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Article

Trends and Potential of the Market for Combine Harvesters in Germany

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Abstract: Combine harvesters used today can achieve throughput rates of over 70 tons of grain per hour; however, their technical performance potential is currently not being exhausted by any means. The global market for combine harvesters, its stocks and recent production is described. According to farm size distribution and regional field sizes, Germany was divided into three combine-harvesting regions. The simulation results show that in Germany about 45,000 units of combine harvesters in three performance categories are necessary. However, the calculations also show that future domestic sales of combine harvesters will depend greatly on the service life of the units currently in use.

Keywords: combine harvesters; technical development; stocks and demand

1. Introduction

The technical development of the combine machines has been enormous over time. Larger and larger cutting widths, improved performance and advanced electronics in the cockpit lead to the increase of effectiveness of the new machines and as a result fewer harvesters are demanded. This article first briefly describes the technical development and the portfolio development of combines and then forecasts the sales of combines for three sub regions of Germany. The main purpose of the article is to show how much stocks of combine harvesters have changed in the past and what harvester sales figures manufacturers can expect in the future.

2. Technical Development and Manufacturers

Since the invention of the stationary threshing by the Scots in 1785 by Andrew Meikle, revolutionary technological advances have taken place in grain-crop harvesting. The United States and the countries of Western Europe are the pioneers of self-propelled equipment for combine harvesting with ever-higher demands on effectiveness, throughput and precise straw spreading in the swath chopped. Self-propelled and stationary equipment for combine harvesting were used in 2007 worldwide for the harvest of about 695 million hectares of cereals and 153 million hectares of oilseed acreage. Grains account for around two-thirds of cultivated crops planted on the global arable land. In 2007, these planting proportions resulted in a worldwide harvest of 2.35 billion tons of cereals [1] and 150 million tons of oilseeds, which is the most important nutritional basis for a growing world population from the present 7.3 billion people [2].

The technical development of each of the highest performance classes of combine harvester parts has increased steadily over the last 25 years (Table 1). The parameters cutterbar width and grain tank capacity have almost doubled in 25 years in the top performance class of combine harvesters and the engine power tripled approximately. In addition, the high performance potential is complemented by electronic control in critical functions in the workflow. The rapid technological advance in combine harvesting is strongly associated with the world and European leading manufacturers of combine harvesters John Deere, CNH, AGCO and Claas. Combines of the highest performance class use cutters with a working width up to 12 m, equipped with an engine power up to 434 kW and have a grain tank capacity up to 12,500 L for grain crops.

Table 1. Technical development of combine size classes 1985–2010.

Code	Year						
	1985	**1989**	**1995**	**1999**	**2004**	**2005**	**2010**
Engine power (KW/PS = horse power)	147 (200 PS)	206 (280 PS)	243 (330 PS)	265 (360 PS)	316 (430 PS)	390 (530 PS)	434 (590 PS)
Grain tank capacity (L)	6300	9100	9500	9700	11,500	12,000	12,500
Cutting width (m)	6.1	7.3	7.4	9.2	9.2	9.2	12.0

Source: [3].

By increasing electronic equipment in the combine, the leading manufacturers pursue the following objectives: facilitating drivers, precise working, maximum capacity use and documentation of numerous performance measures. The large machines, whether combine or self-propelled agricultural machines, are always equipped with the latest technology, because additional costs in relation to the high unit price are less important. After a successful test of new integrated electronic solutions, it will also be installed in the mid-market segment.

Nine types of combine harvesters were offered on the Western European market in the 2010 season by international producers: New Holland and Case I (CHN), John Deere (John Deere), MF, Fendt and Gleaner (AGCO), Claas (Claas), Sampo and Sampo (SDF) and Laverda (ARGO). Technically, the harvester can be divided as follows: The conventional combine has a tangential and straw shaking (four-, five-, six- and eight-shaking versions) are equipped from 85 to 335 kW (115–455 hp (horse power)). Tangential harvesters with one or two separation rotors feature engine outputs from 268 to 431 kW (365–586 hp). In the performance category of axial combine harvesters, the engines range from 205 to 435 kW (279–591 hp). Cutting widths are available from working widths of 3.1 m to 12.0 m. The Austrian provider of cutters, BISO, additionally offers a cutting system with a working width up to 15 m on a modular aluminum construction. From Western European production with international links, there are over 40 combines series, 80 to 100 combine models and numerous additional equipment variants for the Western European market available.

3. Stocks of Combines and Sales Worldwide

3.1. Stock of Combines

In 2007, the EU-27, with just under 700,000 machines, possessed the second largest stock of harvesting machines in the world. There are about 2.8 million harvesters, including threshers, on the Asian continent.

In the Member States of the EU-27, the combine stock counted nearly 715,000 machines in 2006 at a threshing area of approximately 70 million hectares of cereals and oilseeds. This corresponds to an average threshing area of 98 hectares per combine in the EU-27, but which varies within the member countries due to different agricultural structures and combine stocks. The largest combine stock within the EU-27, with 124,000 machines, is found in Poland, followed by Germany with 88,500 and France with 78,000 machines. Nearly two-thirds of the 27 member states have a combine stock of less than 20,000 units. Only Malta, the Mediterranean island with a subtropical climate, has no combines. In the agricultural area of Malta, about 10,000 hectares, mainly fruit trees and citrus fruits are grown [4].

3.2. Sales of Combines

Technical progress including new features as well as the structural changes in agriculture have led to a decrease of combine sales from formerly about 48,000 to 7000 units per year in Western Europe within the last 40 years. The average 7000 units per year in the Western European represents 20% a share of the global harvester market in 2004 (Figure 1). In 2004, the world market was slightly more than 35,000 units. The sum of the two separately listed markets in Europe is 14,620 units (41.6%), South America follows with 10,300 units (share 29%) and North America with 8000 units (23% market share) [5].

In the Western European market, the number of combine units of sold is relatively constant with about 7,000 units per year for the last ten years. These numbers include the four-shaker combines up to the central five- and six-shaking combine harvesters with a market share of approximately 43%. In the upper performance category of conventional combines, a market penetration of six- or eight-shaking combine is characteristic with about 37%. The remaining market share of 20% is covered by the hybrid and axial combine harvesters, which show an upward trend [5]. The approximately 6800 sold units in 2007 equals nearly that of 2005; differences were only in the distribution among individual countries. With a total of nearly 4000 units, equivalent to 58.6% of Western Europe combine sales, Germany and France have the largest market in this segment. The high amount of combines in these two countries can be explained by the strong cultivation of cereals; both countries are among the strongest grain producers in the EU-27, along with Poland, Spain and Romania [6].

In contrast to the stable tendency of slightly decreasing volumes in Western Europe, the monetary sales volume has increased because of engine power and upgraded electronic features.

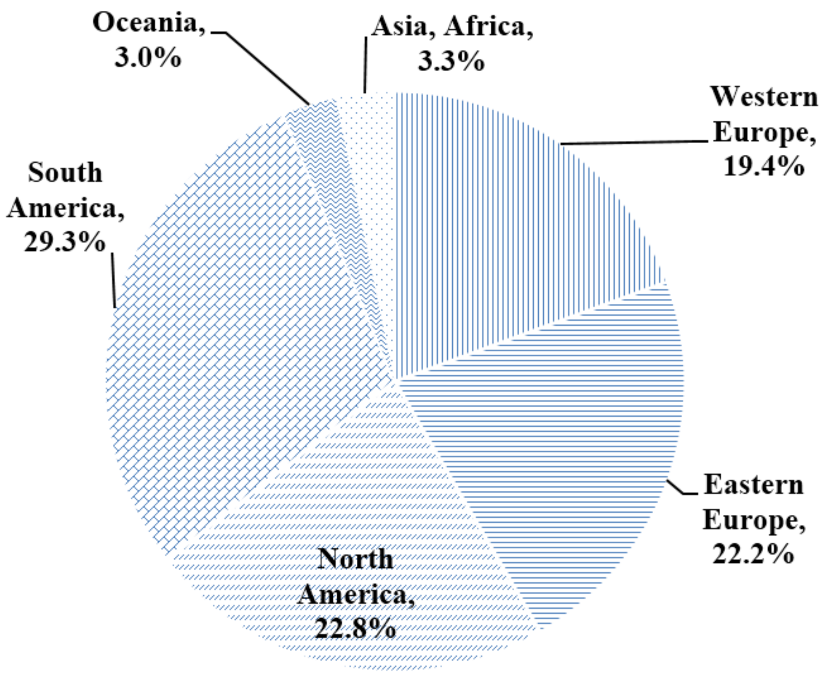

Figure 1. Combine world market in 2004. Source: New Agriculture (adapted from [5]).

Eastern Europe offers good prospects for increasing sales of harvesters, particularly the CIS countries (Commonwealth of Independent States—former Soviet republics, excluding the Baltic States). With the collapse of the Soviet Union, the major combine maker from there has been on the brink of bankruptcy. Before the political changes, 35,000 units were produced annually in the Soviet Bloc. In 1998, in Russia an all-time low of just over 1000 units produced. Furthermore, the current 200,000 unit combine stock is greatly outdated. In addition, 50% of the harvesters are not operational because of technical defects. Furthermore, Russia and Ukraine intend to expand their grain production greatly. Russia alone plans to increase production of cereals to 120 million tons in 2015. Compared to 2004 when 78 million tons of grain was produced, this represents an increase of 65% over a period of 10 years [5]. This means a considerable investment gap and low demand for combine harvesters. This is compounded by faltering production and by increases in import prices after the import tariffs on agricultural machinery have been raised to 15% in the wake of the world economic crisis in 2009. After the trade embargo, which was imposed because of the Crimean crisis in 2014, sales of agricultural machinery to Russia have almost completely collapsed.

The Asian market, with major grain producers China and India that together produced 740 million tons of grain in 2008, is less promising for an increased production of combines from the West. Nevertheless, for example, John Deere Jiamusi in China and Claas in India Faridabad and Chandigarh have production facilities for harvesters to participate in the sales potential of the Southeast Asian market and to show presence as a strategic “global player” [7]. In addition to the leading international manufacturers in India, there are 48 domestic companies (e.g., Preet Agro Industries Private Limited, Nabha, India) manufacturing combine harvesters [8]. With an inventory of 477,000 combine harvesters and threshers, the Indian market, after the Chinese (632,400 units) and Japanese markets (957,000 units), is the most significant in Asia [9].

4. Development of Domestic Sales and the Stocks of Combines in Germany

4.1. Production and Domestic Sales

The production of agricultural machinery in Germany covers a wide range of agricultural machinery and supplies for agriculture. In the period from 2006 to 2008, the production increase of combines units was 53%, followed by the plant protection equipment (48%) and planting machines (40%) [10]. In 2008, the 10,692 combines produced predominantly originated from the production sites of Claas in Harsewinkel and John Deere in Zweibrücken. The German agricultural machinery industry is strongly export oriented, especially in the field of combines and forage harvesters. For example, in 2007, 80% of the 6994 combine units manufactured were exported [9].

Domestic sales have more than halved from 2678 in 1998 to 1279 in 2008. Between 2000 and 2008, a decreasing trend can be observed. On average, domestic sales from 1990 to 2008 amounted to 1864 units sold (Figure 2) [11]. The market volume in the harvesters and equipment segment in 2008 amounted to 715 million euros. After the tractor, with a turnover of 1.6 billion euros, the harvesting machinery and equipment market in Germany is the second largest market for the agricultural machinery industry. Totally, sales of tractors and harvesters covered about 50% of the market volume in 2008.

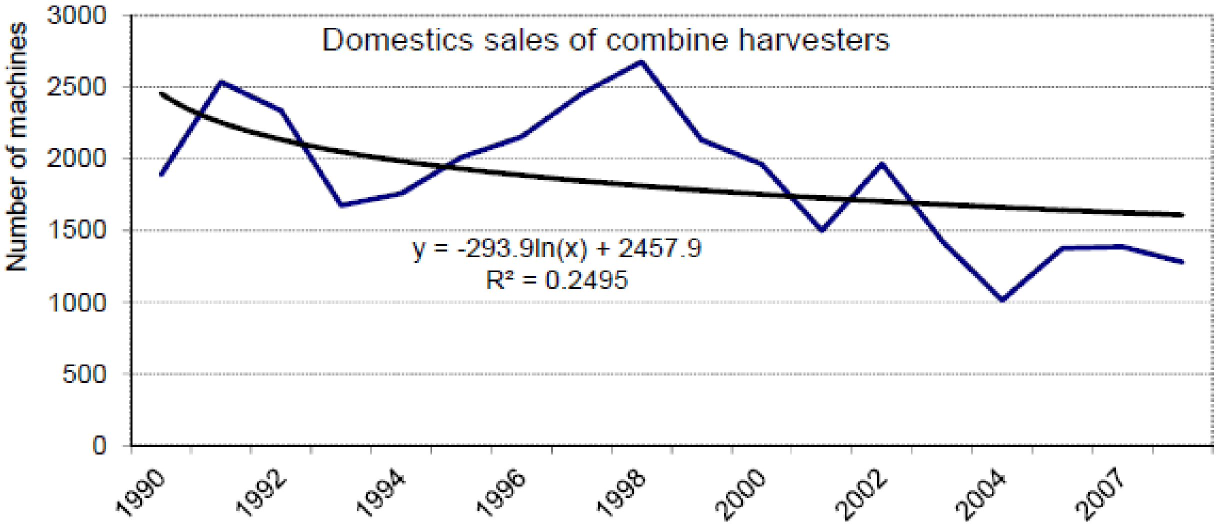

Figure 2. Domestic sales of combine harvesters in Germany (1990–2008) (own calculations based on [11]).

Sales of combine classes are similarly distributed all over Western Europe, where the four-, five- and six-shaking combine harvesters have a market share of about 43%. In the upper performance category of conventional combines, a market penetration of about 37% is typical. The remaining market share of 20% is covered by the hybrid and axial combine harvesters [5].

4.2. Inventory Development of Combine Harvesters

Stocks of combine harvesters rose from the mid-1950s, with the first self-propelled combine harvesters and the highly popular drawn threshing machines, to the year 1975 to total more than 189,000 units. The proportion of self-propelled combines was five times greater in 1976 compared to the drawn combine harvester. In the following years, the proportion of the drawn harvesters has declined sharply. With further technical developments, coupled with increases in performance with increased operational variables as well as due to the structural change in agriculture, the stocks of combines decreased in the following years by half [9].

For the grain crop harvest of 9.9 million hectares with a harvest of 61 million tons, nearly 85,000 combine harvesters were used in 2008. In the average of the years 2003 to 2009, about 9.8 million ha, over 56 million tons, were harvested by 93,200 combines [4]. Although through constructive ways the performance potential of the combines always increased in recent years, the combine's installed capacity is only exploited in the field to half the degree possible, which corresponds to a field efficiency of about 50% [12].

Figure 3 shows the decreasing old stocks of harvesters, beginning in 1990 and, for the period 1990 to 2008, the number of annual harvester sales and for each the fading out due to segregation (colored lines). The accumulated inventory, the sum of the corresponding number of harvesters in a certain year, results in the stock of combines, which has decreased from the previous count of 156,890 in 1990 to 79,153 units in 2008, a drop of approximately 50%.

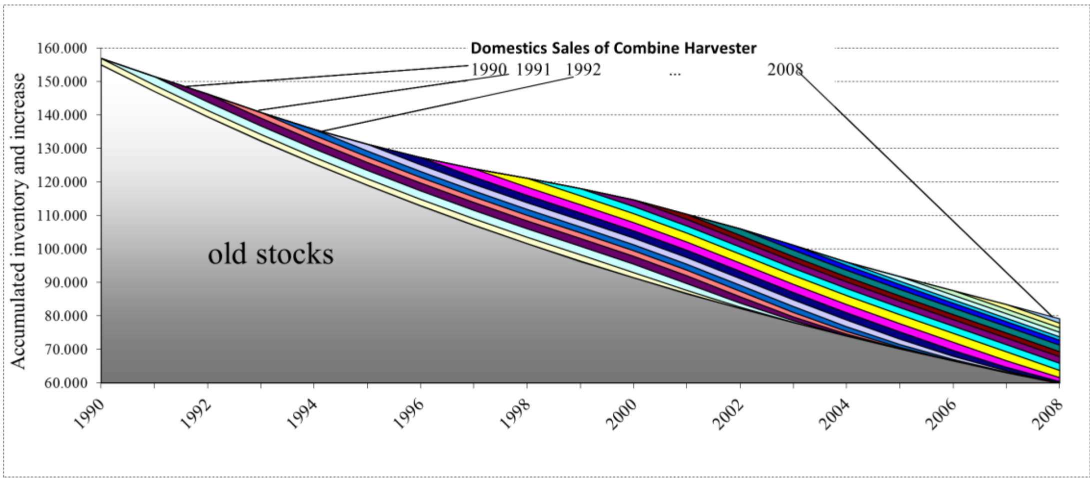

Figure 3. Inventory of combine harvesters (old stocks; domestic sales 1990 to 2008—colored lines; all area together = accumulated inventory) 1990–2008. Source: Own calculations based on [9,11].

According to FAO data, in Germany, in 2007, there were about 85,480 harvesters. Since the period from 1990 to 2008, *i.e.*, the 17 years of the investigation period, 20,248 new combine harvesters were added, which means there are still 63,193 combine harvesters 17 years or older in use [13]. If the old portfolio is updated at a rate of 5%, then in 2022 there would still be 28,632 older harvesters (potentially from before 1990) that remain in the stock. A faster replacement of very old combine harvesters is also conceivable, if newer machines are used to a larger extend. Therefore, the future structure of the combine fleet, in particular with respect to the old stock, is not clearly determined.

4.3. Factors Influencing the Threshing and Deriving the Minimum Capacity

The demand for combine harvesters is determined by several factors. In addition to crop management, other factors affect the extent of the actual performance. Ahead of the other factors, breeding and agronomic measures play an important role how a field is harvested.

Production failures, such as lying grain, even through optimal management efficiency of the harvesters can no longer be sustained. Another factor, which the farmer cannot influence, but determines the threshability decisively, is the weather [14].

Subsequently, the minimum necessary stocking of combines for the region of Germany should be estimated. Here, Germany is divided into three sub-regions, which differ due to local factors (farm size and field size) and where the use of smaller, medium and large harvesters makes sense (Figure 4).

Figure 4. Germany and its three sub-regions for harvester sizes depending on farm size and field size. Source: [15]; own assumptions and changes.

Furthermore, the influence of environmental factors (weather affecting harvest amount, available threshing hours and field efficiency) is simulated in a kind of risk analysis. Unfavorable constellations require the use of a larger number of machines and lead to higher harvesting costs. If there were insufficient harvesters available, higher natural losses and costs could arise; and, in extreme cases, a part of the fields could remain unharvested.

Results of these simulations show the region-specific necessary number of harvesters and the costs of harvest. Based on the average cost of the threshing and the marginal losses in crops, the minimum necessary number of combines is calculated.

4.4. Division into Threshing Regions for the Calculations

The basis for the calculation of the stock of development combines is the distribution of grain crops acreage in Germany in three sub regions. The federal states, with the exception of the city states of Berlin, Hamburg and Bremen, are, in accordance to their average farm size, classified into the following categories: below 40 ha utilized agricultural area (UAA), 40 to 60 ha UUA and 60 ha UAA (Table 2). Accordingly, the relevant crop and areas sown can be assigned. Decision criterion for the allocation of a performance class of combines for a sub-region is the parameter throughput in quantity of grain per hour.

Threshing region 1 (Southern Germany) comprises the federal states Hessen (HE), Nordrhein-Westfalen (NW), Rheinland-Pfalz (RP), Bavaria (BY) and Baden-Württemberg (BW). In these five states, between 18.4 and 24.1 million tons of grain crops were harvested on average in the years 2003 to 2008 on a cultivated area of 3.5 million hectares annually. In threshing region 1, combines with an engine output of 200 kW, a grain tank of 8500 liters and a cutter of 5 m were used for the harvest of grain crops (Table 3). With this combine size, it is possible to achieve a throughput capacity of 15 tons per hour. The four states of Schleswig-Holstein (SH), Sachsen (SN), Niedersachsen (NI) and the Saarland (SL) represent the second largest combine harvest area (North-West Germany), which has a cultivated area of 2.2 million hectare. In the years 2003 to 2008, on average 13.2 million tons of grain were harvested, which corresponds to 27% of the German grain harvest. For the grain crop harvesting in the threshing region 2, a combine with a power size of 275 kW, a grain tank capacity of 10,500 L and a cutting bar width of 7.5 m are used (Table 3). A throughput of 30 tons per hour can be achieved with this harvester size because of the larger farm structures in region 2. In the federal states of Mecklenburg-Vorpommern (MV), Saxony-Anhalt (ST), Brandenburg (BB) and Thuringia (TH), where on cultivated area of 2.8 million hectares (33.2% of the German grain crops acreage), on average over 16 million tons harvested. In the threshing region 3 (Middle-Eastern Germany), the cultivation of commercial crops is most important. About 47% of the commodities are harvested in these four countries. The utilized agricultural area per farm in Mecklenburg-Vorpommern and Saxony-Anhalt is more than 150 ha, the greatest among the regions. For grain crop harvest in the threshing region 3, combines of the motor power class of over 375 kW, a grain tank capacity of 12,000 L and a cutting bar width of 9 m is common (Table 3). A throughput of 50 tons per hour can be achieved with this harvester size on the large acreage.

Table 2. Classification of threshing regions in Germany on the basis of the average farm size in ha utilized agricultural area (UAA).

Region (Average Farm Size)	Countries	UAA per Farm	Cropping Area	Harvest
		ha	**1000 ha**	**1000 t**
Region 1: Southern Germany (<40 ha)	HE	34.9	382.7	2552.6
	NW	31.5	743.0	5836.0
	RP	28.0	302.6	1855.7
	BY	26.4	1443.8	8977.2
	BW	25.1	651.9	4264.4
	Average	**29.2 ha**		
	Sum		***3,524.0 ha***	***23,485.9 t***
	Proportion		***41.0%***	***42.4%***
Region 2: North-West Germany (40 to 60 ha)	SH	57.3	444.7	3360.5
	SN	54.7	574.5	3333.4
	NI	52.3	1161.8	8357.7
	SL	47.6	29.6	164.4
	Average	**53.0 ha**		
	Sum		***2210.6 ha***	***15,216.0 t***
	Proportion		***25.7%***	***27.4%***
Region 3: Middle-Eastern Germany (more than 60 ha)	MV	170.5	834.8	5181.8
	ST	154.2	779.5	5141.8
	BB	96.8	721.9	3277.3
	TH	64.9	518.4	3149.2
	Average	**121.6 ha**		
	Sum		***2854.6 ha***	***16,750.1 t***
	Proportion		***33.2%***	***30.2%***
Germany	**Average**	**56.0 ha**		
	Sum		***8589.2 ha***	***55.452.0 t***
	Proportion		***100.0%***	***100.0%***

Source: [16].

Table 3. Combine sizes in relation to the operational structure (farm size) in the regions.

Regions in Germany	Combine Key Figures					
	Motor Power	**Grain Tank**	**Cutting Bar Width**	**Throughput-Performance**	**Additional Equipment**	**Acquisition Costs**
Region 1: Southern	200 kW	8500 L	5.0 m	15 t/h	Rape cutting table	217,100 €
Region 2: North-West	275 kW	10,500 L	7.5 m	30 t/h	--	295,100 €
Region 3: Middle-Eastern	375 kW	12,000 L	9.0 m	50 t/h	--	358,400 €

Source: Machinery and equipment [2]; grain harvest [11]; own assumptions.

Applying Monte Carlo method using @RISK [17] with 10,000 simulations for every scenario, the variations on the three external factors, harvest amount (yields), available threshing hours in a certain season and field efficiency, can be considered:

- a small harvest together with high threshing hours and a high field efficiency,
- a great harvest at low threshing hours and low field efficiency, or
- any other possible combinations.

In the first case, a small number of combine harvesters would be sufficient, while a maximum number of harvesting equipment would be needed in the second case. How often unfavorable, average or favorable situations occur is specified with triangular distributions, with extreme values, *i.e.*, unfavorable or favorable situations, occurring less frequently than average values (Figure 5).

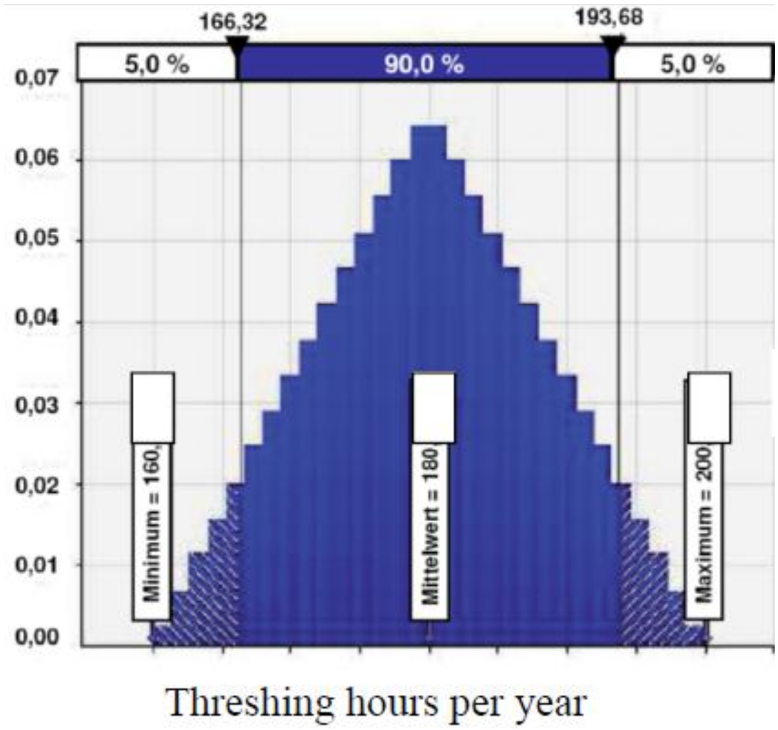

Figure 5. Available threshing hours per year in all regions combine harvesting. Source: [17]; own calculations.

For example, it is assumed that the available threshing hours may vary between 160 h per year as a minimum value (rare), 180 h per year on average and up to 200 h per year as the maximum value (also rarely occurs). Regional differently vary the quantities harvested and the field efficiency, the latter is assumed to be lowest for the small-scale south region (region 1) with an average of 40% (in the span from 30% to 70%) and, at the highest and most expensive in the large structured middle-east area (region 3) with an average of 60% (40%–80%) (Table 3).

The results of the simulations give the number of a necessary minimum set of combines, which is required to harvest the volumes in all simulated years. From these values, the annually sold harvester units can be derived assuming an average service life.

In Table 4, the results of the simulation are summarized. In order to ensure that—with a probability of 100% at 10,000 iterations—the cultivated areas are completely threshed in all years, a combine fleet of 44,385 units would be required. The majority of harvesters (approximately 30,000 units) are for the region 1; this relatively high number is due to the assumed smaller power class of 15 tons per hour. In the other two regions, with approximately 8600 (region 2) and 4900 pieces (region 3), significantly fewer units are required (Figure 6).

Introducing a limit to the fluctuation range to cover for 90% of all cases, *i.e.* cutting off the 5% lowest (best) and 5% highest (worst) values:

- On the minimum cost side, it becomes more expensive, when the harvest could be cheaper due to an "over"-capacity of combines.
- On the other side, it becomes cheaper due to the lower stock of combines; in 5% of all cases, a higher number of combines would be needed. The latter variants could still be realized, namely when other management reserves are developed, for example, additional inter-company co-operation and emergency relief to harvest all under difficult weather conditions.

Table 4. Assumptions (minimum, medium and maximum values of the triangle distributions) and simulation results (in the 90% range).

Region	Key Figure	Unit	Minimum	Average	Maximum
Region 1: Southern Germany	harvest	Mio. t per year	18.43	22.02	24.12
	available threshing hours	h per year	160	180	200
	field efficiency		30%	40%	70%
	threshing costs (90%)	€uro/t	17.83 20.79	26.40	38.63 32.90
	necessary stock of combine harvesters (90%)	number of machines	10,011 12,800	18,068	**30,891** 24,240
Region 2: Northern-West Germany	harvest	Mio. t per year	11.94	13.60	15.63
	available threshing hours	h per year	160	180	200
	field efficiency		35%	50 %	70 %
	threshing costs (90%)	€uro/t	14.26 15.96	18.66	25.57 21.93
	necessary stock of combine harvesters (90%)	number of machines	3190 3830	4980	**8627** 6440
Region 3: Middle-Eastern Germany	harvest	Mio. t per year	13.14	15.70	17.21
	available threshing hours	h per year	160	180	200
	field efficiency		40%	60%	80%
	threshing costs (90%)	€uro/t	12.18 13.18	14.97	20.04 17.29
	necessary stock of combine harvesters (90%)	number of machines	1877 2289	2970	**4867** 3848
Germany	Stock of combine harvesters	number of machines	15,078	25,737	**44,385**
	(90%)		**18,919**		**34,528**

Source: own calculations.

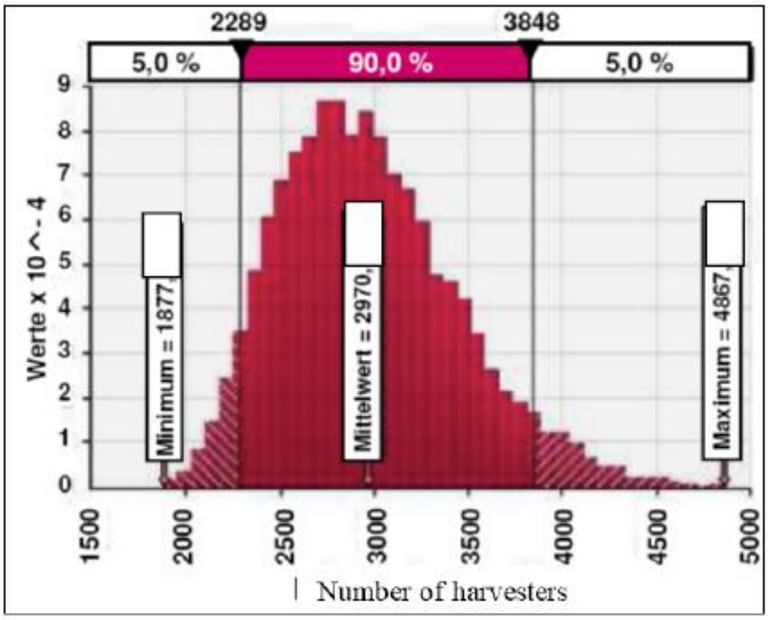

Figure 6. Distribution of the necessary number of harvesters in the threshing region 3. Source: [17]; own calculations (10,000 simulations).

4.5. Future Development of the Number of Combine Harvesters

Historical data for inventory and sales of combines have been analyzed in this study, until 2008 and before. The current stock of combine harvesters in Germany amounting to approximately 80,000 machines is almost twice as high as the calculated necessary inventory with about 44,000 units (Table 4). This explains the relatively low domestic sales in recent years. Due to the overcapacity of combine harvesters, the latest development of destocking, with relatively low replacement, will continue (although powerful modern combine harvesters are not yet in use everywhere) until the necessary stock of about 44,000 combine is reached. For the future, it is assumed that the existing stock of combines will decrease by 5% annually, similar to the period from 1990 to 2008 observed. In addition, the sales of combines per year are estimated (and therefor limited) according the trend line determined during the period from 1990 to 2008 (Figure 2):

$$y = -293.9\mathrm{Ln}(x) + 2457.9 \ (R^2 = 0.2495) \tag{1}$$

where y = number of combines in Germany in units per year, and x = year from 1990 onwards.

Because of the high old stock of harvesters, the annual sales of combines might decrease to 1283 units in 2009 and further to 727 units in 2019 (Figure 7). Thus, on average, over the years 2009 to 2019, a relatively small substitution of an average 1005 combines per year would be sufficient in Germany.

In the calculations for Figure 8, it was assumed that by 2009 for the newly sold combines a 10-year using age could be expected. After this time, annually 20% of the old machines could be eliminated, so after 15 years, none of these machines would be available. In the following years (from 2019), the useful life of the new combines has been limited to a maximum of eight years.

From 2019, the old stock would be so far degraded that a larger replacement demand of approximately 3000 combines a year is expected. In the long term, however, according to the assumptions, about 4400 new combines are annually necessary to replace a total stock of 44,385 units of combine harvester in Germany.

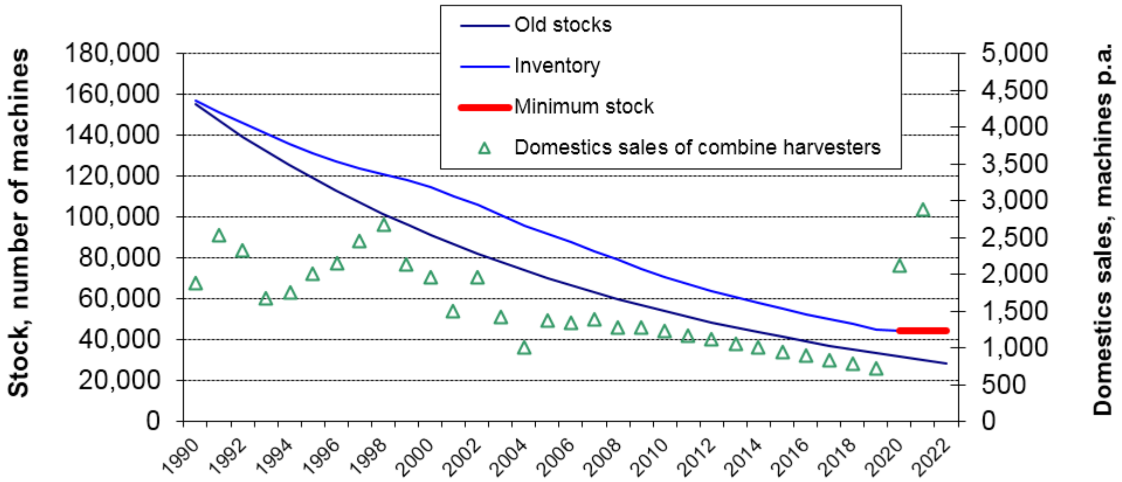

Figure 7. Sales and inventory of combine harvesters (1990–2022). Source: Own calculations based on [9,11].

After adjusting, the stocks of combine harvesters will reach a minimum constant level of at least about 44,000 units from 2019 to 2030; the colored lines in Figure 7 show the initial number of future harvesters sales in a certain year and their path of decrease.

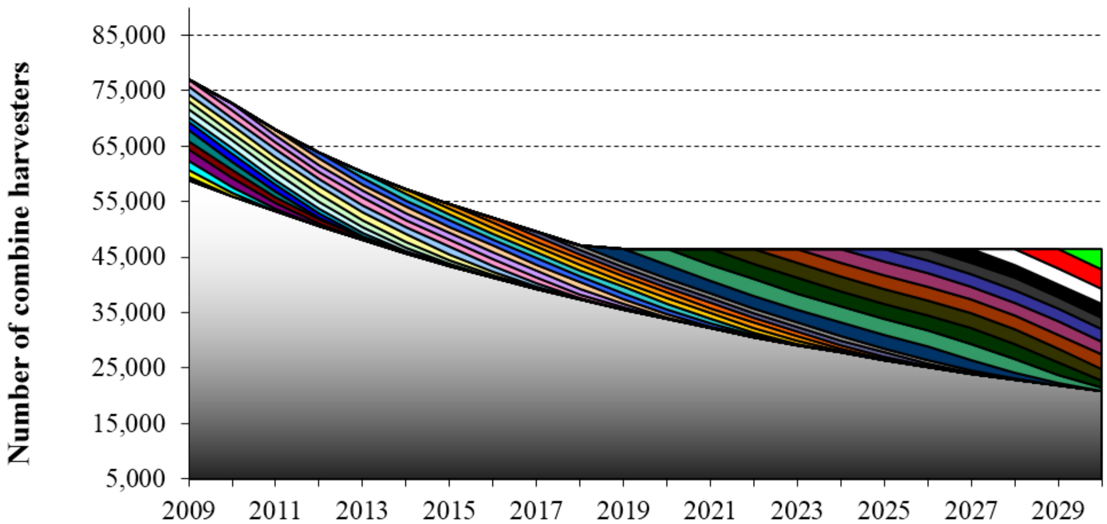

Figure 8. Inventory of combines cumulated from old stock and calculated domestic sales (2009–2030, colored lines). Source: Own calculations based on [9,11].

5. Summary

Development Tendencies and Potential of the Market for Combine Harvesters in Germany

Combine harvesters used today can achieve throughput rates of over 70 tons of grain per hour; however, their technical performance potential is currently not being exhausted by any means. In this paper, a survey of major harvester manufacturers and models is given and factors influencing the combine harvesting performance are presented.

The objective was to reflect the complexity due to factors like size of farm and field size as well as combine performance and environmental factors (weather, with impact on yield and number of hours available for combine harvesting). Therefore, Germany was divided into three combine-harvesting regions. Certain performance categories of combine harvesters were assigned according to farm and regional field sizes. Triangle distributions with assumptions for harvest size, field efficiency, and harvest days are the basis for the applied Mote Carlo simulation, which shows the minimum capacity of combine harvesters necessary to reap the harvest safely.

The simulation results show that, in Germany, 44,385 units of combine harvesters of the three performance categories are necessary. However, the calculations also show that future domestic sales of combine harvesters will depend greatly on the service life of the units currently in use.

Author Contributions

Mathias Urbanek did his Master' Thesis at the University of Applied Sciences Neubrandenburg, Germany in 2010 [18] under the supervision of Clemens Fuchs and Joachim Kasten. Clemens Fuchs and Joachim Kasten wrote the English version of the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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