logic that guided it.

We will describe a model of change in intensive, small-scale organic agriculture in a context of socio-ecological transition that would give way to the Green Revolution after World War II. In the decades prior to the Spanish Civil War, scientific contribution to innovation was facilitated by the creation of a State apparatus for innovation. The institutional development of market inputs and outputs coexisted with the logic of an organic system in which farmers could accept or reject innovations and begin to organise themselves into societies and cooperatives, through which they in turn intervened in market and innovation processes. This period combines the logic of organic agriculture with the potential of science-based intensification without actually breaking organic dominance. Contrary to the standard assumptions, this was not an inevitable teleological transition towards hyperintensive post-World War II agriculture; nor was it a unidirectional or unidimensional prelude to modernisation.

3) State innovation and research in Galicia through local and regional experimental facilities

There are similarities in the direction and rhythms of agricultural policies for State innovation in Spain and other European countries during the period we are discussing. Debate around the idea of creating a system for agricultural organisation and experimentation began in the1860s, leading to the 1875 formation of a Central Agronomic Station in Madrid and the 1879 creation of the Corps of Agronomic Engineers. In 1881, the School of Engineers (1855) followed suit with the inauguration of the Alfonso XII Agricultural Institute in Madrid and the development of a regional experimental farm model that was soon operating in six provinces. Between 1887 and 1892 a final three-tier model was established that included:

1.-A Central Station (*Estación Central*) in Madrid for research that would eventually include specialised stations in pathology, oenology, seeds…

2.-Ten Experimental Farm-Schools (*Granja-Escuela Experimental*) in the ten newly-organised agronomic districts;

3.-County Agricultural Demonstration Fields (*Campos de Demostración Agrícola comarcales*) that put farmers in direct contact with technology and

> formed the central pillar of the system from 1900 on. The Decree that created these experimental fields stated that measures adopted by the government "*should contribute to alleviate the difficulties (the demise of agriculture) but will not fully cure them unless the farmer can learn from everything that science offers today*". (R.O. 6-IV-1888).

In this model, research from the first and second levels was made available to the Regional Farms, which adapted innovation to specific productive realities and shared the tasks of diffusion, advice and US-style extension services with the county Demonstration Field facilities. The new apparatus could adapt complex technical and scientific innovation to the local setting. Thus, the 1875-1892 agricultural crisis coincided with a paradigm shift from an erudite model aimed at the educated, pioneering landowner to one based on research and innovation aimed at all farmers.

State expenditure on agriculture increased four-fold between 1880 and 1914. In 1912, this institutional framework consisted of thirteen Regional Farms, four research stations in Madrid, fourteen specialised regional stations, eleven oenology stations[1] and twenty-nine Demonstration Fields. In the first three decades of the twentieth century, the system expanded to include specialised research stations; some of which were connected with the central station and others that were adapted to regional needs such as grassland farming, phytopathology or olive cultivation.

The agrarian innovation network became significant in Galicia: in 1888 the first Regional Farm was established in the city of A Coruña, which also served Asturias, and ten Demonstration Fields were functioning by 1912. The system incorporated both State and private initiatives, including those of new organisms such as the Council for Continuing Education (*Junta de Ampliación de Estudios*). This para-state organism was created in 1907 to foster research that led to the founding of the Biological Mission of Galicia in 1921. It also benefitted from the involvement of organisms in the Americas thanks to the large groups of immigrants from northern Spain. In the 1930s, the system included a phytopathology station annexed to the A Coruña Farm, several centres created by immigrants, a plague laboratory at the University of Santiago de Compostela and fourteen Demonstration Fields serving much of the region. These were directed by agricultural technical experts of various sorts, including four to six engineers and researchers at the Farm and the Mission along with mid-level agricultural experts in the Demonstration Fields. During its peak years of activity, several other projects were envisioned for new centres and stations, which were linked to the development of the regional autonomy statute. More installations implied political triumph: a visible demonstration of the weight of agricultural interests and the importance of Galician agriculture and livestock farming.

The main research centres (Regional Farm and Mission) functioned as guiding organs for the innovation apparatus. Though connected to State central organs, they were endowed with significant autonomy in defining lines of research and scientific connections, guided by their respective heads of department. In general they sought to improve agricultural and livestock processes and crop systems. The Regional Farms in the North developed a primary focus on livestock and forage crops, while in the South

[1] The first was founded in Málaga in 1879 as a response to the phylloxera plague. It is proof that the system was set up with both centralized and decentralized tendencies, due to new needs arising, in this case, from the threat of total loss of vineyards in Málaga.

of Galicia the Mission emphasized food crops and animal genetics, mainly pigs. Both responded in a fairly complementary fashion to the productive characteristics of the areas they served. Both also addressed fertilisation, offered recommendations on the use of new products and attempted to limit fraud.

Perhaps the most significant aspect of this system, however, was that it addressed the needs of existing agriculture as expressed by the farmers themselves, rather than following enlightened and arbitrary past tradition. Resources to the Regional Farm tripled between 1896 and 1910 and were translated into facilities, laboratories, libraries and personnel.

Efforts at reaching the target audience involved regular bulletins and pamphlets, articles and regular columns in the regional press, radio programmes, travelling teachers with film projectors and vehicles for public relations in the 1920s. Direct links between the Farm, the Demonstration Fields and technicians who locally reproduced innovations facilitated farmer access to new technology. On-going relations with supply companies served at times as the main channel for penetration of innovation, though relations between institutions and companies were always kept quite professional. More important was cooperation with locally organised agricultural or livestock societies and cooperatives or even the creation of new ones with the help of technical experts from the Farm or Demonstration Fields. The Biological Mission was even involved in organising a Seed Producers Trade Union for experimenting with and disseminating hybrid maize.

The creation and functioning of this Spanish institutional system occurred at a different pace than in other countries, each of which responded to the technological capacity of its farmers to overcome environmental productive limitations. Though new technology offered new capabilities, agronomists with their new knowledge had to interface with the farmers and their capacity for adopting innovations. This required the selection and adaptation of technology to the physical-climactic and socio-productive conditions of each type of agriculture, which was the essential work of the established institutional innovation system. Successful resolution depended to a large degree on the ability of technical experts to understand and interact within the logic of the existing agrarian economy. In Galicia, an alliance was formed that merged new science-based knowledge with peasant farming knowledge in a process that we name as *tchaianovization* [2]. Agronomists studied and understood the social and productive conditions of agriculture in order to propose practical solutions that would be acceptable to farmers, the true subjects of innovation in this new paradigm. The fusion of scientific or educated agronomy with unschooled peasant agrarian knowledge was the task of the technical experts and led to better or worse results. In 1913, the director of the A Coruña Farm wrote: "*For years … it has been easier to translate than to experiment on our own soil (…) So what I tell you will be Galician in its essence and practical in its development (…) In my very modest work, experimentation takes priority over what is 'written'* " Leopoldo Hernández Robredo (1913) (in Fernández Prieto-2007).

In this case, a rather perfect fusion was also favoured by the available technology, which was more adaptable to Galician mixed farming than to Mediterranean agriculture.

[2] In reference to Russian agrarian specialist, Alexandre Tchaianov, and his 1925 publication, *The Organization of Peasant Economic Units* (*La organización de la unidad económica campesina*).

Thus, the State innovation apparatus was more successful in implementing a new technological paradigm in Galicia. Good rapport between the innovation apparatus and farmers meant that these innovators could influence the selection of technology according to the needs of their agro-ecosystems. In other words, farmer involvement in the selection of innovations favoured the process of technological change because it was based on *their* needs and *their* farms. Agronomists from the research, experimentation and demonstration centres became interpreters and translators of the needs of the farming community.

Similar processes were occurring in other European territories that shared a similar climate and conditions for strengthening peasant agriculture. In this case, it was due to:

1) a moment of productive 'perfection' in the Galician agricultural system (Bouhier, 1979; Soto, 2006);
2) its capacity to produce for the market (Carmona, 1982);
3) the social dominance of farmers who were becoming landowners (Villares, 1982);
4) the capacity of the agrarian population to organise itself into associations that provided their local communities with access to markets, politics and innovation (Fernández Prieto, 1992; Cabo, 1998).

4) Who selects new technology? *Quid prodest*? The small-scale farmer as decision-maker for innovation

Technological change tailored to the needs and interests of small-scale farming is easy to demonstrate in Galicia, but has not generally been understood in the traditional interpretation, anthropology or historiography of this type of agriculture. So it is necessary to clarify the precise time and space. Here we refer to a society of small-scale family farms that control production and land management, following both a reproductive and a mercantile logic in which the sphere of moral economy intersects with the sphere of capitalist economics. We will discuss three key technological developments that exemplify the direct action of the innovation system in small-scale farming. These reinforced rather than undermined the existing agricultural system and the growing capacity of small-scale farms to intervene in the market, without questioning family reproductive logic. Productive, reproductive and mercantile logics were reinforced by the innovative process. They demonstrated and enhanced the social and political status of farmers, who in this period were known as *labregos*, or land workers, and who became independent owners of their land. The three specific innovations we will discuss are: a) Breeding changes and the creation of the new Galician Red cow; b) The general adoption of threshing machines in an agrarian economy centred mainly on livestock and; c) The pioneering of hybrid maize and its diffusion throughout Europe in the 1920s and 1930s.

a) Breeding changes and the creation of the Galician Red cow. The issue of improving national cow breeds was a primary concern of the innovation system in Galicia. Loss of the important English market during the agrarian crisis of the late nineteenth century damaged the most dynamic sectors of the Galician economy. Producers, intermediaries and exporters were key elements in the Galician mercantilisation process. With the creation of the Regional Farm, debates shifted from economic to zoological and technical issues related to cross-breeding versus pure breeds. Agronomists and veterinarians sought to make breeds more productive by improving their feed, since “the feed makes the breed” according to L. Hernández Robredo.

Institutional efforts at innovation involved many actions and instruments. Select national or Swiss Simmental stud bulls were sent to the research centres for cross breeding, a genealogical register was instituted that included private breeding; selection criteria were defined for highest quality purebreds; livestock contests were held that became central to local festivities; and new institutional organisms started new programmes for treating livestock health.

In the early twentieth century, the *labregos* themselves became involved in breeding selection in their parishes and hamlets. Farmers developed and directed the purebred selection process, following new selection and interbreeding criteria and recommendations from the innovation centres. The objective was clear: to respond to the growing domestic demand for meat by developing better, heavier, more fertile animals for greater market impact (Martínez, 1996). Although these objectives had been in place since the mid-nineteenth century, they were now shared by commercial interests, agronomists and producers. Meat, muscle and milk were the requirements of the new breed, which materialized as the Galician Red cow. It was the *labregos* who determined the Galician Red to be the ideal breed, due to its triple aptitude in providing meat, traction power for agricultural work and milk products for family consumption and for the nearby urban markets that began to expand at the end of the nineteenth century. In 1906, the Galician Red breed was not yet listed in the Rof Codina veterinary reference register; but the breed was dominant in Galician herds by 1940, alongside similar breeds derived from cross-breeding with Simmental or Schwitz cows.

b) The introduction and widespread use of threshing machines in an agrarian economy centred mainly on livestock. Innovation in grain threshing makes it possible to better identify and classify the model of technological change, the extent to which this innovation met the needs of the *labregos*, and how their productive and reproductive needs determined the selection of this innovation. This type of mechanisation was incompatible with the specialisation logic imposed by the post-World War II technological paradigm and underscores the differences between the two processes and periods. The elements that supported family labour productive strategies and were closely related to livestock specialisation during the second half of the nineteenth century were considered incoherent with any livestock specialisation tendency after 1950. This was discussed in detail in our 1997 study on the spectacular spread of mechanical threshing machines prior to 1936 in Galicia, where they were much more commonly used than in the rest of Spain.

Threshing machines symbolised the mechanisation of European agriculture before tractors became extensively used (D. Grigg, 1992). In many areas of Galicia prior to 1936, threshers were the most widely adopted innovation due to the greater efficiency of their motors and machinery. In spite of the relative statistical weakness, the figures and qualitative evidence suggest that by the 1930s mechanical threshing had replaced the traditional mallet. The threshing machine became known as the ‘mallet machine’. Both the old logic and community organisation in sharing threshing labour and machinery among the different farms remained intact.

Here, three ideas should be highlighted: 1.- the direct relationship with the new mechanised technology involved the use of the combustion engine and introduced a 'Fordist'-like rhythm to the production chain that saved a great deal of individual labour. 2.- it was rapidly incorporated into Galician mixed farming, which was increasingly specialized in livestock, in contrast with the weak mechanisation of some of the grain farming that was dominant in Mediterranean Spain. It reaffirmed the selection capacity of farmers who prioritised mechanical innovation linked to the continuity of the family farm over market production. During certain seasons, mechanical innovation was linked to the production of fodder, so that savings in human food (bread) production made it possible to produce more animal feed: hay, grass, maize, beets and turnip, for example. Machines saved time that could be dedicated to other tasks, which took on greater importance and competed with or speeded up the harvesting of wheat or rye. Machines also ensured harvesting and improved the final product by minimising risk associated with unexpected rain. 3.- Community participation in manual threshing was transferred to mechanical threshing. Organisation and collective adoption of mechanised innovation allowed the community to face both the high monetary cost of machinery and the social cost of ridicule if the innovation failed.

Collective adoption of innovation was often fostered by farmers' societies, a new form of voluntary association that became a key instrument in facilitating and leading technological innovation for the *labregos*. Community relations and logic underpinned the movement towards associations and the collective adoption of innovation. Many societies had their own threshing equipment after 1908. For farmers willing to innovate, collective purchasing was the only way to access mechanised equipment. More importantly, it was the only socially viable way to risk innovating in rural communities. In the unlikely case that a single family could afford to purchase its own equipment, it would not dare to do so for fear of ridicule and failure, which would drastically undermine internal and external family well-being. However, associational involvement in innovation was a relatively safe means of collective experimentation that reduced risks and the potential for embarrassment. If the innovation underperformed, the collective social and economic setbacks would be more manageable. So, what many authors have interpreted as rural distrust may also be seen as a display of necessary prudence.

Collective innovation implied the purchase of equipment for shared use and helped explain both the rapid diffusion and updating of the first machines. The shift from winch- to gasoline-powered machines took place in the second and third decades of the twentieth century. Contemporary forms of informal cooperativism associated with rural communities have also been observed in areas of Denmark, Sweden and Holland (Grigg, 1982). Shared use of machinery was a regular practice in Galicia, even if purchase was not collective or involved other means. Machinery could be purchased by groups of farmers not affiliated into societies or in mountain areas with no organised associations. In other cases, more affluent individual farmers would purchase machinery and rent it in surrounding areas. Individual purchase for exclusive use appears to be very rare. Communities used machinery more intensively and extensively, all the while forming and propagating work groups adapted to the new system; which weakened the continuity of manual systems.

c) The pioneering of hybrid maize for diffusion in Europe in the 1920s and 1930s. A brief overview of this matter will complete the picture of innovative small-farm agriculture in Galicia, which first experienced the development and introduction of hybrid maize in Europe. The agronomist Cruz Gallástegui was the first director of the Biological Mission of Galicia. He had worked closely with D.F. Jones in experiments that led to the first double-cross hybrid maize at the Connecticut Experiment Station in 1919. Both individuals appear in all the press photographs surrounding this scientific breakthrough. In 1921, Gallástegui organized the Biological Mission of Galicia around animal and vegetable genetic research in Santiago de Compostela. The Mission was moved to Pontevedra in 1926. He studied local agriculture, interacted with farmers and created a Seed Producers Trade Union for experimenting in various areas and producing larger quantities of hybrids. The Mission was successful in developing a double-cross hybrid maize adapted to Galician agro-ecosystems.

Gallástegui illustrates the ideal linking of research with specific agricultural conditions. This agronomist mixed large doses of realism with a vocation for innovation and trusted in the farmers' capacity to incorporate something as sophisticated and beneficial as hybrid maize:

> *"Here I remind you of a dilemma (...) Should we develop a maize seed that produces maximum harvest for maximum intensity cultivation or should we (…) provide farmers with a variety that is best adapted to a deficient and impoverished agricultural system? There is no seed that can do both things at once. Only one can be chosen. In a region as densely populated as Galicia, there can be no doubt about the answer: maximum performance for maximum intensity agriculture. This seed is the double-cross hybrid."*

(C. Gallástegui Unamuno (1934) "Ventajas e inconvenientes de la semilla doble híbrida en relación con la semilla de variedades" in *Boletín del Sindicato de Productores de Semillas*, 16.)

The introduction of maize into crop rotations along the Atlantic coast in the eighteenth century was one reason for the success of intensive mixed farming, which spread throughout Galicia. It increased annual harvests without competing with other crops and produced good fodder for cows, pigs and poultry. If the need arose due to demographic growth, it could also feed humans. This was the kind of agriculture that Gallástegui was envisioning with his new maize: more animals, more manure and more humans in an intensifying virtuous cycle.

Here, we are referring to a technology derived from genetic science, a field that emerged in the late nineteenth century but is more generally associated with the technological paradigm of the post-World War II Green Revolution. What is really significant is that the innovation system and small-scale Galician agriculture could develop, embrace and implement such a futuristic technology in the first decades of the twentieth century. This was above all due to the dedication of this eminent agronomist, his team and his laboratory to introduce cutting-edge technology into small-scale agriculture that participated in a market economy.

These three examples of innovation in Galician agriculture illustrate the fusion of science-based and experience-based agriculture. Farmers themselves selected and implemented innovations that had primarily been developed in line with their intensification needs, which involved both commercialisation and family reproduction.

Technology did not threaten community or family equilibrium; instead it empowered processes that were already operative in affirming small-scale farming, such as land ownership, agricultural intensification and commercialisation.

5) **The impact of technological changes on the transformation of agriculture centred on livestock**

We have outlined the magnitude of the economic changes in Galician agriculture in the decades prior to the Spanish Civil War. We have also shown the significance of the State innovation apparatus and the capacity of farmers to choose innovations best adapted to the advanced organic agriculture of the Atlantic northwest. In this section, we will show the real agronomic impact of these innovations on small-scale agriculture specialising in livestock. For this, we shall analyse the impact of technological change on the evolution of physical production.

Table 3. Coruña. Evolution of production

	1900	1910	1922	1933
Grain crops, domestic extraction(1)	595	674	833	922
Residual crops, domestic extraction(1)	368	263	303	419
Total crops, domestic extraction(1)	963	937	1135	1340
Physical productivity of cultivated land(2)	3.7	3.9	4.7	5.8
Physical productivity of labour(3)	7.0	7.1	8.4	11.9

Unit: (1) thousands of metric tons dry matter; (2) thousands of metric tons dry matter/ha; (3) thousands of metric tons dry matter/active worker

Source: author's own elaboration based on Soto (2006), and Domínguez and Soto (2012)

This table shows a pattern similar to other studies on the physical evolution of agriculture: the growth rates of physical production (domestic extraction) were well below those of monetary production. The monetary production of the crops in the province of A Coruña grew by 273% between 1900 and 1933, while physical production only increased 39%. Here we note that physical production comprises all types of production, including those that have no monetary value, but are fundamental for family reproduction and ecological maintenance of production (residual).[3] Production with a direct commercial purpose grew most rapidly. Much of the growth in physical production involved crops for feeding cattle (fodder and artificial pasture); and was therefore directly related to the process of livestock intensification.

Especially significant was the increase in physical productivity that placed the province of A Coruña at the forefront of organic Atlantic agriculture. Productivity grew from 4.7 metric tons of dry matter per hectare in 1922 to 5.8 tons per hectare in 1933. This is a very clear difference from Mediterranean Spain: in fact, the national average never rose above 1.7 tons per hectare during that period (González de Molina et al., 2013). Environmental factors played a very important role in the divergence of results, since Galicia's Atlantic climate implied much greater net primary productivity than in Mediterranean areas of Spain. However, livestock specialisation and the resulting

[3] See the detailed study of olive plantations in Infante (2012)

availability of fertiliser are also central to explaining the agronomic possibilities for growth in land productivity.

Table 4. Coruña. Evolution of livestock farming and fertilizer availability

	Unit	1900	1910	1922	1933
Evolution of livestock farming	thousands of metric tons live weight	66	99	162	170
Manure production	thousands of metric tons fresh matter	1221	1832	3194	3263
Chemical nitrogen consumption	tons of N	?	5	5	1084
Chemical phosphorus consumption	tons of P	?	276	1042	3704
Manure nitrogen consumption	tons of N	4612	6975	11311	11838
Manure phosphorus consumption	tons of P	1908	2900	4679	4932
Chemical nitrogen over total	%	?	0.1	0.0	8.4
Chemical phosphorus over total	%	?	8.7	18.2	42.9

Source: author's own elaboration based on Soto (2006) and Domínguez and Soto (2012)

The Table 4 demonstrates how livestock growth was far above the domestic extraction of crops. Total live livestock weight in Galicia increased by 160%, in contrast with a 39% increase for crops. This is not surprising given that livestock specialisation drove the development of that period. Changes in livestock farming and the introduction of chemical fertilisers played a central role in explaining how such high physical land productivity rates could be maintained. Almost all European agriculture began to use phosphate fertilisers earlier and more heavily than nitrate fertilisers, which were the key to agricultural industrialisation after World War II. This can be explained in part by technological and supply factors. However, there are also agronomic causes for this process in Galicia. Cereals and legumes were traded in the intensive crop rotation and mixed farming of Galicia from the mid-eighteenth century, which maximised the use of nitrogen but not of phosphorous. However, the increase in livestock farming constituted the most important nitrogen replenishing element in Galician agriculture at that time. Chemical nitrogen played a minor role compared to phosphorous. Though the supply of phosphorous through manure also increased, dependence on industrial sources became more embedded, growing from 18% in 1922 to 43% in 1933.

The title of this paper could have been: **How farmers adopted new technologies in Atlantic Iberian agriculture (1880-1940).** It would have put the spotlight on the subjects of innovation in a specific agrarian region rather than on the innovation apparatus and its capacity for technology transfer. It also draws attention to a *peasant form of agrarian innovation* in Atlantic Iberian agriculture. This specific form of implementing innovation and agriculture spanned the period from the agrarian crisis of the late nineteenth century to the beginning of the Spanish Civil War (1936-39), which directly preceded World War II.

We have explained how a highly productive and intensified Atlantic mixed-farming region integrated itself into a new agrarian technological paradigm, how this occurred and how the State innovation system acted to facilitate adaptation or adoption of scientific and industrial innovation. For the innovating subjects of this change, the State innovation model was decisive, with its network of research and innovation facilities; Regional Farms and local Demonstration Fields. We have not addressed the role of the companies supplying the innovations mentioned and have only briefly referred to farmers associations, which were essential for the spread and adoption of technology.

Tchaianovian scientists shaped the rural economy in Galicia between the two World Wars, making technology transfer possible and bringing innovation to small-scale farming. We have addressed the question of who selected and whom benefited new technology in this particular space and time and how technology affected productivity in Galician farming prior to 1940. We have supported our proposals with three specific examples of innovation in this context: the threshing machine, hybrid corn and the creation of a new breed of cow to increase cattle production.

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