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Steam engines in agricultural use in Croatia and Slavonia during the Austro-Hungarian Monarchy

Dampfmaschinen in der Landwirtschaft in Kroatien und Slawonien während der Österreichisch-Ungarischen Monarchie

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Summary

Industrial revolution and modernization of agriculture in Croatia and Slavonia began in mid-19th century and evolved at a slower pace compared to the other countries of the Austrian Empire. The main reasons were lack of capital, shortage of good river- and land traffic routes, slowness in the construction of railways, slowness in the introduction of steam engines, lack of skilled workforce and extensive farming. The second agricultural crisis in Europe, which lasted from 1873 until 1895, motivated large holdings in Croatia and Slavonia to introduce steam engines and machines for the purpose of rationalization of agricultural production. Locomobiles were mostly represented on holdings with over 575.5 ha. The then country of Slavonia, as an eminently agrarian region and the main source of wheat was leader in the use of steam engines, steam ploughs and steam-powered machines in agriculture. The locomobile was used in agriculture until the mid-20th century and was discontinued with the growing use of tractors with internal combustion engine and the use of combine harvesters. Until 1918, Croatian lands were a part of the Austro-Hungarian Monarchy.

Keywords: industrial revolution, locomobile, steam plough, steam-powered threshing machine

Zusammenfassung

Die industrielle Revolution und Modernisierung der Landwirtschaft in Kroatien und Slawonien begann Mitte des 19. Jahrhunderts und entwickelte sich im Vergleich zu anderen Ländern des Kaisertums Österreich langsamer. Der Hauptgrund dafür war der Mangel an Kapital, der Mangel an guten Land- und Flussverkehrswegen, die Langsamkeit beim Bau von Eisenbahnen, die Langsamkeit bei der Einführung von Dampfmaschinen, der Mangel an qualifizierten Arbeitskräften und die extensive Landwirtschaft. Die zweite Agrarkrise in Europa, die von 1873 bis 1895 andauerte, veranlasste große landwirtschaftliche Betriebe in Kroatien und Slawonien, Dampfmaschinen einzuführen, um die landwirtschaftliche Produktion zu rationalisieren. Die Lokomobile war überwiegend auf Landgütern mit über 575,5 ha vertreten. Damaliges Slawonien, als überaus agrarische Region und Hauptweizenquelle, war führend im Einsatz von Dampfmaschinen, Dampfpflügen und dampfbetriebenen Maschinen in der Landwirtschaft. Die Lokomobile wurde bis Mitte des 20. Jahrhunderts in der Landwirtschaft eingesetzt. Mit der zunehmenden Verwendung von Traktoren mit Verbrennungsmotor und dem Einsatz von Mähdreschern geriet sie schließlich außer Betrieb. Bis 1918 waren die kroatischen Länder Teil der Österreichisch-Ungarischen Monarchie.

Schlagworte: Industrielle Revolution, Lokomobile, Dampfpflug, Dampfdreschmaschine

1. Introduction

In agriculture, the human and animal power, as well as the power of wind and water began to be substituted with the power of steam by the end of the 18th century in England. At that time, agriculture was the leading sector of economy and one which, with its ever-growing share in transport and with the development of steam engines and steam-powered machines, contributed to the onset of industrial revolution. Between 1816 and 1861 the productivity in agriculture rose by 78% and further development of this sector of economy was more and more dependent on machine industry and chemical fertilizers, all of which led to an industrialization of agriculture (Defilippis, 2005). At the beginning, steam engines were massive and stationary. They were too expensive for use on medium-size farms. With the development of semi-portable (semi-stationary) and portable steam engines, and the production of cheaper steam engines, the road was opened for their more extensive use in agriculture.

In mid-19th century, Croatia and Slavonia found itself in a structural crisis with the transition from feudal into capitalist economy, and it had to face all the problems related to market, money, railways, credits and so on (Bićanić, 1948). In the agriculture of Croatia and Slavonia, the traditional, extensive method of plant production and cattle rearing was predominant. In the modernization of agriculture, the lead was taken by large holdings, which had skilled workforce, introduced special crop rotation and better soil fertilization, and in addition, cultivated the soil and applied modern agricultural tools and machines, including steam engines.

Until 1867, Croatia and Slavonia were part of the Austrian Empire, following which, until 1918, they became part of the Austro-Hungarian Monarchy. Croatia and Slavonia were divided into eight counties and covered approximately 67% of the present-day territory of the Republic of Croatia. We should also note that around 36% of the total area of the then Srijem County is today part of the Republic of Croatia. Data in Tables 1, 2 and 3 are based on the first Census of holdings and cattle of 31st December 1895, published in the Statistical Yearbook from 1905. Areas of holdings were expressed in a measurement unit called "jutro", converted into hectares (1 "jutro" = 0.575464 hectares). The power of steam engines in original literature was expressed in horsepower, and in the paper, this was converted to kilowatts. For steam engines listed for the period after 1876, when the metric system became mandatory in Austro-Hungarian

Monarchy, the power was converted from metric horsepower into kilowatts (1 HP = 0.73549875 kW). For steam engines listed and produced before 1876, the power was converted from mechanical (imperial) horsepower into kilowatts (1 iHP = 0.745699872 kW). Literature from the 19th century was also used as a source. Most frequently quoted is "Gospodarski list" (Economical Bulletin), the Croatian agronomic journal, which was launched in 1842 as a news outlet of the Croatian-Slavonian Economic Society in Zagreb. Since 1855 to the present day, it is called the Gospodarski list.

2. Industrial revolution on the territories of the present-day Croatia

2.1. Beginnings of the industrial revolution

The process of industrialization and the construction of railways as a basis for the development and modernization of agriculture started in Croatia at a later date and took longer than in the developed countries of Europe. In England, industrial revolution covered a period of fifty years, from 1780 until 1830. Other European countries, including Austria and south-eastern Europe caught up with this trend only gradually, accepting and applying new inventions at a slower pace. Due to the complexity of this process, it is difficult to pinpoint when exactly the industrial revolution started in any given country, but we can assume that in Germany and Austria, it lasted from the 1830s until the 1870s (Bićanić, 1948). Industrial revolution in Croatia lagged behind significantly and its effects in production until the year 1848 were feeble (Bićanić, 1948). It was only in the period from 1850 until 1875 that it gained momentum. In the second half of the 19th century, Croatia was a predominantly peasant country. According to Zoričić (1896), in Croatia and Slavonia in the year 1890, a total of 84.6% of the population lived off the land, and in Dalmatia, the share of the population was 86.1%. After the abolishment of serfdom in 1848, there began a process of gradual removal of feudal relations and it took several decades for the consolidation and modernization of agriculture. After the conclusion of the Austro-Hungarian agreement in 1867, the perspectives for a more intensive implementation of industrialization in Croatia and Slavonia were opened. This was due to a greater access of capital, construction of modern roads and the strengthening of urban centers (Vranješ-Soljan, 1998). Industrial revolu-

Table 1. Area of holdings in Croatia and Slavonia in 1895 (Statistical Yearbook of the Kingdom of Croatia and Slavonia I, 1905)

Tabelle 1. Fläche der Agrarbetriebe in Kroatien und Slawonien im Jahr 1895 (Statistisches Jahrbuch des Königreichs von Kroatien und Slawonien I, 1905)

County	Area of holdings ('000 ha and %)				
	Total	Arable land and vegetable garden	% ¹	Forest	% ¹
Lika-Krbava	163	90	55.36	4	2.46
Modruš-Rijeka	250	100	39.80	57	22.92
Zagreb	497	233	46.93	121	24.42
Varaždin	221	90	40.75	72	32.60
Bjelovar-Križevci	313	196	62.68	33	10.64
Požega ³	322	157	48.67	93	29.04
Virovitica ³	436	202	46.38	155	35.58
Srijem ³	481	337	70.01	43	8.96
Total	2,683	1,405	52.36	580 ²	21.62

¹Percentage of the total area of holdings in the county.²Amounts are rounded to '000 ha, they do not have to match the sum of values in the columns exactly.³Slavonian counties

tion was accelerated with the accessibility of foreign capital, which sought to channel its way toward profit-making areas of economy, such as exploitation of forests and the export of flour. In the Habsburg Monarchy, the leading role in the application of steam engines in agriculture was taken by Austrian lands, especially Bohemia and Moravia, then the inner territory of Hungary, with the then Croatia and Slavonia trailing behind (Pavličević, 1989).

2.2. The first steam engines

The first steam engine in Croatia and this part of Europe was purchased in 1833 by the paper factory Smith & Meynier in Rijeka (Grgurić, 2007). Until 1938, this factory had three steam engines, although its needs for power were primarily met by the exploitation of water energy. At the beginning, steam engines were introduced into production as a substitute for water power, in places where the latter was insufficient, or would imply forbidding costs. The use of steam engines in agriculture closely reflected the developmental stage of and individual farm, region or country as a whole. This is also true of processing the industrial products and the beginnings of food industry (Pavličević, 1989). In the first phase of industrialization, mostly the steam-powered mills were represented, while a growth of wood-processing industry and sugar beet processing was also in evidence. Industrial processing of sugar beet by the use of a steam engine began in Slavonia in Čepin in the

year 1836, and in 1846, the sugar refinery was established in Virovitica (Karaman, 1974a). The first known steam-powered mill was in the pasta factory in Ponsal in Rijeka, where it was introduced in 1845 (Karaman, 1974b). It was followed by the steam-powered mill in Korod near Vukovar in 1846 (Galović, 2000). Construction of steam-powered sawmills began in 1849 in the Gorski Kotar area in Prezid, and in Slavonia, it began in Krivaja near Orahovica in 1858 (Ištvančić et al., 2008). With the adoption of steam power in sawmills, the export of wood and exploitation of forests in Croatia gained momentum in the second half of the 19th century. Until 1854, only fifteen steam engines were in evidence and the majority of industrial plants were established in the 1860s and the beginning of 1870s (Galović, 2000). Bićanić (1948) states that in the Austrian Empire in 1851, there were 647 steam engines (6,338.4 kW / 8,500 iHP). In Croatia, by comparison, in 1857 this number stood at 15 (151.4 kW / 203 iHP) (Bićanić, 1948). According to the Croatian Technical Encyclopedia, until 1864 in Croatia there were 39 steam engines, half of which were used on agrarian holdings and foodstuff factories. Their total power was 519.0 kW (696 iHP).

2.3. Roads and the beginning of railways

For the upgrading of agriculture, it was necessary to construct roads, waterways and railways, which serve to broaden the market and enable a better utilization of the existing

Table 2. Area and number of holdings with over 575.5 hectares in Croatia and Slavonia in 1895 (Statistical Yearbook of the Kingdom of Croatia and Slavonia I, 1905)

Tabelle 2. Fläche und Anzahl der Agrarbetriebe mit über 575,5 Hektar in Kroatien und Slawonien im Jahr 1895 (Statistisches Jahrbuch des Königreichs von Kroatien und Slawonien I, 1905)

County	Area and number of holdings > 575.7 ha ('000 ha / %)						Nos. > 575.5 ha
	Area	% ¹	Arable land and vegetable garden	% ²	Forest	% ²	
Lika-Krbava	-	-	-	-	-	-	-
Modruš-Rijeka	48	19.3	0.25	0.5	45	93.6	6
Zagreb	75	15.1	13	16.9	44	58.3	44
Varaždin	35	16.0	9	26.7	20	56.2	30
Bjelovar-Križevci	24	7.7	4	15.6	16	65.4	11
Požega ³	94	29.1	7	7.8	82	87.1	14
Virovitica ³	245	56.2	54	22.0	153	62.2	72
Srijem ³	81	16.9	25	30.7	40	49.5	32
Total	603 ⁴	22.5	112	18.6	399 ⁴	66.2	209

¹Percentage of the total area of holdings in the county (Table 1)²Percentage of the total area of holdings > 575.5 ha in the county³Slavonian counties⁴Amounts are rounded to '000 ha; they do not have to match the sum of values in the columns exactly.

agricultural potential. German cameralist Johann Heinrich Gottlob von Justi (18 century) had a marked influence on the creation of Austrian economic policies of modernization, which were more oriented towards the Pannonian plain (food) and the Adriatic Sea (foreign trade). His greatest merit was in stressing that the construction of roads and waterways was crucial for the upgrading of agriculture, whereby a broadening of the market for agricultural products is being achieved (Stipetić, 1986). Since 1770, a vigorous wheat trade from the large estates in Slavonia and Baranja towards Austrian countries began (Mirković, 1958). The goods were transported by rivers or on horses, mules and donkeys, using wagons if the roads were adequate, such as the Jozefina road towards Senj, and Karolina and Luzijana roads toward Rijeka. Industrial revolution in Croatia lasted until the end of the 19th century. This was partly due to the slow construction of railways, especially those linking the Danube Region with the Adriatic Sea, specifically the ports of Rijeka and Senj. Under those circumstances, the development of internal market was also slow. The lack of railways and good roads obstructed trade and export of products, which caused a plummeting of prices and consequently lack of cash, which in turn limited the investments in agrarian production (Pavličević, 1989). Large holdings depended on a cheap and fast transport of agricultural products and we can observe a marked role

of landowners in the initiatives to build railways (Karaman, 1974b). The first railway track was built in 1860 in Međimurje. The track connected localities of Kotoriba and Donji Kraljevec with the town of Čakovec, from where it continued on towards Slovenia, linking Budapest with the existing railway track Vienna – Trieste (Croatian Technical Encyclopaedia). Subsequently, in 1862, the track Sisak – Zagreb – Zidani Most was built, as the first railway track in Croatia and Slavonia. This track was 127.58 km long, and stretched all the way to the Sava port in Galdovo (Bunijevac, 2012). Having gained the connection to the Vienna – Graz – Zidani Most – Ljubljana – Trieste railway track, a more vigorous development of economy in Zagreb and Sisak occurred, notably the opening of production plants and other commercial facilities. However, in spite of some initial successes, Croatia continued to lag significantly behind most other countries within the Austro-Hungarian Monarchy (Pavličević, 1989). The commissioner of the government in Vienna Baron Hohenbruck and agricultural advisor Dr. Pabst concluded that for the advancement of economy in Croatia and Slavonia, it is necessary, among other, to build a railway track as soon as possible that would link Slavonia with the Adriatic sea, continue with the regulation of Sava and Drava rivers, making them fit for shipping and build the most necessary roads (Gospodarski list, No. 5, 1865).

Table 3. Number of steam engines, steam-powered machines and steam ploughs on holdings with over 0.6 hectares in Croatia and Slavonia in 1895, including area and number of holdings (Statistical Yearbook of the Kingdom of Croatia and Slavonia I, 1905)

Tabelle 3. Anzahl der Dampfmaschinen, Dampfmotoren und Dampfpflüge auf landwirtschaftlichen Betrieben mit mehr als 0,6 Hektar Fläche in Kroatien und Slawonien im Jahr 1895, einschließlich Fläche und Anzahl der landwirtschaftlichen Betriebe (Statistisches Jahrbuch des Königreichs von Kroatien und Slawonien I, 1905)

County	SM ¹	The size of holdings in ha and in "jutro" ²					Total
		> 0.6–11.5	> 11.5–57.5	> 57.5–115.1	> 115.1–575.5	> 575.5	
		> 1–20	> 20–100	> 100–200	> 200–1000	> 1000	
Lika-Krb.	-	-	-	-	-	-	-
Modruš-Rijeka	LM	-	-	-	-	1	1
	TR	1	1	-	1	1	4
	OM	1	1	-	-	-	2
Zagreb	LM	-	-	-	7	17	24
	TR	2	1	1	5	16	25
	OM	-	-	-	3	-	3
Varaždin	LM	-	-	-	6	18	24
	TR	-	-	-	8	17	25
	OM	-	-	-	-	1	1
Bjelovar-Križevci	LM	1	9	1	4	6	21
	TR	8	11	-	6	8	34
	SP	1	2	-	2	-	5
	OM	-	-	-	1	-	1
Požega³	LM	5	3	2	13	11	34
	TR	10	5	2	7	8	32
	OM	2	1	6	-	9	18
Virovitica³	LM	1	10	17	34	107	169
	TR	12	70	12	23	80	197
	SP	-	-	-	-	1	1
	OM	14	42	-	1	7	64
Srijem³	LM	8	48	37	33	52	178
	TR	28	144	28	26	46	272
	SP	-	11	-	-	3	14
	OM	12	39	1	-	10	62
Total	LM	15	70	57	97	212	451
	TR	61	233	43	76	176	589
	SP	1	13	-	2	4	20
	OM	29	83	7	5	26	151
Area and number of holdings > 0.6 ha ('000 ha)							
Total		1,326	601	42	98	603	2,669 ⁴
Arable land		792	374	25	43	111	1,345
Forest		98	46	7	29	399	580 ⁴
Nos.		318,945	33,433	550	380	209	353,517

¹Steam engines, steam-powered machines and steam ploughs: LM – locomobile, SP – steam plough, TR – steam-powered threshing machine, OM – other steam machinery²1 "jutro" being equal to 0.575464 hectares³Slavonian counties⁴Amounts are rounded to '000 ha, they do not have to match the sum of values in the rows exactly.

3. Steam engines and steam-powered machines on holdings

3.1. Initial period and the second agrarian crisis

Immediately upon the abolishment of serfdom in Croatia and Slavonia in 1848, there occurred a lack of manpower. Thus, the sugar refinery in Čepin and the tobacco factory in Varaždin ceased to work (Bičanić, 1948). Additional problems were lack of seasonal workforce and the issue of wages in agriculture (Gospodarski list No. 44, 1856). One of the proposed solutions was the introduction of agricultural machines, for example, straw cutting machines, threshing machines, maize shelling machines and so on (Gospodarski list No. 45, 1856). In Gospodarski list, No. 24 from 1857, it is stated that “our country needs machines, because we have a lot of land and too few hands, and expensive labourers”. The reasons for a slow introduction of steam engines and steam-powered machines in Croatian and Slavonian agriculture were an apprehension towards the use of steam engines, which were a complete novelty, their high purchase price and operational costs, questionable usability, that is, the cost-effectiveness of high-power machines with respect to work volume, the lack of trained personnel who would man the engines, and finally, a scarcity of available servicing and repair shops (Gospodarski list No. 47, 1859). The problem in Croatia and Slavonia was that farmers did not have enough cash to purchase the expensive steam engines, and at the beginning, crediting was also out of the question (Gospodarski list, No. 24, 1857). In addition, all such steam engines were of foreign make, which made their cost prohibitive. As the more powerful steam engines of 6.0–8.9 kW (8–12 iHP) were both too expensive and too strong for less demanding work, the production of cheaper steam engines, ranging from 1.5–2.2 kW (2–3 iHP) has begun in England (Gospodarski list, No. 47, 1859). These steam engines were associated with lesser operational costs, primarily lower fuel consumption. They could not work the whole day long, but were still cost-effective because they could be used 8 months in a year to power the threshing machines, chaff and root cutting machines, millstones for grain and pomace oil, water pumps and wood sawing machines (Gospodarski list, No. 47, 1859). At the beginning, it was only in England, followed by northern Germany that the so-called contractors offered their services with steam engines to farmers (Gospodarski list, No. 47, 1859). The purchase of a steam engine as for instance a locomobile was only cost-effective for major landowners

or a group of several middle-size or small-size landowners acting through an association. At the beginning, the price of a balance plough, locomobile and portable anchor (John Fowler’s steam ploughing apparatus) in the Austrian Empire was twice the one in England and the interest rate was 10–20%, compared to only 2–4% in England (Gospodarski list No. 29, 1861). Consequently, the crop yield was higher in England and the price of wheat was better (Gospodarski list No. 29, 1861). A Croatian-Slavonian Economic Society was set up in 1841 as a professional body with the goal of developing and upgrading of agriculture, but it was only in 1910 that it made possible a more favorable purchase of a steam locomobile by offering a discount and a favorable credit package with a repayment period of 3–6 years (Gospodarski list No. 19, 1910).

In June 1861, the Fowler’s steam ploughing apparatus was presented in the Austrian Empire at the location on the right side of the Danube close to Bratislava (Gospodarski list, No. 29, 1861). A self-propelled locomobile with portable anchor and 6-furrow balance plough has been used in the presentation. After a successful presentation of steam-powered ploughing, a proposal was made to establish a society for the introduction of steam engines in agriculture and a board was nominated. Agriculture in Slavonia, especially in its lowland part was more developed and human labor was more and more substituted with the use of machines, steam engines and steam-powered machines. Foremost in their use were Slavonian large holdings, which, like the ones in Austria and Hungary, availed themselves of the achievements of science and technology. With this, they also stimulated changes in smaller-size farms (Pavličević, 1989). According to a list published in 1864 in the journal *Sidro*, majority of the early industrial steam engines was used in mills and sawmills, in the production of flour and wood that were the main branch of export trade, and alongside them there were agricultural steam engines used on large Slavonian holdings (Karaman, 1974b). In Slavonia, during that time period (without Baranja), there were 8 steam engines used in agriculture, a total power of 43.3 kW (58 iHP). Pavličević (1989) states that only in Slavonia, steam engines were used directly on holdings (Daruvar, Virovitica, Našice, Valpovo, Gornji Miholjac and Donji Miholjac). Lambl, the director of the Economical and Forestry Educational Establishment in Križevci, describes in 1864 the use of locomobiles for powering wheat threshing machines and maize shelling machines in the Virovitica area (Slavonia). The construction of a railway track enabled the organizing of the First

Dalmatian-Croatian-Slavonian Economic Fair in Zagreb in 1864, an event that also attracted exhibitors from other parts of the Austrian Empire. Under subsection XIV of the Fair, the farm implements and machines, waggons and so on were presented. Most impressive among these exhibits was a locomobile of 6.0 kW (8 iHP), produced by Clayton Shuttleworth & Co of Lincoln, England, having their representative office in Vienna. The same exhibitor also presented a threshing machine and various other machines and tools (Fair Catalogue, 1864).

The second agrarian crisis hit Europe between 1873 and 1895. It was caused by an influx of large quantities of cheap wheat on the European market, coming from the USA, Canada, India, Russia and the Ukraine. Hardest hit were large holdings with extensive production of cereals. In order to compensate for the losses incurred due to falling prices of main cereals, new mechanization was introduced and the number of laborers reduced, along with the number of ox team and horse team harnesses, which were used until that time to cultivate the land (Stipetić, 1986). However, the agrarian crisis halted the developmental tendencies of a large part of Slavonian large estates (Karaman, 1986).

3.2. The census of holdings from 1895

By the end of the 19th century, the then Croatia and Slavonia consisted of eight counties, of which the Požega, Virovitica and Srijem counties were in Slavonia, the most developed region in terms of agriculture and also the main source of wheat. At that time, Baranja was not part of Slavonia. The overall area of arable land contained in the holdings of Croatia and Slavonia was 1,350,507 hectares and of vegetable gardens was 54,554 hectares (Statistical Yearbook I, 1905). The holdings in Slavonia had around 696,000 hectares of arable land and vegetable gardens, which represented around 50% of the total surface of arable land and vegetable gardens of all holdings in Croatia and Slavonia (Table 1). Also, in Slavonia, there were around 50% of forests present on its holdings (around 291,000 hectares) (Table 1).

A number of large estates in Slavonia possessed large forestry complexes, which often yielded greater profit than agriculture (Karaman, 1986). This fact, all until the First World War, had an adverse influence on the motivation of Slavonian large landowners to improve the production of their own agrarian units (Karaman, 1986).

Large size of arable land and a large number of holdings with over 575.5 hectares in the Virovitica and Srijem coun-

ties were the driving forces of modernization of agriculture and investment into steam engines and steam-powered machines (Tables 1, 2 and 3). Irrespective of the fact that Slavonian landowner aristocracy generated a greater part of its income with the sales of wood raw stuff to sawmills and wood processing companies, it carried out a modernization and rationalization of business on large estates with the introduction of steam engines and steam-powered machines. We can assume that part of the profit from forestry complexes was channeled into the modernization of agriculture. According to the census of holdings and cattle of 31 December 1895, in all eight counties, there were 1,211 steam engines and steam-powered machines (Table 3). These were driving engines and driven machines as well as steam ploughs. On holdings in Slavonia, there was a total of 1,041 steam engines and steam-powered machines (85.96%), of which 381 were locomobiles (84.48%), 501 steam-powered threshing machines (85.06%), 15 steam ploughs (75.00%) and 144 other steam machinery (95.36%). The above data clearly illustrates the predominance of Slavonia in terms of use of steam engines and steam-powered machines in agriculture. On top of the list were the Virovitica and Srijem counties with a total of 957 steam engines and steam-powered machines (79.03%), of which 347 were locomobiles (76.94%) and 15 were steam ploughs (75.00%). Other counties had a significantly smaller number of steam engines and steam-powered machines, or had none (Table 3). Locomobiles were mostly in evidence on holdings with an area of over 575.5 hectares (Table 3). Virovitica County had the largest number of holdings with over 575.5 ha on which there were 107 locomobiles (Tables 2 and 3). The greatest number of steam-powered threshing machines (39.56%), steam ploughs (65.00%) and other steam machines (54.97%) were used on holdings of 11.5–57.5 hectares (Table 3). We can assume that a part of these holdings formed associations or offered their services to other farmers, especially for steam ploughing. Steam ploughing was poorly represented in Croatia and Slavonia, with only 20 steam ploughs in evidence. They were mostly present on holdings of 11.5–57.5 hectares in the Srijem County in Slavonia (Table 3). Of all the counties, the then Srijem County had the greatest amount of arable land, as well as steam engines, steam-powered machines and steam ploughs (Tables 1 and 3). It had less forest areas compared to the other Slavonian counties (Table 1). In the then Croatia and Slavonia, there were a total of 30 holdings with an area greater than 5,755 hectares. Fifteen of them were in the Virovitica County, five in the Požega County and ten in other counties (Statistical Yearbook I, 1905).

3.3. Threshing of cereals with steam engines in 1918

According to the report on the success of threshing in 1918, a total of 5,961 threshing machines were used (Glavni izvještaj – Main Report, 1918). A total of 304,664 t of cereals were threshed (wheat, rye, barley and oats). Of the threshing machines, 2,174 were steam-powered (36.47%), around 96% of which were used in Slavonia. Compared to the year 1895, the number of steam-powered threshing machines increased by 3.7 times. In the first decades of the 20th century, the output of threshing machines was between 430 and 1,600 kg of wheat grains per hour, depending on the power of the locomobile and the dimensions of the threshing drum; the above was calculated for an effective power of 3.7–19.9 kW (5–27 eHP), length of the drum between 760 and 1,530 mm and the diameter of the drum of 500–610 mm (Fantoni, 1929a).

4. Locomobile and steam plough in agriculture

4.1. Locomobile

In Croatian agriculture, it was customary to regard a locomobile as a steam engine on wheels, which was towed by animals or was self-propelled. This is how it was described in the domestic literature of the time (Šah and Kišpatić, 1882; Fantoni, 1929a). They were used primarily for the propulsion of driven machines (threshing machines or similar) (Figure 1). Portable steam engine was placed on a wheeled chassis and towed by animals, or it could be moved by its own engine like a self-propelled engine. Locomobile was immovable when used to drive other machines via a belt drive or when it hauled the implements with a steel cable by means of a winding drum (Figures 2 and 6). The main purpose of a self-propelled locomobile was the use of its own motion power instead of animal power for the purpose of easier relocation from one farm to another, where it could be used to power agricultural machines. The development of locomobile as a portable steam engine on wheels began in England. The first public presentation of a portable steam engine designed to power the threshing machines took place at the Exhibition of Implements at the Liverpool Meeting in 1841, organized by the Royal Agricultural Society of England (RASE) (Parkes, et al., 1841; Parkes et al., 1843). Robert and James Allen Ransome from Ipswich displayed a portable steam engine,

threshing machine, plough and harrow. Steam engine and boiler of 3.7 kW (5 iHP) with its carriage on a pair of wheels did not exceed 1,778 kg (35 cwt [1 cwt is equal to 50.80234544 kilogram]) and it was towed by horses. On a farm near Liverpool, a comparative study was made of work efficiency and quality of work of threshing machines operated by hand and by Ransome's portable steam engine. The study showed that the steam engine is equivalent to the work of 24–25 persons in a time span of 23 minutes and 30 seconds (Parkes, 1841). The comparison was even more favorable for the steam engine when we reckon that in manual work, people would occasionally need a break or be replaced by another shift. On the Exhibition of Implements at the Bristol Meeting in 1842 (RASE), Ransome's self-propelled steam engine on four wheels was presented (Parkes et al., 1842). At the beginning, steam boilers were placed vertically on the wheeled chassis. As it evolved, the steam boiler began to be placed horizontally whereby the power of the steam engine was enhanced, as well as the boiler pressure. Locomobiles of a greater power were also built with a steam superheater, while those of lesser power usually did not have one (Fantoni, 1929a). The necessary number of persons to man the locomobile with one other machine (threshing machine or similar), or with a steam plough depended on the distance to water and fuel supply, on the type of a driven machine and whether two loco-

Figure 1. Locomobile Hofherr-Schrantz-Clayton-Schuttleworth (Wien und Budapest) (Fantoni, 1929a)

Abbildung 1. Lokomobile Hofherr-Schrantz-Clayton-Schuttleworth (Wien und Budapest) (Fantoni, 1929a)

Figure 2. Self-propelled locomobile Kemna (Germany) with winding drum mounted below the steam boiler (Černý, 1926)

Abbildung 2. Selbstfahrenden Lokomobile Kemna (Deutschland) mit einer unter dem Dampfkessel montierten Seilwinde (Černý, 1926)

biles were used in steam ploughing. This number could go up to 14 persons. To fuel the steam boiler steam coal or brown coal (lignite), beech or hornbeam wood and straw were used. In operating a steam locomobile, there was a danger of self-ignition due to sparking from the engine smoke box or a steam boiler explosion.

4.2. Steam ploughing

With the development of a steam engine and plough in England in the 19th century the term steam plough came into existence. During ploughing, the steam engine would stand at the end of the field on the headland, and drew the plough attached to the cable with winding drum or the steam engine pulled the plough with which it moved across the field. Ploughing by direct steam traction with attached plough had one drawback, namely because the steam engine had a great mass, it compacted the soil underneath it, found it difficult to move over light soil and spent additional power for its own movement. At the beginning, almost as a rule, steam ploughs were used that were dragged by cable with winding drum using one or two locomobiles (cable cultivation system).

The idea to use rope and mechanical power for the drawing of mole plough appeared in England around 1800. In the 1830s, John Heathcoat from England presented a method of ploughing with a balance plough that was dragged by rope and winding drum powered by a steam engine (Blacklock, 1837; Partridge, 1973). The first potentially practical and cost-efficient method of drawing of the mole plough, by winding drum and rope, was developed by John Fowler (England) in the 1850s. Firstly, he

used horse power, and since 1852, steam power. In 1854, he successfully presented drawing of the mole plough by locomobile of 4.5 kW (6 iHP) on a RASE fair in Lincoln (Baker and Clarke, 1855). Two years later, he presented a tillage system with balance plough and locomobile (Cavendish and Amos, 1856), and in 1856, he patented the system of ploughing with two self-propelled locomobiles (double-engine system). Ransome's catalogue from 1860 described Fowler's single-engine system with the following key words: self-propelled locomobile of 7.5 kW (10 iHP), portable anchor, steel cable, 4-furrow balance plough, cultivator, harrow, subsoil plough and so on (Partridge, 1973). Since 1867, steam ploughs began to be used largely outside England as well, notably in France and Germany, as well as overseas (Gospodarski list, No. 8, 1870). With these developments, the so-called "itinerant ploughmen" came into being who shifted locomobiles and steam ploughs from one farm to another and carried out ploughing on contract (Gospodarski list, No. 25, 1871).

Ploughing was carried out by balance plough with two sets of plough bodies attached to the angular beam upon an axle and two wheels (Figure 3). It was pulled by steel cable and the machinist sat on the frame keeping a rectilinear direction of ploughing by means of a steering wheel. The rear part of the balance plough (where the machinist sat) was in the soil and did the ploughing, while the front part was above the ground. There were two steering carts and seats and it was a reversible plough. Steam ploughing was performed with one or two locomobiles stationed on the edge of the field, on the headland. For ploughing according to the single-engine system, it was necessary to have a locomobile with winding drum, steel cable, portable anchor and a balance plough. Locomobile was stationed at one side of the field (on the headland), while on the opposite side of the field, there was an anchor that formed the point of resistance for an endless cable. Balance plough was

Figure 3. Balance plough for steam ploughing (Fantoni, 1929a)

Abbildung 3. Kipp-Pflug zum Dampfpflügen (Fantoni, 1929a)

attached to the cable and pulled across the field by means of the winding drum on the locomobile. It was possible to also use three portable anchors (roundabout system), where the locomobile was stationed in one corner of the field and the portable anchors at each other corner. The plough traversed the field between two of the anchors, which were gradually moved down the headlands towards the engine (Fantoni, 1929a). Fowler's system of steam ploughing with two locomobiles (double-engine system) without portable anchors proved to be the most efficient, but it required more financial outlays. Locomobiles were placed one opposite the other along the edges of the field, and they acted alternately: one played out the cable while the other wound it in, the ploughing implement attached to the cable being dragged from one end of the field to the other (Figure 4) (Partridge, 1973). Fantoni (1954) states that with Fowler's system of ploughing with two locomobiles, it was possible to achieve a ploughing performance of 2.27 ha h^{-1} at a depth of 24 cm and a specific resistance of soil of 0.6 kg/cm^2 , provided the power of each locomobile was 110.3 kW (150 eHP). Effective power represented the power on the driving axle, that is, the flywheel of the engine, but the steam engine had to work with overload (power greater than effective power). The system with two locomobiles could achieve a working speed of ploughing of $6\text{--}9 \text{ km h}^{-1}$ (Fantoni, 1929a and 1954).

In relation to ploughing with animal traction, fields ploughed with steam plough due to greater speed of ploughing had a better soil loosening, the stamping of the field was avoided, and the yield was greater, especially that of fodder beet (Gospodarski list, No. 8, 1870). The greater and more even the surface, the better the steam plough could work. For deep tillage at a depth of 40–70 cm, the single furrow plough was used, and for stubble field ploughing at a depth of 15 cm, the 10-furrow plough was

used. Locomobiles were used also for the drawing of cultivators, harrows, sugar beet diggers and so on. Oftentimes, together with the plough, other implements were dragged, such as a roller. It was more cost-effective to use the steam plough on hard treatable soils for deep ploughing where greater power was necessary than on light soils where the force of the locomobile was less pronounced. Ploughing with locomobile paid off only on large areas of roughly rectangular shape, and in addition there had to be access roads to the fields due to the locomobile mass.

4.3. The twentieth century

Locomobiles were used in the cultivation of land on large farms in Europe and USA, but this method began to lose importance after the First World War. The production of locomobiles was prevalent until the 1920s, and then gradually decreased (Jejčić, 2010). Locomobiles were also used in scientific research on universities. Prof. Raimond Fantoni graduated from the High Technical School in Vienna in 1909 where he specialized in 1911, and in 1919/1920, founded the present-day Institute for the Mechanization of Agriculture at the Faculty of Agriculture of the Zagreb University. In 1926, he conducted research into the quality of ploughing with a locomobile, which over a belt drive powered a separate machine with a winding drum, steel cable and change-speed gear mechanism (Figure 5). The goal of the research was to determine the impact of plough velocity on the quality of ploughing and power consumption. The obtained results were published in several Croatian and foreign publications (Fantoni, 1927, 1929a and 1929b).

In Europe, locomobiles were used in agriculture until the middle of 20th century, mainly to power the wheat threshing machines, and occasionally, they even survived until the 1970s. The discontinuation of locomobiles in European agriculture was due to the delivery of tractors from the USA as post-war aid, an increased number of combine harvesters, lack of coal after the war and so on (Jejčić, 2010). Still, occasionally, they were retained in road construction (Jejčić, 2010). The cultivation of soil by steam plough on the Belje estate (Croatia) was dominant until 1956 where this method was mainly applied for ploughing, harrowing and tilling the soil with disc harrow. Steam ploughs remained in use until the spring of 1958, and, according to professional opinion at the time, the crops were better where these ploughs were used, compared to ox team or horse team harness (Musa, 1986). Specifically, steam ploughing was of greater quality without soil compaction,

Figure 4. Steam ploughing with two locomobiles – double engine system (Fantoni, 1929a)

Abbildung 4. Dampfpflügen mit zwei Lokomobilen – Zweimaschinensystem (Fantoni, 1929a)

Figure 5. Ploughing with locomobile in 1926 at the Faculty of Agriculture of the Zagreb University (archives of the Department of Agriculture Engineering)

Abbildung 5. Pflügen mit Lokomobile im Jahr 1926 an der Fakultät für Agronomie der Universität Zagreb (Archiv des Instituts für Landtechnik)

and in addition, the steam engines were very long-lasting (50 or more years) and more powerful than the tractors of that time (Musa, 1986).

5. Conclusion

In Croatia and Slavonia, the process of industrial revolution as well as the modernization of agriculture began at a later date (in the middle of the 19th century) and unfold-

Figure 6. Locomobile Kemna (Germany) with winding drum for steam ploughing, painted by Dušan Jejčič 2000 (Jejčič, 2010)

Abbildung 6. Lokomobile Kemna (Deutschland), mit Seilwinde zum Dampfpflügen, gemalt von Dušan Jejčič 2000 (Jejčič, 2010)

ed at a slower pace compared to the developed European countries. The main reasons were structural crisis with the transition from feudal into capitalist economy, lack of capital, shortage of good land and river traffic routes and slowness in the construction of railways. In the second half of the 19th century, Croatia and Slavonia was a predominantly peasant country and the traditional extensive method of plant production and cattle rearing was predominant. In the modernization of agriculture, the lead was taken by large holdings that had skilled workforce and applied modern agricultural tools and machines, including steam engines and steam-powered machines. The lack of manpower after the abolishment of feudal relations, as well as the beginning of the second agrarian crisis, stimulated the introduction of steam engines in the agriculture of Croatia and Slavonia. On holdings in Croatia and Slavonia in 1895, there was a total of 1,211 steam engines, steam-powered machines and steam ploughs. Locomobiles were mostly represented on large holdings with an area of over 575.5 hectares. What was then the country of Slavonia, as a predominantly agrarian region and the major source of wheat was a leader in the usage of steam engines, steam-powered machines and steam ploughs in agriculture. Until the end of the 19th century, steam ploughing was poorly represented in Croatia and Slavonia, with only 20 steam ploughs in evidence. Of all the counties, Virovitica and Srijem counties had the greatest amount of steam engines, steam-powered machines and steam ploughs. Large estates in Slavonia disposed of large forest complexes, which often yielded more profit than agriculture. This discouraged the Slavonian landowners until World War I to move ahead and develop agrarian production. Locomobiles were used in agriculture until the middle of the 20th century. The main reason why they were discontinued was the predominance of tractors with internal combustion engines, and later, a growing use of combine harvesters.

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