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Characterisation of the National Network of Silos and Granaries in Castilla y León, Spain: A Case Study

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Abstract: In 1995, Spain's National Network of Silos and Granaries was divided into a basic network and a secondary network. Of the total storage units identified, 541 are vertical units or silos forming part of the secondary network. Unlike the silos of the basic network, many of the secondary network silos, which were primarily reception units sited near the areas where the grain was grown, have been repurposed. This article describes a methodology developed to inventory silos based on their general features, construction and technological facilities, and its application to the 123 silos in the secondary network in the Spanish region of Castilla y León. The exercise was conducted in conjunction with a socioeconomic analysis of the communities where the silos are located. All the silos studied are located in the most productive areas and close to farms, have small storage capacities and include all but one silo typology, the transition macro-silo. Some are still used for grain storage, whilst others have been converted into multi-purpose warehouses, gymnasiums, community centres or other specialised facilities. Ideas for silo repurposing implemented in other regions of Spain and other countries might well be applied in Castilla y León. In addition, this methodology has proved useful to identify proposals that are viable in the more highly populated communities.

Keywords: agroindustrial buildings; industrial heritage; reuse; silo; storage unit

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1. Introduction

Since ancient times, one means of guaranteeing a population's food supply has been to store grain, primarily wheat in Western Europe, for instance. The mid-nineteenth century invention of the grain elevator changed storage radically from traditional horizontal to vertical structures the world over [1,2]. In Spain, after the Spanish Civil War in the late 1930s, the state created the Servicio Nacional del Trigo (national wheat service, Spanish initials SNT) to monopolise the wheat market [3]. As part of that initiative, the state built the National Network of Silos and Granaries (NNSG).

The precedents for grain silo construction in Spain include 15 such structures built in 1924 at Zorroza, a quarter of Bilbao, for Grandes Molinos Vascos, flour manufacturers [4,5]; Hortaleza Silo (Madrid 1928) [6]; the Duke of Alba's silo [6–8]; and the silos built for Panificadora y Fábrica de Harinas (Vigo, 1931) [6,9]. Other smaller feed storage silos were built in 1933 under a Ministry of Agriculture tender [6,8].

Although a few horizontal storage units (HSUs) or granaries were erected, construction focused on silos or vertical storage units (VSUs) [10–12]. The network was created in 1949, but it was not actually launched until 1951 when the silos at Córdoba, Alcalá de Henares and Mérida were commissioned [6]. Grain (mainly wheat, although sometimes barley, oats

and rye as well) was stored in the network for over 50 years (construction on the last, in Valchillón, a town in southern Spain, was completed in 1990) [6,10], although starting in 1986 when Spain joined the European Economic Community, use waned substantially. The country's agricultural guarantee fund, the Fondo Español de Garantía Agraria (FEGA), successor to the former SNT, devolved competence for storage unit (SU) management to the regional governments (Spain's 'autonomous communities'). In 1995, the NNSG was divided into two networks: (i) a basic network (comprising the most modern and largest VSUs) and (ii) a secondary network (made up of all the other VSUs). In recent years, FEGA has gradually auctioned off the silos in the basic network to private companies and cooperatives that continue to use them mainly to store wheat and barley [13]. To lower maintenance costs, FEGA assigned responsibility for the secondary network silos to the regions in 2000–2004 [14,15]. The silos in Castilla y León were leased at first by farm cooperatives and a number of private companies for grain storage: in 2006, 58% of the silos were in the hands of such organisations. As time passed, however, some of the tenants returned their silos to the Castilla y León government, whilst some municipalities asked to have ownership of their silos assigned or returned. As a result, silo condition has been worsening despite attempts to find a second use for silos [6], which is a fact highlighted by a number of authors [16–18]. Like Spain, countries such as Portugal and Italy have twentieth-century networks of storage silos, mainly for storing wheat, that have since been largely either turned over to private interests or abandoned and only occasionally repurposed [19,20]. National silo networks can regain their importance, because they are strategic elements of infrastructure that can mitigate dependence on grain exports in adverse scenarios, conflicts such as the current war in Ukraine, pandemics and blocked trade routes.

Like other agroindustrial buildings, silos are sited in the countryside, where they form part of the cultural and architectural heritage [17]. Since their construction, silos have formed part of village skylines along with historic churches and castles [17,21,22]. They should be inventoried to establish their status as elements of the region's cultural heritage, prevent their disappearance and seek formulas for their reuse [17,23–27]. Preparing a thorough inventory is the first step toward being able to make good decisions for real silos and their environment today. A large amount of resources went into building these silos, so it is our duty to try and avoid demolition and give these buildings a second life, thus contributing to greater environmental sustainability by reducing the carbon footprint. No studies on a methodology for systematically characterising grain storage buildings or any other kind of heritage infrastructure in southern European countries appear to exist in the literature.

The primary objectives of the present article are to propose a methodology for characterising Spain's National Network of Silos and Granaries and to describe the results of its application to the silos in the secondary network in Castilla y León.

2. Materials and Methods

In the absence of any catalogue containing detailed information on silos, the materials used consisted of data collected from the FEGA's general archives in Madrid and the archives kept by the Castilla y León Regional Department of Agriculture at Valladolid. Information was collected about all the secondary network silos located in that autonomous region, which is located in northwestern Spain (Figure 1).

The first step was to conduct an inventory based on the archival source data; the second was to identify the variables of interest grouped by subject. Field work was then performed to establish a detailed inventory, after which all the data were analysed and a proposal for action was formulated (Figure 2).



Figure 1. Site map of the autonomous community of Castilla y León.

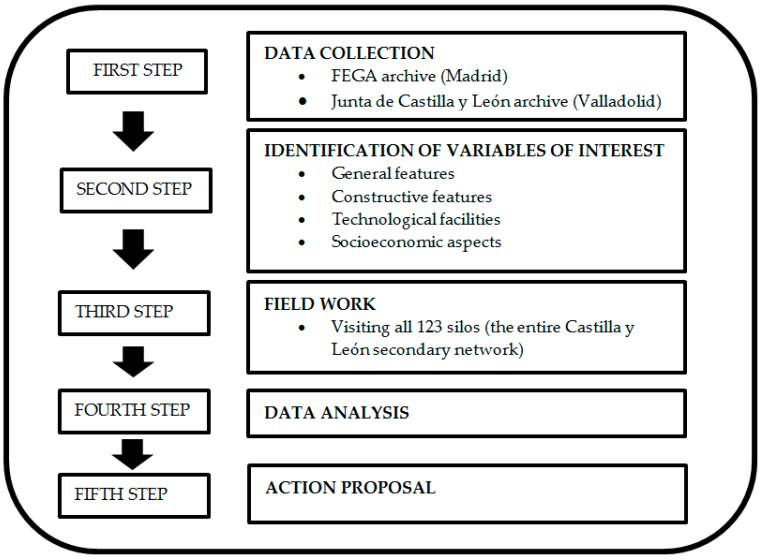


Figure 2. Methodology workflow.

The workflow for silo characterisation and evaluation was drawn from a PhD dissertation authored by the first author [28]. All 123 silos (Castilla y León's total secondary network) were visited during the fieldwork. Each silo was photographed and its most prominent features recorded, including (Table 1):

- General features:
  - Location (province and town or village);
  - Year of construction;
  - Ownership (regional government or municipality);
  - Use (grain store, without use or reused);
  - State of conservation (good condition, fair condition or unusable).
- Constructive features:
  - Category (port, reception, transition and reserve, transition macro-silos, seed selection and grain drying);
  - Typology (P, A, B, C, D, E, F, GV, H, J, MC, MR, TR, T, SV, SA and SG);
  - Storage capacity (t);
  - Ground plan (square, T-shape, cruciform and L-shape);
  - Roof shape (flat roof, gable roof and hip roof);

- Tower position (interior tower, central tower, corner tower, side tower, front tower and front tower between two cells);
- Number of cells;
- Shape of cells (square and circular);
- Cell construction material (concrete block, reinforced brick, reinforced concrete and sheet steel);
- Position of cell rows (cells raised off ground storey floor, cells resting directly on ground storey floor and rows alternately resting on and raised off ground storey floor).

- Technological facilities:
  - Machinery capacity (lorry or railway) (t/h);
  - Weighbridge (lorry or railway) (t);
  - Existence of railway (yes or no).
- Socioeconomic aspects: population, demographic patterns, debt per capita (€/inhabitant), yearly municipal budget (€), economic activity, land communications and distances to larger urban centres (km).

Table 1. Fieldwork variables used to inventory the 123 silos in the secondary network of silos in Castilla y León.

Categories	Variables of Interest
General features	Province Town/Village Year of construction Ownership Use State of conservation
Constructive features	Category and typology Storage capacity (t) Ground plan Roof shape Tower position Number of cells Shape of cells Cell construction material Position of cell rows
Technological facilities	Machinery capacity (t/h) Weighbridge (t) Existence of railway
Socioeconomic aspects	Population Demographic patterns Debt per capita (€/inhabitant) Yearly municipal budget (€) Economic activity Land communications Distances to larger urban centres (km)

The information collected is all available in the Supplementary Materials Tables S1 and S2. Basic statistical analyses were conducted on all data.

3. Results and Discussion

3.1. Secondary Network

Today, the secondary network in Spain comprises 541 VSUs or silos with a total capacity of 1,448,830 t. The secondary structures are located primarily where wheat output was highest: Castilla y León, with 123 silos accounting for 24% of the total storage capacity,

Castilla-La Mancha with 123 silos and 21%, Andalucía with 113 silos and 24%, Extremadura with 52 silos and 9% and Aragón with 46 silos and 7% of the total capacity. The remaining 84 silos are located across the rest of the country (Table 2).

Whilst a substantial number of secondary network silos are found in other regions, Fernández-Fernández [28] identified very few basic network structures there. The explanation may be that when the initial, smaller silos were built, grain production was high but later declined in favour of other crops in regions such as Castilla-La Mancha, Navarra and Cataluña, where fewer large silos were erected, or other regions, such as País Vasco, Comunidad Valenciana, Canarias and Murcia, where no silos were built at all [29,30].

Table 2. Spanish silos: storage capacity by region and network (basic or secondary) [13,26].

Autonomous Region	Basic Network Silos		Secondary Network Silos		Total	
	t	No.	t	No.	t	No.
Castilla y León	326,200	50	340,560	123	666,760	173
Castilla-La Mancha	93,000	5	308,815	123	401,815	128
Andalucía	189,250	12	342,410	113	531,660	125
Extremadura	100,020	15	122,470	52	222,490	67
Aragón	171,600	37	101,405	46	273,005	83
Cataluña	19,500	2	76,480	25	95,980	27
Navarra	31,100	4	72,350	29	103,450	33
País Vasco	0	0	22,100	10	22,100	10
Madrid	10,000	1	20,780	7	30,780	8
La Rioja	11,550	3	19,600	6	31,150	9
Canarias	0	0	12,000	1	12,000	1
Murcia	0	0	5400	3	5400	3
Valencia	0	0	4460	3	4460	3
TOTAL	952,220	129	1,448,830	541	2,401,050	670

t: Capacity in tonnes; No.: Number of units.

3.2. General Features

The results in Tables 3 and 4 were prepared on the basis of the data in Table S1.

Secondary network silos are located in grain-producing areas close to grain farms. There are no silos in the mountainous areas of the community, where little if any wheat is grown. With 20 silos, the province of Zamora has more than any other, which is followed by the provinces of Burgos and Salamanca, with 17 silos each. Bringing up the rear are the provinces of Ávila and León, with eight silos each. These figures are completely logical, since two of the top three provinces are part of Tierra de Campos, the foremost wheat-producing area in Castilla y León. Ávila and León, on the other hand, are the most mountainous provinces and have the smallest area available for wheat production. Provinces such as Valladolid and Palencia, which are big wheat producers, have fewer silos in the secondary network because most of their silos belong to the basic network. The location of the silos in the secondary network in the community of Castilla y León is illustrated in Figure 3.

The first silo built was a reception silo located in Villada, Palencia in 1949, and the last one built in 1981 was also a reception silo located in Alcañices, Zamora. The reception silos of the Castilla y León secondary network were built over a time span of more than 40 years, which was clustered into shorter periods of time according to typology within the different categories. The first silos to be built, in the 1950s, were of types A, B and C. Later, in the 1960s, silos of typologies E, F, GV, H and MC in the reception category, the SA typology in the seed selection category, the SG typology in the grain drying category and transition and reserve silos were built. In the 1970s, the MR reception typology was built. It should be noted that type D is the most abundant: 85 units were built over a period of almost 30 years (Table 3).

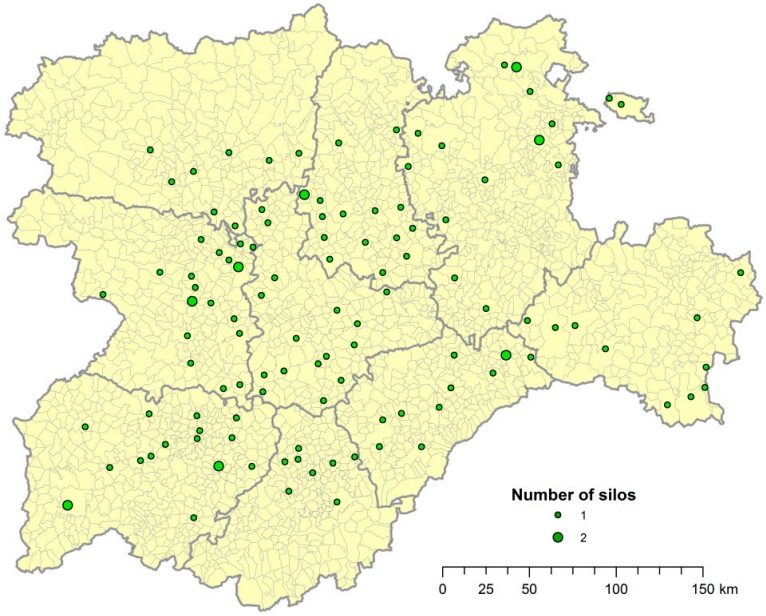


Figure 3. Sites of 123 vertical storage units (VSUs) or silos in the Castilla y León secondary network.

Table 3. Category, typology, number, construction period and capacity of secondary network silos in Castilla y León.

Category	Typology	No.	Year of Construction	Capacity (t)
Port	P	0		
Reception	A	4	1949–1961	750–3500
Reception	B	6	1954–1956	2200–2500
Reception	C	6	1952–1956	1650–3000
Reception	D	85	1953–1981	900–5150
Reception	E	3	1967–1971	4700
Reception	F	2	1960–1964	4000
Reception	GV	1	1966	1000
Reception	H	2	1966–1968	2800
Reception	J	1	1981	5000
Reception	MC	7	1966–1967	2500–5000
Reception	MR	2	1970–1973	2400–2630
Transition and reserve	TR	2	1961–1964	21,000–22,000
Transition macro-silos	T	0		
Seed selection	SV	0		
Seed selection	SA	1	1960	2300
Grain drying	SG	1	1967	1960
TOTAL		123		

Table 4. Statistics from of data on silos in the Castilla y León secondary storage network.

Category	Total	Min.	Max.	Mean	Silo Distribution in Percentages
Province	9				6.5% Ávila; 13.8% Burgos; 6.5% León; 13.0% Palencia; 13.8% Salamanca; 8.9% Segovia; 8.1% Soria; 13.0% Valladolid; 16.4% Zamora
Town/Village	115				
Year of construction		1949	1981	1962	

Table 4. *Cont.*

Category	Total	Min.	Max.	Mean	Silo Distribution in Percentages
Ownership					88.6% regional government; 11.4% municipality
Use					29.3% grain store; 22.0% reused, 48.7% without use
State of conservation					71.5% good condition, 17.9% fair condition, 7.3% unusable, 3.3% demolished/collapsed
Typology	13				
Capacity (t × 10^3)	340,560	750	22,000	2.768	
Ground plan					92.7% square; 2.4% T-shape; 1.6% cruciform; 3.3% L-shape
Roof shape					50.4% flat roof; 43.9% gable roof; 5.7% hip roof
Tower position					17.1% interior tower; 0.8% central tower; 4.9% corner tower; 3.3% side tower; 54.4% front tower; 19.5% front tower between two cells
No. cells		2	121	17	
Form of cells					89.4% square; 10.6% circular
Construction material					4.9% concrete block; 87.0% reinforced brick; 0.8% reinforced concrete; 7.3% sheet steel
Position rows cell					11.4% cells raised off ground storey floor; 14.6% cells resting directly on ground storey floor; 74.0% rows alternately resting on and raised off ground storey floor.
Machinery capacity (t/h) Lorry		11	100	31	
Machinery capacity (t/h) Railway		62	62	62	
Lorry weighbridge (t)		20	50	46	
Railway weighbridge (t)		90	90	90	
Railway					15.5% yes; 84.5% no

At this time, 89% of the 123 secondary network silos in Castilla y León are in the hands of the regional government. Of these, 51% are in disuse, with regional departments storing furniture and similar items in only a few. The electric power supply has been discontinued in most to lower upkeep costs. A further 33% is leased to farm cooperatives or private storage firms that use them to store grain or as pick-up sites for onward shipment (the most active is COBADU, a cooperative in the province of Zamora that has leased 10 silos for such purposes) (Figure 4). The remaining 17 silos are assigned to municipal governments (11), public entities such as the Instituto Tecnológico Agrario de Castilla y León (agricultural technology institute, Spanish initials ITACyL) or local farm councils. This means that almost half of the silos (49%) are without use, and around 30% are still used as grain stores.

Just 11% of the silos no longer belong to the regional government (Table 4). Most have been returned to the municipal governments that initially provided the land for their construction. Although the most common present use is multi-purpose storage, municipal governments have instituted many other uses. Medinaceli, in the province of Soria, and Puebla de Arganzón in Burgos, have converted them into gyms, whilst the silo at Ledesma in the province of Salamanca serves as a funeral home, and Vitigudino's former silo is now a Red Cross station. At Langa de Duero, also in the province of Soria, the local fire

department parks its vehicles in the silo; at Paredes de Nava, in Palencia, the silo is a garage for farm machinery and at Pozáldez, in Valladolid, the yard outside the silo is a recycling centre. Another frequent use is to house television booster stations, mobile telephone masts or even River Ebro Management Board flood sirens, such as at Monteagudo de las Vicarias, Soria. Primarily in the province of Salamanca, nests for the lesser kestrel (Falco naumanni), a small insectivorous falcon, have been placed on silo roofs as a conservation measure [31]. Some silos, such as at Benavente, province of León, and Aranda de Duero, Burgos, were demolished to favour urban development. Others were blown down (MS type silo at Ampudia, Palencia) or as at Quintana del Puente, Palencia, were expropriated to build the high-speed train line. As silos were very soundly built, despite the lack of upkeep over the last two decades, 72% are in good condition, i.e., with no significant construction defects, although the mechanical facilities are in a poor state of repair. Another 18% are in fair condition (leaks, water in the elevator shaft, electric wiring lost to burglary, perimeter fencing broken, loose roof tiles), whilst 7% are badly damaged or even in ruins. The silos in this third group either have steel cells (types MC and MR) or were built with high alumina cement that has compromised their structural strength (Boceguillas, Segovia) (Figure 5).

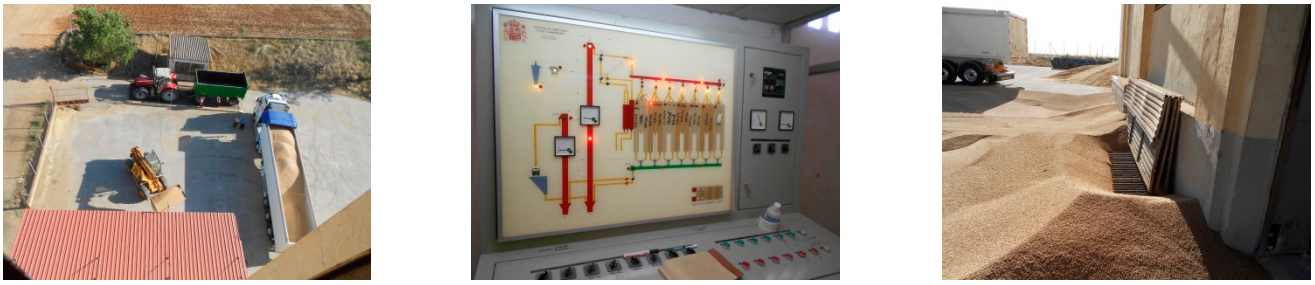


Figure 4. Typical secondary network silo usage: COBADU pick-up and storage site at Manganeses de la Lampreana, Zamora. Detail of pick-up site, control panel and hopper.



(**a**) (**b**)

Figure 5. *Cont.*



(**c**) (**d**)

Figure 5. The state of conservation of the secondary network silos in Castilla y León is very diverse: the silos located at Tordesillas, Valladolid (**a**), and Alcañices, Zamora (**b**), are well preserved, whilst other silos present serious structural deterioration because of leaky roofs (silo at Nava del Rey, Valladolid: **c**) or lack of vertical enclosure (silo at Piedrahita de Castro, Zamora: **d**).

3.3. Construction Type

All categories except port and transition macro-silos established by the SNT, later the Servicio Nacional de Productos Agrarios (national farm product service, Spanish initials SENPA) [32] and subsequently FEGA [13] are present in Castilla y León's secondary network. All typologies are represented as well except for P, T and SV (Table 3). All the transition macro-silos were assigned to the basic network on the grounds of their higher capacity and more recent construction [6,28]. Approximately half of the transition and reserve silos were included in the secondary network, possibly the ones that due to urban growth were absorbed into the city core where, as in the case of other agrifood industries, their use could inconvenience residents [33]. The cities of Burgos and Palencia exemplify this trend (Figure 6).

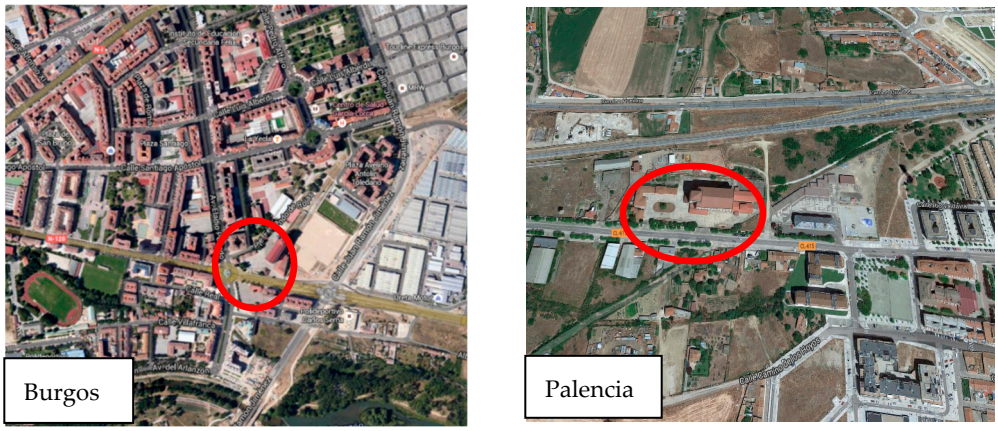


Figure 6. Silos located within the urban core at Burgos (**left**) and Palencia (**right**).

Most of the reception silos (types A, B, C, D, E, F, GV, H, J, MC and MR) were classified as secondary network structures, for they are older, smaller and fitted with less modern

machinery [28,34]. In some typologies (F and MC), almost all the silos form part of the secondary network. The presence of a single structure of each type in the basic network appears to have had more of a token than storage significance [6]. The small capacity of most seed selection (SV and SA) and grain-drying (SG) silos determined their classification in the secondary network [34]. Table 3 shows that capacity is lowest in the earliest types of reception silos, which were built mainly in the 1950s. Capacity in the 85 type D silos, erected over a span of almost 30 years, was observed to range from 900 to over 5000 t. Later types (E, F, H, J) almost all featured greater capacity, many accommodating close to 5000 t, whilst capacity in the one GV type silo was a much lower 1000 t. The explanation lies in the fact that type GV silos were built where the wheat volume was insufficient to justify a larger silo [6]. Metal circular (MC) and rectangular cell (MR) silos were built in very specific years and had very similar capacities, because they were built by private companies [24]. The two transition and reserve silos had a much larger capacity than any of the preceding types, inasmuch as they were designed to store the wheat transferred from the reception silos [12,34]. Only one seed selection silo and one grain-drying silo were found, each with a storage capacity of around 2000 t, their purpose being not to store but to select or dry wheat [35]. Reception silos worked at a turnover ratio of 3 to 4, and transition and reserve silos and transition macro-silos worked at a turnover ratio of 5 to 10. As the mean annual wheat production in Castilla y León is 3 to 3.5 million t, the storage capacity of the silo network (basic and secondary) would have been on the low side. Nevertheless, it should be borne in mind that the network was sized to suit mid-twentieth century grain production, which was lower. In terms of construction characteristics, square-plan silos were found to account for 93% of the total, with flat roofs in 50%, gabled roofs in 44% and some hip roofs [7]. The position of the tower varied greatly, depending on the type of silo, although more than half of the silos (54%) had a front-facing tower. Most wheat storage cells (89%) were square, and 87% were made of reinforced brick. Cell rows were observed to vary by silo type, although in 74% of the silos, rows were set alternately resting on and raised off ground storey floor. The number of cells ranged widely, depending on storage capacity: one silo in Ampudia, Palencia, had just two metal circular (MR) cells, whilst the transition and reserve (TR) silo in Burgos had 121 cells. The mean number of cells per silo was 17 [6].

3.4. Technological Facilities

The installed machinery capacity ranged between 11 and 70 t/h. Capacity was small or very small in all but five of the silos, which were fitted with facilities able to operate at 100 t/h. The mean was 31 t/h. Of the 123 silos visited, only one, the TR (transit and reserve) silo at Palencia, had the capacity to receive grain and ship it out by rail at the rate of 62 t/h. A very similar situation was found for weighbridges: the lorry weighbridge capacity was from 20 to 50 t, and there was only one railway weighbridge, at the Palencia silo, which was capable of handling 90 t. Just 15.5% of the silos had railway infrastructure with sidings where the cars stood as the grain was dispatched. If intended for sale, the grain was weighed at destination, but it was not if it was merely shipped to a larger (generally a type TR) silo.

3.5. Socioeconomic Aspects and Possible Reuse of Silos

The silos of the secondary network are more numerous and, given their location in smaller towns, they are characteristic of the rural landscape of Castilla y León (Supplementary Materials Table S1). They are often taller than the village church towers, with which they appear to engage in dynamic architectural dialogue [36]. According to Martínez [37], although their vitality has waned with time, their presence has not faded and they continue to proudly stand as a characteristic element of Spain's rural landscape. Whilst other agroindustrial buildings with essentially open ground plans are readily reusable, silos are not. A number of authors have noted that silos are difficult to use other than for the purposes for which they were built because their rigid division into vertical cells with small net floor areas makes them highly specialised spaces [9,26,38]. As a result, the only parts of silos

that are generally reused are the ground floor and/or attached warehouses. Substantial investments have been made in some silos, such as the 2,897,410 euros spent to convert the rear of Segovia's silo into the ITACyL's Aquaculture Centre or the sums invested to house the Innocencio Bocanegra International Radio Communications Museum in the silo at Belorado in the province of Burgos [7,35] (Figure 7). Plans are on the drawing board to convert others into community centres, such as at Torquemada, Palencia. Municipal governments in other regions have also converted their silos: in 2003, the silo returned to Alcalá la Real, Jaén, was remade into the village's youth centre [39]. In 2017, the bay adjacent to the silo at Almagro, Ciudad Real, was converted into a multi-purpose building. After a private sector investment of 1.4 million euros, the type D silo at Bello, Teruel was remodelled into a rock climbing gym and the upper storey was transformed into an observatory (Figure 7). Many silos outside Spain have also been repurposed. At Moscow, Idaho, a silo known as 'Tank 41' is now a theatre [40]. 'Silo City' at Buffalo, New York, in turn, is a cultural park circling three vacant grain elevators, amongst the first ever erected in the United States, in a once vigorous industrial area that later sank into decline [41]. A former silo at Oslo, Norway, is now GrünerlØkka student quarters [9].



Figure 7. Examples of reused silos in Spain (from top to bottom and left to right): Aquaculture Centre in the Segovia' silo; museum in Belorado, Burgos; silo at Bello, Teruel, exterior and interior.

After the recent crisis, Spain's authorities are logically unwilling to invest large sums to convert silos into theatres, lookouts or similar, such as at Pozoblanco, Córdoba, or Fuentes de Andalucía, Seville, for even when co-funded by European agencies, such projects entail high costs for taxpayers [35,42,43]. At the same time, however, the growth in the country's economic and cultural standard of living, the availability of more leisure time and the improvement in transportation and communications have raised the demand for cultural services [44]. Ethnographic and industrial tourism are becoming more and more popular. Abandoned structures such as cereal and olive oil mills, wine cellars, dams and so on have been converted into tourist attractions [45], in the realisation that such buildings are elements of the agroindustrial and cultural heritage of historic and social value rather than useless eyesores [46–49]. Some authors have even established GIS techniques to use historical and geographic data to analyse and catalogue vernacular architecture [50,51]. In addition, with heightened social awareness, more allegedly cost-effective solutions involving demolishing and replacing these structures are being disregarded for what they

would mean in terms of destruction of the national heritage and generation of a larger carbon footprint due to higher energy costs, raw material consumption and GHG emissions [9,52–55]. The sustainable and responsible repurposing entailed in silo rehabilitation, in contrast, would benefit both human beings and the surrounding environment [56–59].

The secondary network structures in Castilla y León are located primarily (89%) in villages with populations of under 10,000. Their reuse would therefore afford such places social, cultural and economic benefits as well as forward-looking opportunities [45]. On the basis of socioeconomic data, the towns and villages with silos were classified into three groups with a view to raising public funds to ensure silo viability over time (Supplementary Materials Table S2). The first 21 have populations of over 5000, and seven are provincial capitals with over 50,000 inhabitants. Their populations are either stable or growing, and they are readily accessible and have both a substantial tertiary sector and an acceptable municipal budget (although in some cases they are highly indebted). Mateo [56] contends that some manner of public investment could be recommended to a first group of towns/villages (population > 5000) (primarily in tourist, cultural, sports, retail, administrative or public residential activities). In a second group, consisting of 94 villages with under 5000 inhabitants (61 of which have a declining or steeply declining population of under 1000), small public investments with low maintenance costs might favour rural development. No public investment in silos is recommended in Mateo's third category, comprising 40 poorly accessible villages with fewer than 500 inhabitants apiece, negative or very negative demographics and an economy focused exclusively on the primary sector. Such places may nonetheless be open to private investment (such as at Bello, Teruel).

The examples of reuse to integrate silos into the rural environment in Castilla y León were found in the first or second group of towns/villages with acceptable socioeconomic indicators. This proves the usefulness of the proposed methodology.

4. Conclusions

A methodology for the characterisation of the silos belonging to Spain's National Network of Silos and Granaries was used. This was useful to inventory the secondary network silos located in Castilla y León and to evaluate other reuse alternatives. For over 50 years, wheat was stored in Spain's National Network of Silos and Granaries. Use declined drastically with the country's accession to the EEC, and the network was divided into basic and secondary divisions, the responsibility for which was ultimately devolved to the autonomous regions. The more numerous secondary network storage units consist primarily in silos that have come to form part of the rural landscape in villages across the country. This paper describes the general and constructive features and technological facilities of the secondary network silos. Type D structures prevail, accounting for 85 of the 123 network silos still standing. The many variations on that scheme were built between 1953 and 1981. They are characterised by their small capacities for storage (barely 5000 t, with just two exceptions), reception and dispatch. At this time, 87% of the 123 secondary network silos in Castilla y León are in the hands of the regional government. Just under one-third (33.0%) of these are still in use, leased to farm cooperatives or private storage companies to store wheat or barley. The silos no longer owned by the regional government have been returned to the municipalities that originally provided the land for their construction. Although the most common present use is multi-purpose storage, municipal governments have instituted many other uses. The vast majority of the silos, 72%, is in good condition despite 20 years of abandonment, whereas 18% are in only a fair state of repair and 7% are badly deteriorated or even in ruins. A number of authors have noted that silos are difficult to use other than for the purposes for which they were built, given their rigid division into vertical cells, but the ground floor and/or attached buildings can always be used. Examples of reuse to integrate silos into their rural environment, primarily to house tourist or cultural facilities, can be found in Castilla y León and other regions as well as outside Spain, although often at a very high investment cost. Whilst

public investment may be beneficial in villages with populations of over 5000, promising demographics, good connectivity and a buoyant service sector, it is not recommended in villages with populations of under 500. The methodology proposed in this study can be applied to characterise silo networks in other regions of interest. Future work might focus on proposals for rehabilitating the secondary network silos with the greatest potential for reuse in Castilla y León and integrating unused silos into the landscape.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15043755/s1, Table S1: Data on vertical storage units (VSUs) or silos in the Castilla y León secondary storage network; Table S2: Indicators for 115 villages in Castilla y León, sites of 123 secondary network vertical storage units (VSU) or silos.

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References

1. Banham, R. *A Concrete Atlantis. US Building and European Modern Architecture*; MIT Press: Cambridge, MA, USA, 1989.
2. Salido, J. El almacenamiento de cereal en los establecimientos rurales hispanorromanos. In *Horrea d'Hispanie et de la Méditerranée Romaine*; Arce, J., Goffaux, B., Eds.; Casa Velazquez: Madrid, Spain, 2011; pp. 127–142.
3. Bohigas, O. *Modernidad en la Arquitectura de la España Republicana*; Tusquets: Madrid, Spain, 1998.
4. Martínez, A. *"Grandes Molinos Vascos", un Hito en la Arquitectura Industrial Bilbaína*; Diputación Foral de Bizkaia: Bilbao, Spain, 2004.
5. Villar, J.E. *Grandes Molinos Vascos S.A.; Diputación Foral de Bizkaia Departamento de Cultura*; Colección Patrimonio Industrial de Bizkaia: Bilbao, Spain, 2005.
6. Azcárate, C.A. *Catedrales Olvidadas. La Red Nacional de Silos en España 1949–1990*; Ministerio de Medio Ambiente y Medio Rural y Marino: Madrid, Spain, 2009.
7. Salamanca, D.; Mateo, C.; Moreno, M.; Rodríguez, L.; Alarcón, A. Red Nacional de Silos. Integración en la Realidad Urbana Andaluza y su Reutilización para Nuevas Tipologías. 45–50. Available online: http://www.juntadeandalucia.es/fomentoyvivienda/portal-web/web/areas/arquitectura/texto/9ccb71fc-8489-11e1-b3ef-6583fdb537d9 (accessed on 10 October 2022).
8. Cavero, M.L. *Ponencia Sobre la Red Nacional de Silos en España. Los Diversos Tipos de Silos y Sus Construcciones*; Ministerio de Agricultura, Servicio Nacional del Trigo: Madrid, Spain, 1959.
9. Salazar, A. *Del Trigo al Hombre. Rehabilitar el Silo. Trabajo Fin de Master. Máster en Intervención Sostenible en el Medio Construido*; Escuela Técnica Superior de Arquitectura del Vallès, Universidad politécnica de Cataluña: Barcelona, Spain, 2015.
10. SNT. *La Red Nacional de Silos*; Servicio Nacional del Trigo, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1947.
11. SNT. *Tipos de Silos y su Construcción*; Servicio Nacional del Trigo, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1950.
12. SNT. *Ponencia Sobre la Red Nacional de Silos en España. Los Diversos Tipos de Silos, su Construcción y Evolución*; Servicio Nacional del Trigo, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1959.
13. FEGA. *Estudio y Toma de Decisión de Las Unidades de Almacenamiento Que Han de Incluirse en la Red Básica y en la Red No Básica*; Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 2003.
14. SENPA. *Reordenación y Redimensionamiento de la Red de Silos del SENPA*; Servicio Nacional de Productos Agrarios, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1994.
15. BOE. Real Decreto 2/2000, de 7 de Enero, Sobre Traspaso a la Comunidad de Castilla y León de los Medios Adscritos a la Gestión Encomendada en Materia de Agricultura, Fondo Español de Garantía Agraria (FEGA). Available online: https://www.boe.es/boe/dias/2000/01/28/pdfs/A03810-03845.pdf (accessed on 10 October 2022).
16. García, A. La red nacional de silos y graneros en España. *Cuad. Amigos Mus. Osuna* **2016**, *18*, 153–161.
17. González, M.J.; Rodríguez, A. La decadencia de los silos en Tierra de Campos en la región de Castilla y León (España). *An. Geogr. Univ. Complut.* **2019**, *39*, 59–83. [CrossRef]

18. FEGA. Fondo Español de Garantia Agraria. Red de Almacenamiento. Available online: https://www.fega.gob.es/es/PwfGcp/eu/regulacion_mercados/almacenamiento_publico/Red_basica_de_almacenamiento/Red_basica_de_almacenamiento.jsp (accessed on 10 October 2022).
19. Amaral, L. Política e economía: O Estado Novo, os latifundiarios alentejanos e os antecedentes da EPAC. *Anal. Soc.* **1996**, *31*, 465–486.
20. Vaquero, M. Innovation in times of autarky: The construction of the wheat silos in Fascist Italy. *Fabrikart* **2011**, *10*, 264–277.
21. Mateo, C. Red nacional de silos y graneros. Integración en la realidad urbana contemporánea. *Rev. Lámpara* **2010**, *3*, 8–17. Available online: https://issuu.com/cdmdsn/docs/revista3 (accessed on 10 October 2022).
22. Garrido-Cifuentes, M.; Santiago-Zaragoza, J.M.; Lafuente-Bolivar, F.J. Silos, Reused Machine-Buildings: A Proposal for Its Transformation. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *245*, 082051. [CrossRef]
23. Benito, P. Patrimonio industrial y cultura del territorio. Boletín AGE 2002, 34, 213–227. *Boletín AGE* **2002**, *34*, 213–227.
24. Cano, M. Arqueólogos en la fábrica. Breve recorrido por la historiografía de la arqueología industrial. *SPAL Rev. Prehist. Arqueol. Univ. Sevilla* **2007**, *16*, 53–67. [CrossRef]
25. Mateo, C. Red Nacional de Silos y Graneros de España. In Proceedings of the 3rd Int Venue of the Agriculture and Food Productivion Section of TICCIH, Nogent-sur-Seine, France, 20–22 October 2011. Available online: http://www.patrimoineindustriel-apic.com/silo/5reseau%20national.pdf (accessed on 10 October 2022).
26. FEGA. *Informe Sobre Posibles Usos Alternativos de los Silos*; Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 2012.
27. Florido, A. Patrimonio histórico industrial de Gran Canaria. In Proceedings of the III Jornadas de Patrimonio Industrial Activo, Murcia, Spain, 15–16 November 2013.
28. Fernández-Fernández, M.V. Catalogación de las Unidades de Almacenamiento Vertical de Cereales de la Red Básica de Castilla y León, Propuesta de Una Nueva Clasificación y Posibilidades de Reutilización. Ph.D. Thesis, Universidad de León, León, Spain, 29 January 2016.
29. MAPAMA. Anuario de Estadística. Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, Gobierno de España. Available online: http://www.mapama.gob.es/es/estadistica/temas/publicaciones/anuario-de-estadistica/2016-avance/default.aspx?parte=3&capitulo=13&grupo=1&seccion=2 (accessed on 10 October 2022).
30. SNT. *Realizaciones del Servicio Nacional del Trigo en sus Primeros Veinticinco Años*; Servicio Nacional del Trigo, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1962.
31. GREFA. Proyecto Corredores para el Primilla. Grupo de Rehabilitación de la Fauna Autóctona y su Hábitat (GREFA). Available online: https://www.grefa.org/proyectosgrefa/corredores-para-el-primilla-%C2%B7-generando-biodiversidad.html (accessed on 10 October 2022).
32. SENPA. *Informe Sobre la Denominación de las Diferentes Unidades de Almacenamiento, Estado de las Mismas y Red de Comunicación*; Servicio Nacional de Productos Agrarios, Archivo General del Fondo Español de Garantía Agraria (FEGA): Madrid, Spain, 1973.
33. Fuentes, J.M.; López-Sánchez, M.; García, A.I.; Ayuga, F. Public abattoirs in Spain: History, construction characteristics and the possibility of their reuse. *J. Cult. Herit.* **2015**, *16*, 632–639. [CrossRef]
34. Moreno, A. Un análisis tecnológico sobre la red nacional de silos y graneros desde la ingeniería industrial en el ámbito agrario: ¿con qué maquinaria y cómo funcionaban? In Proceedings of the I Jornadas de Patrimonio Industrial Agrario: Silos a Debate, Badajoz, Spain, 26–28 September 2014.
35. Fernández-Fernández, M.V.; Marcelo, V.; Valenciano, J.B.; López-Díez, F.J. History, construction characteristics and possible reuse of Spain's network of silos and granaries. *Land Use Policy* **2017**, *63*, 298–311. [CrossRef]
36. Azcárate, C.A. Catedrales olvidadas, la Red Nacional de Silos. Agroindustria. Paisajes y patrimonio de la industria de la alimentación. In Proceedings of the IV Seminario Sobre Patrimonio Arquitectónico Industrial, Madrid, Spain, 15–17 February 2017; Available online: https://www.youtube.com/watch?v=gG2p8lnrRoY (accessed on 10 October 2022).
37. Martínez, S. Silos y Graneros de la Rioja, una historia bajo el hormigón. *Belezos Rev. Cult. Pop. Tradic. Rioja* **2012**, *20*, 46–52.
38. Giuliani, F.; De Falco, A.; Landi, S.; Bevilacqua, M.G.; Santini, L.; Pecori, S. Reusing grain silos from the 1930s in Italy. A multi-criteria decisión analysis for the case of Arezzo. *J. Cult. Herit.* **2018**, *29*, 145–159. [CrossRef]
39. Palomares, S. Recuperación de Silos. El caso de Alcalá la Real (Jaén). In Proceedings of the III Jornadas Andaluzas del Patrimonio Industrial y de la Obra Pública, Málaga, Spain, 23–25 October 2014.
40. Río, A.S.; Blanco, S. La tempestad en el silo: Reutilización de un almacén de grano para representaciones teatrales. In *Espacios Industriales Abandonados. Gestión del Patrimonio y Medio Ambiente*, 15th ed.; Colección: Los Ojos de la Memoria; INCUNA, CICEES, Eds.; Miguel A. Álvarez Areces: Gijón, Spain, 2015; pp. 433–440.
41. Campo, D. Historic Preservation in an Economic Void: Reviving Buffalo's Concrete Atlantis. *J. Plan. Hist.* **2016**, *15*, 314–345. [CrossRef]
42. JA. *Informe Final del Expediente POZ/2004/SIL Sobre la Actuación en el Silo de Pozoblanco Iniciado en 2004*; Junta de Andalucía, Consejería de Agricultura, Pesca y Desarrollo Rural: Sevilla, Spain, 2006.
43. JA. *Informe Final del Expediente FUE/2010/SIL Sobre la Actuación en el Silo de Fuentes de Andalucía Iniciado en 2010*; Junta de Andalucía, Consejería de Agricultura, Pesca y Desarrollo Rural: Sevilla, Spain, 2013.
44. Bedate, A.; Herrero, L.C.; Sanz, J.A. Economic valuation of the cultural heritage: Application to four case studies in Spain. *J. Cult. Herit.* **2004**, *5*, 101–111. [CrossRef]

45. Laumain, X.; López, A.; Moreno, J.; Sanchez, D. Turismo como desencadenante de la recuperación de patrimonio industrial. In Proceedings of the III Jornadas de Patrimonio Industrial Activo, Murcia, Spain, 15–16 November 2013.
46. Aguilar, I. Arquitectura industrial, testimonio de la era de la industrialización. *Bienes Cult. Rev. Inst. Patrim. Histórico Español* **2007**, *7*, 71–101.
47. Sánchez, D. El patrimonio industrial arquitectónico, el gran olvidado del siglo XX. In Proceedings of the CAH 20th C International Conference Intervention Approaches for the 20th Century, Madrid, Spain, 14–16 June 2011.
48. Benito, P. Territorio, paisaje y herencia industrial: Debates y acciones en el contexto europeo. *Doc. D'anàlisi Geogràfica* **2012**, *58*, 443–457. [CrossRef]
49. Blagojević, M.R.; Tufegdźić, A. The new technology era requirements and sustainable approach to industrial heritage renewal. *Energy Build.* **2016**, *115*, 148–153. [CrossRef]
50. Hernández, J.; García, L.; Ayuga, F. Integration methodologies for visual impact assessment of rural buildings by geographic information systems. *Biosyst. Eng.* **2004**, *88*, 255–263. [CrossRef]
51. Ford, M.; Griffiths, R.; Watson, L. The Sanford Inventory of Earth Buildings constructed using a GIS. *Build. Environ.* **2005**, *40*, 964–972. [CrossRef]
52. Fuentes, J.M. Methodological bases for documenting and reusing vernacular farm architecture. *J. Cult. Herit.* **2010**, *11*, 119–129. [CrossRef]
53. García, A.I.; Ayuga, F. Reuse of abandoned buildings and the rural landscape: The situation in Spain. *ASABE* **2007**, *50*, 1383–1394. [CrossRef]
54. Fuentes, J.M.; Gallego, E.; García, A.I.; Ayuga, F. New uses for old traditional farm buildings: The case of the underground wine cellars in Spain. *Land Use Policy* **2010**, *27*, 738–748. [CrossRef]
55. Cano, M.; Garzón, E.; Sanchez-Soto, P.J. Historic preservation, GIS, & rural development: The case of Almería province, Spain. *Appl. Geogr.* **2013**, *42*, 34–47. [CrossRef]
56. Mateo, C. Grupo de Investigación para la Defensa de la Red Nacional de Silos y Graneros (1944–1990). Available online: https://www.youtube.com/watch?v=yMlbLoHK3SI (accessed on 10 October 2022).
57. Bocanegra, A. Proyecto silos: Difusión, ocupación y rehabilitación del patrimonio industrial. In Proceedings of the III Jornadas de Patrimonio Industrial Activo, Murcia, Spain, 15–16 November 2013.
58. Castañeda, C. La reutilización del patrimonio industrial como recurso generador de nuevos usos en el tejido urbano: El caso de las fábricas de tabacos en España. In Proceedings of the III Jornadas de Patrimonio Industrial Activo, Murcia, Spain, 15–16 November 2013.
59. Bocanegra, A. Proyecto silos: Difusión y revitalización del patrimonio industrial abandonado. *Panor. PH Inst. Andal. Patrim. Histórico* **2016**, *89*, 18–19. [CrossRef]

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