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RELATIONS BETWEEN PRODUCTION VOLUME AND DRAFT FORCE RESOURCES IN POLISH AGRICULTURE

Abstract

In 1949-2010, the draft force resources in Polish agriculture increased by 420.6%. At the same time, there was more than eightfold increase in mechanical draft force and reduction in live one by 90%. In 2010, the value of gross output in constant prices was higher than in 1949 by 113.2%, final output – by 186.7% and market output – by 370.9%. It was noted that there is a positive correlation between equipment in the draft force and the value of agricultural production. Its strength, when considering only the mechanical draft force, was higher as compared to the total draft force taken into account. The correlation is the strongest when the market output is taken as a measure of agricultural production and the weakest for the gross output. The correlation is the strongest when the market output is taken as a measure of agricultural production and the weakest for the gross output.

Keywords: draft force, agriculture, agricultural production, correlation.

Introduction

Agricultural production requires, e.g., involvement of draft force enabling to perform technological treatments in plant and animal production processes. There are two types of draft force: live and mechanical. Its type predetermines the level of mechanisation and consequently the efficiency of work at farms. Economic transformations that occurred in the 20th century, contributed to elimination of live draft force in developed countries. The need to research how the process of replacing the live draft force with the mechanical one proceeded in Poland and how it was linked to agricultural production volume motivated the author to write this paper.

Wójcicki (2014a) drew attention to the need for research of technical and economic changes at farms. The issue of technical provision of farms was covered in many publications. It was discussed in the works of: Kurek and Wójcicki (2011); Marczuk (2013); Muzalewski (2015); Pawlak (2015a, b); Wójcicki (2014b); Wójcicki and Rudeńska (2015).

The research by Wójcicki et al. (2014) indicated the existence of a correlation between the agricultural production value in the form of gross margin and the replacement value of farm equipment at family farms. Whereas Kocira (2008), based on own research, stated that the value of obtained gross margin at farms depends on the status of technical provision.

Replacement of live draft force with mechanical one is connected to an increase in total resources of draft force at farms. Tractors, because they are indivisible, contain many more motive power units[1] than a horse which they replace. On the one hand, it ensures higher operation efficiency during work performance and thus higher probability of their timely performance and reduction in arduousness compared to horse traction; but, on the other, its low level of use at farms of small UAA – which are predominant in Poland – causes relatively high costs of its maintenance. It may be assumed that the correlation between the agricultural production volume and the status of provision with draft force will decrease along with an increase in the resources of the latter, and increase for the share of mechanical force in its structure.

This paper attempted to analyse the changes in provision of the Polish agriculture with draft force in 1949-2010 and the correlation between this provision and the agricultural production value in fixed prices.

Research materials and methods

The above-presented research aim was achieved using the data from the following publications of the Central Statistical Office of Poland (*Główny Urząd Statystyczny, GUS*) (GUS, 1966, 1971, 1976, 1978, 1982, 1987, 1992, 1994, 1997, 1999, 2002, 2003, 2005, 2006, 2007, 2008, 2011a, b, c, 2013, 2015a, b). On this basis, an analysis was conducted that covered changes in qualitative provision of the Polish agriculture with draft force in 1949-2010, which considers, for instance, the structure by its type (live, mechanical). The draft force resources are measured in motive power units.

Data on the condition of draft force in agriculture for 1949-1990 come from subsequent statistical yearbooks (GUS, 1966, 1971, 1978, 1982, 1987, 1992). Whereas estimates were presented for data on the changes in the condition of the draft force at individual farms and in total in agriculture after 1990, for the years when there was no national agricultural censuses. Assuming the values from subsequent censuses, values for intervening years were estimated with the use

[1] Motive power unit in agriculture is 1 draft horse. Conversion tractor (of 2.2 kW power output at hitch point) equals 5 motive power units.

of the interpolation method. Such estimates were necessary because, e.g., according to the data from GUS yearbooks the draft force resources in agriculture in 1991-1993 dropped, while the national census of 1996 showed their increase by 8.7% against 1990. Whereas this value in 2001 was according to GUS by 1.8% higher than that given for 2002, while the growth rate in the period between subsequent censuses (1996 and 2002) amounted to only 0.2%.

Data on the condition of the draft force in agriculture were analysed:
- in total,
- by individual farms,
- by other users (a difference between values referring to the agriculture in total and individual farms).

Given that a GUS data series on draft force resources ended on 2009 and published in the statistical yearbook of (2011a) was and in subsequent yearbooks (2013; 2015a, b) it was no longer considered, the value for 2010 was estimated on the basis of the National Agricultural Censuses (*Powszechny Spis Rolny, PSR*) of 2010.

The aforementioned GUS publications were also used as a data source on values of selected categories of products in the Polish agriculture in 1949-2010. Analysis of changes in the production level in such a long period requires adoption of its values in fixed prices. In respective statistical yearbooks published by GUS relevant values are given as indices of different reference basis. The reference basis for data of 1949-1969 is provided by average values of 1950-1952 (GUS, 1966, 1971). In subsequent yearbooks it was the year 1960 (GUS, 1978) or the "last year = 100" option. This was used as a basis to calculate the values of reference ratios for 1970-2010 to a basis common for the entire period (1950--1952 = 100). The following was used for the purpose:

$$a_{kbr} = a_{kbr-1} \cdot \frac{a_{kr}}{100} \tag{1}$$

where:
- a_{kbr} – value of the ratio of the value of k^{th} agricultural production category in the r^{th} year, against the status of 1950-1952 (%);
- a_{kbr-1} – value of the ratio of the value of k^{th} agricultural production category, against the status of 1950-1952 designated for the year preceding the year for which the value of the a_{kbr} ratio is determined (%);
- a_{kr} – value of the ratio of the value of k^{th} agricultural production category in the r^{th} year, against the value from the last year (%).

Given the rounding up of the values of ratios a_{kr} supplied by GUS, the results of calculations using the above procedure can be biased by error. In order to check the scale of the error, the values of the ratios for all considered production categories were calculated in 2010 against 2000 according to the results

obtained with the use of the discussed method and it was compared to analogous ratios given in the GUS publication (2011b). It was stated that for global production the value of error was 0.09%. The data on final and commercial production did not differ. On these grounds, it was considered that the obtained agricultural production values in fixed prices are sufficiently precise and can be used to research correlations between the condition of the draft force and the agricultural production value.

Using the value ratios for a given agricultural production category against 1950-1952, the values of production were estimated for respective years in fixed prices as follows:

$$WP_{krs} = \frac{WP_k \cdot a_{kbr}}{a_k} \tag{2}$$

where:

WP_{krs} – value of k^{th} agricultural production category in r^{th} year in fixed prices (1950-1952 = 100), (PLN billion);

WP_k – value of k^{th} agricultural production category in 2010 (PLN billion);

a_k – value of the ratio of value of k^{th} agricultural production category in 2010 (%).

The correlation between the provision of agriculture in draft force and the global output, gross value added and final production and commercial production of the Polish agriculture in fixed prices of 2010 was graphically presented indicating their descriptive functions of the highest goodness of fit R^2 coefficient and numerical value of the coefficient.

Results and their analysis

Biological, technical and organisational progress caused increase in agricultural production in Poland in the analysed period. Despite reduction in utilised agricultural area (UAA) by 27.3% the value of global output in fixed prices was in 2010 by 113.2% higher than in 1949, and that of final production and commercial production, respectively, by 186.7% and 370.9% (Fig. 1). Major production level fluctuations in respective years are typical; they are best visible in case of commercial production. Weather conditions in respective years were one of the factors having an impact on changes in agricultural production level. As they precondition wintering of winter crops and consequently their yields. The precipitation level and their distribution over a year, and water resources in the soil influence yielding of crops and indirectly the value of agricultural production. Józwiak et al. (2016) argued that farms on areas experiencing droughts, which have UAA lower by an average of 15.9% than other farms, obtained agricultural production value lower by 22.6%. Agricultural production per 1 ha of UAA for farms at risk of water shortage in the soil was lower by 8.2% than at other farms.

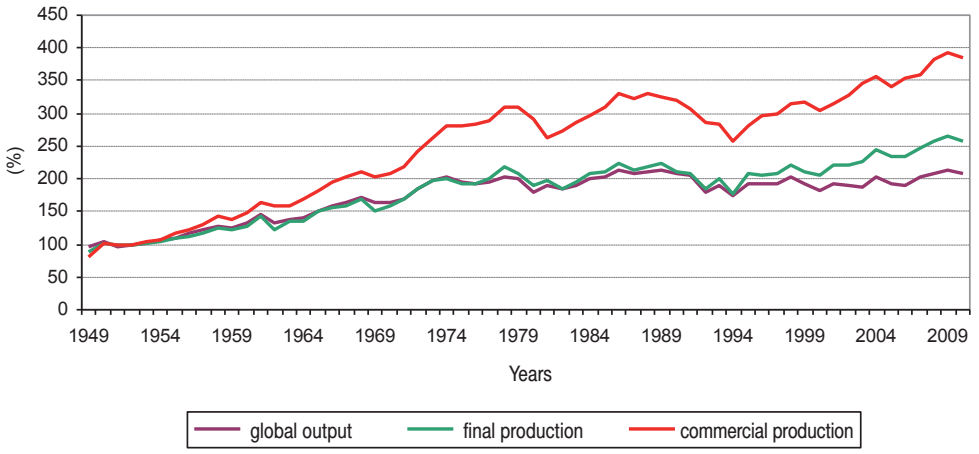


Fig. 1. Dynamics of value of selected agricultural production categories (1950-1952 = 100). Source: own study based on GUS data.

Before World War II agriculture mechanisation in Poland was at a low level and draft horses were the main source of draft force. In 1939, there were around one thousand tractors, mostly located at large-area farms in the then western voivodeships. The damages of war further deteriorated the situation. The draft force resources per 100 ha of UAA decreased from 12.7 motive power units in 1938 to 6.8 in 1946 (Bernacki, 1964). The provision of machinery and equipment was also insufficient both in qualitative and quantitative terms. In the second half of the 1940s and in the 1950s the number of draft horses was gradually increased, mainly due to extended reproduction at farms and partly due to aid provided under the United Nations Relief and Rehabilitation Administration (UNRRA). First deliveries of tractors directed to state-owned farms came from the same source. By 1948, tractors delivered to agriculture came only from abroad (imported, e.g., from Czechoslovakia). In 1949, Ursus Factory launched production of the Ursus C-45 tractor, which was a copy of the outdated German tractor Lanz Bulldog. In 1958, the factory started production of a more up-to--date Polish-design tractor – Ursus 325, with 18 kW engine, later replaced with a model with the power output of 21 kW (Ursus C-328). In 1967, Ursus Factory started production of Ursus C-330 tractor which for many years (and as of 1986 its modernised version – C-330M) had been the most popular tractor at individual farms.

In 1949-2010, the number of tractors in the Polish agriculture increased nearly sixty times. The growth rate in respective subperiods was differentiated. In 1959, a growth by 129.2% against 1949 was noted and the average annual increase amounted at that time to 3223 pieces.

At the times of the Polish People's Republic (*Polska Rzeczpospolita Ludowa, PRL*), the process of agriculture mechanisation was subordinate to the political doctrine. In the first post-war years, mechanisation of agriculture in Poland was limited to large-area farms taken over by the state and over time – along with collectivisation of agriculture – also agricultural production cooperatives. Mechanical services for such farms and cooperatives were provided by the Cooperative Centres of Agricultural Machines and Gmina Centres of Agricultural Machines, especially appointed for the purpose, and as of 1950 – State Centres of Agricultural Machines (*państwowe ośrodki maszynowe, POM*)[2]. In 1949, state-owned farms held 82.4% of tractors and Gmina Centres of Agricultural Machines, liquidated in 1956, had 15.7% of tractors. The remaining 1.9% was the share of State Centres of Agricultural Machines. The percentage share of state-owned farms decreased over time (to 45.2% in 1959 – despite a growth in the number of tractors in the group of users by 25.6%). But then, the share of State Centres of Agricultural Machines increased (from 1.9% in 1949 to 44.1% in 1955) as well as that of agricultural production cooperatives (form 0.4% in 1950 to 2.8% in 1959). For many years, individual farms had problems with buying tractors. Only a change in agricultural policy in 1956, which meant a resignation form mandatory collectivisation of farms, started the process of mechanisation of field works also at individual farms. Initially it was performed mainly through State Centres of Agricultural Machines and then Agricultural Circles, reactivated in Poland after changes of 1956. In 1957, first tractors at individual farms were noted (less than 5.2 thousand pieces). At that time, farmers could buy brand new tractors with foreign currency. Investments in means of agricultural mechanisation were financed from – especially dedicated for the purpose – Agricultural Development Fund, whose funds consisted in the difference between the value of plant and animal production supplied by individual farmers under mandatory deliveries counted (a) in market prices and (b) in prices paid to farmers for the products.

In 1959-1970, the number of tractors owned by Agricultural Circles increased nearly seventy times. This, however, did not bring the changes expected by the contemporaneous authorities in the conditions of live draft force at individual farms. Farmers could not resign from their own draft force and they used the services of Agricultural Circles mainly for arduous field works, like ploughing and harvesting crops. For Agricultural Circles orders for transport services from non-agricultural enterprises were the most convenient ones, especially executed under long-term contracts. This type of activity guaranteed a rather stable scope of works and satisfactory use of tractors and its handling personnel. Thus, the structure of services was predominated by transport works, while field work orders were not always timely executed. Moreover, because of top-down instructions

[2] Over time, the share of repairs in the structure of POM activities increased and the share of mechanical services gradually dropped, which is evidenced by the lowering number of tractors – from a maximum of 22 039 pieces in 1956 to 3517 pieces in 1974.

machines were concentrated in increasingly larger and more remote from most of farms enterprises: inter-circle base of agricultural machines (*międzykółkowa baza maszynowa*) and next Cooperatives of Agricultural Circles. The latter covered with their scope of activates entire gminas. Underdevelopment of technical infrastructure, including rural roads and telecommunication networks, hindered contacts of farmers with dispatchers of the equipment in enterprises of Agricultural Circles, the more the greater was the distance between the farms and the machinery base and centres managing them. Hence, mechanisation of individual farms through Agricultural Circles brought limited effects. The situation changed significantly only after farmers were enabled to purchase their own tractors. At the cusp of the 1960s and 70s, the possibilities of purchasing tractors – first second hand and later on brand new ones – by farmers were much extended.

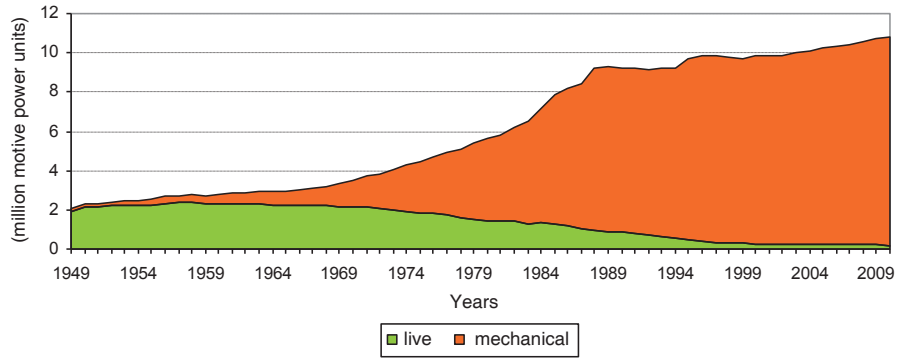
Live draft force in the structure of its total resources at individual farms predominated until 1974, and in overall agriculture – 1973. For other farm users, predominated by state-owned farms, a slight advantage of mechanical draft force over the live force was noted already in 1953 (Fig. 2). Reduction in the total resources of draft force in this group by nearly 32% was caused by farmers leaving production cooperatives on a mass scale upon changes of 1956 that concerned mainly live draft force.

Over the 1970s and 80s there was a dynamic growth in the number of tractors in the Polish agriculture, which was accompanied by a gradual change in the structure of draft force to the advantage of motorised equipment. In 1990, the mechanical draft force constituted already 90.3% of the draft force resources in the Polish agriculture including in individual farms 89.0% (GUS, 1992).

This was a period of the most dynamic development of the automotive industry in Poland. Compared to 1970 the number of tractors was in 1990 by 427.8% higher. In 1971-1990, the number of tractors grew annual by 52 013 pieces.

The transfer from the centrally planned economy to the market economy and release of prices related thereto influenced the increase in the prices of the means of mechanisation against agricultural products, which in turn resulted in a collapse of the demand for the means of production, including the demand for brand new tractors. In 2002, the number of tractors in the Polish agriculture was already by only 15.2% higher than in 1990. Increase in the number of tractors in the period was caused by minimum level of their withdrawal from use at individual farms and imports of relatively cheap second-hand tractors. In 1991-2002, the average annual increase in the number of tractors amounted to 11 428 pieces. The share of individual farms in the structure of second-hand tractors increased (from 87.5% in 1991 to 98.2% in 2002). At the beginning of the 1990s, individual farmers purchased a lot of the farm equipment from sell-out carried out by state-owned farms and Agricultural Circles experiencing difficulties. This caused a drop in the shares of other entities from – the public sector – from 6.8% to 0.2%; agricultural production cooperatives – from 2.0% to 1.2%, and Agricultural Circles – from 3.8% to 0.4%.

a



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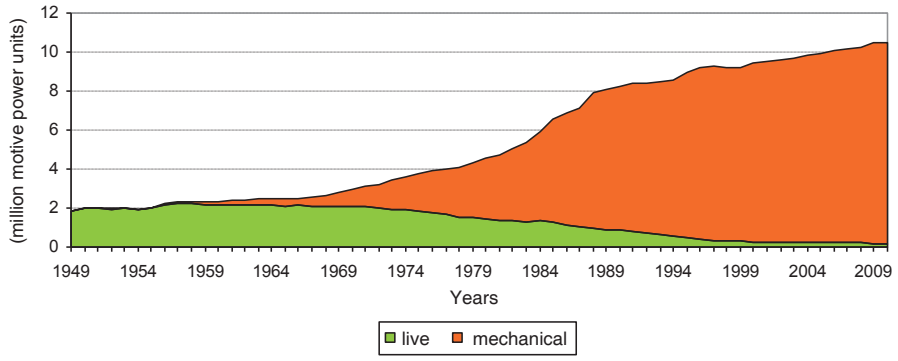

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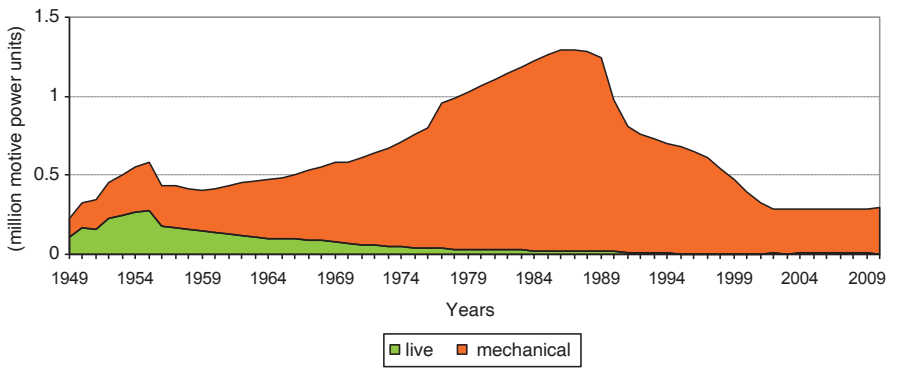


Fig. 2. Level and structure of draft force resources in the Polish agriculture: a – in total, including: b – individual farms, c – other users.

Source: own study based on GUS data.

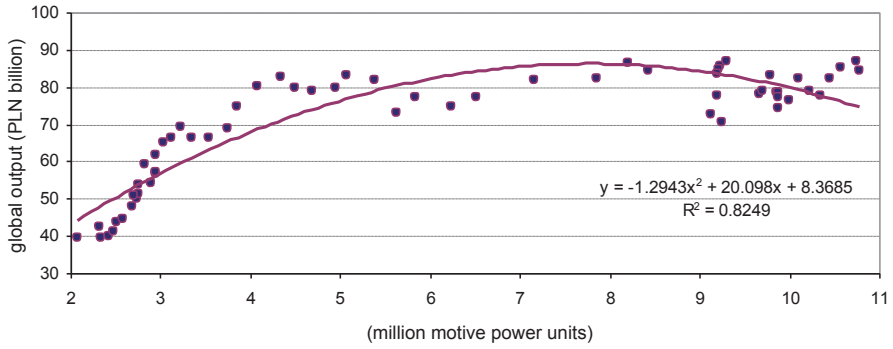
Changes in the provision with other types of farm equipment accompanied the increases in the resources of mechanical draft force. In 1950, state-owned farms had 75 harvesters, and 9 pieces were in the State Centres of Agricultural Machines. In 1987, agriculture employed 65.2 thousand of combine harvesters, including 27.5 thousand at individual farms, 18.5 thousand pieces at enterprises of Agricultural Circles, 14.3 thousand pieces at state-owned farms and 4.9 thousand pieces in agricultural production cooperatives. In 2010, the number of combine harvesters in agriculture was 152.1 thousand pieces, out of which 97.8% was at individual farms.

The most dynamic growth was noted for the means of mechanisation linked to implementation of the energy-efficient production technologies. In 2010, the number of cultivation units exceeded the number of 1996 over ninety times. Reaper-binders are no longer used, although their number increased by 1987. Along with a progress in mechanisation the horse-driven machines were replaced by those adjusted to work with tractors, but temporarily it was quite common at individual farms to aggregate horse-driven machinery and wagons with tractors, among which the so-called SAM tractors had a major share in some regions. These were tractors made using economical means, i.e. using elements of varied vehicles and machines. In 1987, such tractors constituted one third of all tractors of individual farms in the former Bielskie Voivodeship.

The designated functions reflecting the correlations between the total resources of live and mechanical draft force and the values of respective agricultural production categories are characterised by good level of adjustment (Fig. 3). The discussed correlation is demonstrated the strongest in case of taking commercial production as the measure of agricultural production. The coefficient of determination for the polynomial function describing the correlation is 0.87. The lowest value of the coefficient of determination (0.82) is typical of the polynomial function illustrating the correlations between the total resources of the live and mechanical draft force and the value of the global output of agriculture. But, also in this case the level of adjustment is good.

The correlation between the production volume and provision with draft force is positive, but its strength decreases along with an increase in the resources of draft force. The reason for the weakening correlation is, above all, the dropping use of tractors along with a growth in their number and reaching the condition of saturation of farms with tractors. In these conditions it is necessary to seek for solutions enabling to use tractors in a more rational manner, thus limiting their costs of maintenance. These can be achieved using the system of mutual services, e.g. under machinery circles. Such system, commonly used in the western German lands, allows for full mechanisation of works at the participating farms, with lower number of machines and their better adjustment to the power and drawbar pull of the owned tractors.

a



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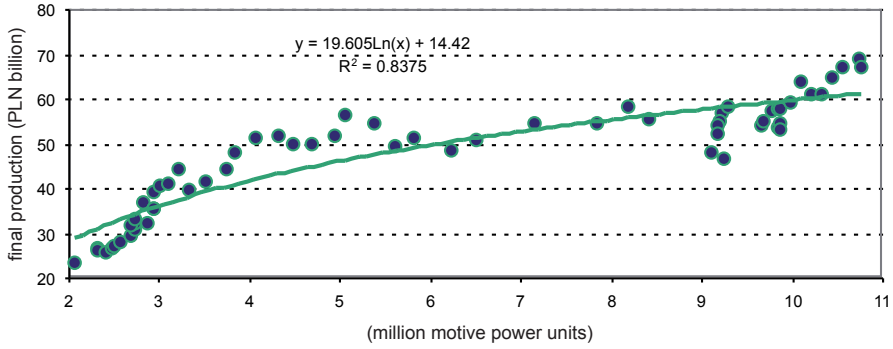

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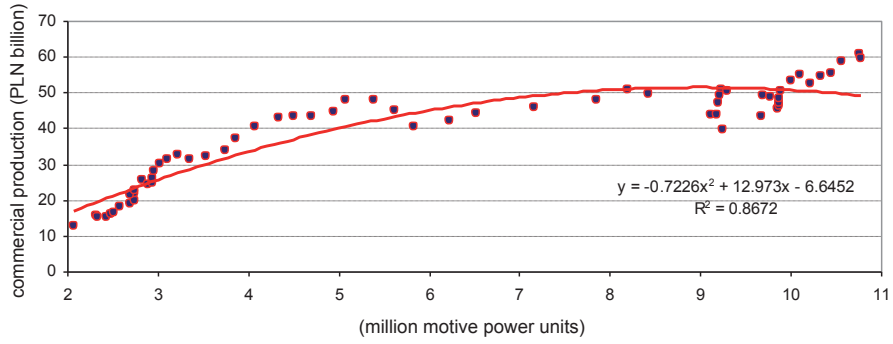

Fig. 3. Resources of draft force in total versus agricultural production measured with the value of: a – global output, b – final production, c – commercial production.

Source: own study based on GUS data.

The correlations between the volume of respective agricultural production categories and resources of mechanical draft force are more strongly marked (Fig. 4) than when total resources of live and mechanical draft force were being considered. Also in this case, the largest value of the coefficient of determination (0.93) is characteristic to the logarithmic function reflecting the correlations between the resources of the mechanical draft force and the value of commercial production of agriculture. A very good level of adjustment (R^2 = 0.90) is characteristic of the logarithmic function reflecting the interdependencies between the resources of mechanical draft force and the value of final production of agriculture. Relatively the weakest is the correlation between the resources of the mechanical draft force and the global output value of agriculture. The value of the coefficient of determination for logarithmic function reflecting it is 0.86.

Regardless of whether the analysis covers total resources of draft force or only the mechanical draft force, the discussed correlations are the strongest at smaller number of motive power units and weaken along with its increase. In the conditions of relative saturation with draft force and its dropping use, further increase in agricultural production is increasingly more dependent on biological progress and improvement in the methods of farming, fertilisation, plant protection and organisation of work whose significance increases in the conditions of using better and better but also increasingly more expensive farm equipment.

Poland's entry into the European Union (EU) improved the situation of the Polish farmers due to implementation of the Common Agricultural Policy (CAP) and launched mechanisms of financial support for agriculture under the established agri-environmental programmes, including those stimulating the development of activity conducted under environmental systems (Jucherski and Król, 2013). According to Józwiak and Ziętara (2013), before Poland's entry into the European Union only ca. 25 thousand (1.3% of the total) of the Polish farms was characterised by good economic standing. Authors estimated that in 2013, there was 74 thousand of such farms. Improvement of the economic situation influenced a growth in demand, e.g. for brand-new tractors (Pawlak, 2012; Zalewski ed., 2015). This creates favourable conditions for modernisation of the status of provision of the Polish agriculture with means of mechanisation and implementation of technologies guaranteeing higher agricultural production in keeping with the requirements of respect for the environment and high efficiency of inputs.

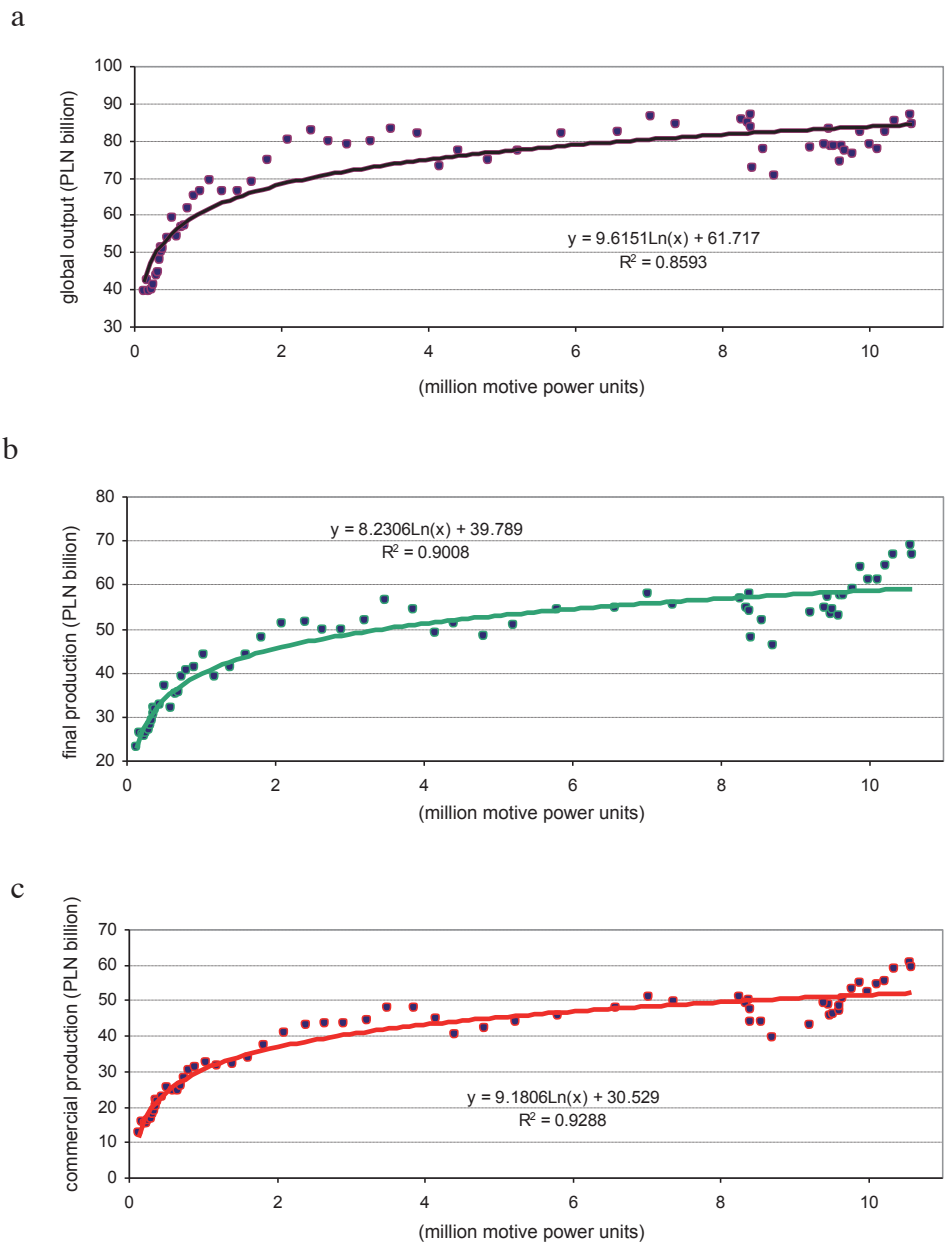

Fig. 4. Resources of mechanical draft force versus agricultural production measured with the value of: a – global output, b – final production, c – commercial production.

Source: own study based on GUS data.

Conclusions

The value of global output in fixed prices was in 2010 by 113.2% higher than in 1949, and that of final production and commercial production, respectively, by 186.7% and by 370.9%.

In 1949-2010, resources of draft force in the Polish agriculture increased by 420.6%. At this time, an over eightfold growth in the resources of mechanical draft force was noted and reduction in the live force by 90%.

The correlation between the provision with draft force and value of agricultural production is positive and strongly marked. The highest value of the function of the coefficient of determination, describing the correlation, was noted for adoption of commercial production as the measure of agricultural production value and the lowest – for adoption of the global production.

The mechanical draft force is more strongly correlated with the value of agricultural production than the resources of the draft force.

The positive correlation between the production volume and provision with draft force is weakening when the resources of the draft force increase. This is caused mainly by limited use of tractors when their number increases and condition of saturation of farms with tractors is reached.

Dropping use of tractors results in growth in their maintenance costs. More efficient use of tractors can be achieved using the system of mutual services, e.g. under machinery circles. Such solution enables full mechanisation of works at the participating farms, with lower number of machines and their better adjustment to the power and drawbar pull of the owned tractors.

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RELACJE WOLUMENU PRODUKCJI DO ZASOBÓW SIŁY POCIĄGOWEJ W ROLNICTWIE POLSKIM

Abstrakt

Wartość produkcji globalnej w cenach stałych była w 2010 r. o 113,2%, produkcji końcowej o 186,7%, a produkcji towarowej o 370,9% większa niż w 1949 r. W latach 1949-2010 zasoby siły pociągowej w rolnictwie polskim zwiększyły się o 420,6%. Odnotowano w tym czasie ponad ośmiokrotny wzrost zasobów mechanicznej siły pociągowej oraz redukcję siły żywej o 90%. Stwierdzono dodatnią współzależność między stanem wyposażenia w siłę pociągową a wartością produkcji rolniczej, która w przypadku przyjęcia wyłącznie mechanicznej siły pociągowej zaznacza się silniej niż wówczas, gdy uwzględniona jest całość zasobów siły pociągowej. Współzależność ta zaznacza się najsilniej, gdy miernikiem produkcji rolniczej jest produkcja towarowa, a najsłabiej – gdy jest to produkcja globalna.

Słowa kluczowe: siła pociągowa, rolnictwo, produkcja rolnicza, współzależność.

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