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INDICES OF SUSTAINABILITY OF HORSE TRACTION IN AGRICULTURE

POKAZATELJI ODRŽIVOSTI KONJSKE VUČE U POLJOPRIVREDI

ABSTRACT

Aim of the research was to find and evaluate the indices of horse traction sustainability in agriculture. The research was done by means of compilation of results of previously published researches and conducted interviews which were subjected to logical analysis and *synthesis, and conclusions were brought upon a logical induction and deduction. The research has revealed that, despite the complete shift to machinery traction in Croatia more than 30 years ago, the use of horse traction is still characterized by many important sustainability indices.*

Key words: *Sustainability, Horse traction, Energy, Agriculture*

SAŽETAK

Cilj istraživanja bio je pronaći i vrednovati pokazatelje održivosti konjske vuče u poljoprivredi. Istraživanje je provedeno kompiliranjem rezultata iz prethodno objavljenih istraživanja i provedenih intervjua koji su podvrgnuti logičkoj analizi i sintezi, a zaključci su doneseni metodama logičke indukcije i dedukcije. Istraživanjem je ustanovljeno da, unatoč provedenoj potpunoj smjeni konjske vuče u hrvatskoj poljoprivredi traktorskom prije više od 30 godina, upotrebu konjske vuče još uvijek karakterizira mnogo, iznimno važnih, pokazatelja održivosti.

Ključne riječi: *održivost, konjska vuča, energija, poljoprivreda*

1. Introduction

There can be found many titles in Croatian newspapers recently warning about a contraction of national economy, about a foreign debt going unsustainable and an increasing unemployment rate during the last few years. Besides, the environmentalists emphasize the need to protect natural resources and to rely on renewables to ensure a sustainable development of society. The aim of this research is to provide the public with an idea that can offer an economically viable and sustainable way of farming which can at least partially contribute to meet the a.m. warnings. The idea comes from an article by Kollodge (1993) who found that at a time when many conventional farmers across the US are in desperate financial straits, traditional Amish farms are still making money and realising profit with a cautious disregard for get-big-or-get-out modern technology and refusing any direct government subsidies, other than those built into market prices, which they can't avoid. Maybe, such traditional way of farming, relying mainly on horse traction, may in some respects really help small Croatian farmers to survive the current crisis? Maybe it can help the society to come up to a healthier environment and a more resilient economy? The paper will try to give an answer.

2. Materials and methods

The research was done by means of compilation of results of previously published researches and conducted interviews which were subjected to logical analysis and synthesis, and conclusions were brought upon a logical induction and deduction.

3. Results

3.1. Use of renewable energy resources

The majority of agricultural production of industrialized economies is currently driven by diesel fuelled tractors. Thus, the agriculture currently relies on distant oil sources used to produce diesel fuel. Moreover, the oil is deemed an exhaustible resource. Namely, the Hubbert's peak oil production is estimated to occur prior 2015 a.d. (Almeida and Silva, 2009) and after that the consistent decline of production is expected. Simultaneously, the world's demand is estimated to continue rising consistently (Hall and Day, 2009) and so will do the prices for oil and its derivatives. The growing importance of non-conventional oil (oil shale, natural bitumen, extra-heavy oil, biofuels and other synthetic conversion of liquids: coal to liquids and gas to liquids) is not forecasted to cease the shortage of oil and its derivatives, and their price will continue to rise due to higher costs of production (Castro et al., 2009; Murphy and Hall, 2011). Moreover, non-conventional oils are coming from exhaustible sources too, except for biofuels. Accordingly, Jurčić et al. (2013.) stress the imperative for every nation to develop renewable energy resources. Biofuels are offering renewable energy but in very limited amounts under current technological achievements, while competing for resources that are normally being used for food production (Demirbas, 2008; Rathmann et al., 2010). Under such circumstances the reintroduction of animal traction in agriculture may look, at least, consolatory, if not reasonable. At the time of emerging energy crisis we have a method for efficient transformation of sunlight energy into mechanical work in agriculture, being widely used since ancient times until some 30 to 40 years ago - namely the horse. Horses are fuelled with cheap and broadly available fodder like hay, straw and little of grain (Harris, 1998.). The renewability of fodder production for draught horse is doubtless since such a plant production requires only the natural sunlight, at least low fertile soil and sufficient rainfall, available in the great majority of terrestrial environments of the Earth. Fitting of horse traction into a renewability scheme accords with findings of Rydberg and Jansen (2002).

3.2. The production of fodder for draught horses would not seriously compete with the production of food for humans

Biofuel production often competes with food production on arable land (Rathmann et al., 2010). Thus an important issue to consider is: What would be the share of land needed for the feeding of horses in the total cultivated area they work? The question can be answered by ratio of land area used to produce horses' fodder and bedding to the total land area horses can work. According to Morrison (1936, cit. Courteau, 2007), the farms using two teams of no more than three horses (in total 4 to 6 horses) cultivated an average of 137 acres (55 ha) of cropland, those using a tractor and four horses farmed 196 acres (79 ha), but those using only horses — eleven horses in big hitches of four or more — tilled an average of 252 acres (102 ha). The a.m. findings came out of a research carried out for USDA and which was conducted on 735 Corn Belt farms in 1929 a.d. Apparently, about 9 ha of arable land could be worked per working horse. But how much of this area is required to produce the horses' fodder? Horses normally can be fed with fodder of poorer quality than that needed for any other modern productive livestock. While the modern milking cows need the average protein content of about 16 % in their fodder and about 35 % of expensive concentrates (grains and processed soybeans), on a dry matter basis (Broderick, 2003), the working horses need only about 9 % protein and 15 to 25 % grain (oats or barley) when working, on a dry matter basis for a whole day, and about 8 % protein and no grain when idle (derived from recommendations of Fouts, 2008). The required fodder dry matter intake is about 2 % calculated from a draught horse's body weight (600 to 900 kg, depending on the breed), while the milking cow needs about 3 % dry matter intake of its body weight (600 to 700 kg). In principle, the total annual need for the horses fodder depends on the expected number of working days which may vary significantly among the farms. Based on an interview conducted with Mr. Antun Mandić, of the Vuka village of Croatia (age 81, experienced horse keeper, not published interview), a pair of working horses was efficiently used to till about 14 ha of cropland. Horses were engaged in agricultural works and transportation about 140 days per year, with an average of about 40 medium-work days and about 100 light-work days. The remaining 225 days in a year they were considered idle (kept in stall, or grazed on the village's roadside vegetation, or grass under plum orchard, etc.). There was no real heavy work for the horses in agriculture, except when they were used for logging in forestry. The total annual need for horse's fodder according to a.m. work load is about 500 kg of oats (grain), 2000 kg of lucerne hay or grass hay, and 2000 kg of straw (byproduct of cereals production) per animal. An arable land area needed to produce the required fodder can be calculated from average crops' yields reported in the official gazette for the Pannonian Croatia during the period 2005 to 2008: 2.0 to 3.4 t/ha of oats (grain) and 6.3 to 8.5 t/ha of lucerne hay (Central Bureau of Statistics, 2009.), and from reported wheat straw yields 2.3 to 7.1 t/ha (Teklić et al., 1994). Thus, for a pair (a team) of work horses about 0.6 ha of lucerne crop, 0.5 ha of oats and 0.5 ha of wheat for straw would be required. If we exclude the area for wheat straw (since the wheat is primarily grown for grain for human's food) the total required area can be estimated to 1.1 ha for a team of two working horses, traditionally used to cultivate about 14 ha of cropland. Thus the share of land used to produce fodder for the horses may be estimated at 7 to 8 % (depending on the productivity of a farmer's land and agronomy practices) in the region of Pannonian Croatia. This estimate is slightly greater than 6 % estimated by De Decker (2008), probably because of lower expected yields of fodder per hectare used in calculation, and because of a poorer utilization of horses on smaller farms. Namely, the above presented needs were calculated for a farm with a lower horse utilization (7 ha per a horse) compared to US average of 1929 a.d. (9 ha per horse). It may be interesting to mention that officially reported yields for Pannonian Croatia are somehow pessimistic, e.g. conscientious farmers realize about 30 to 50 % higher yields, thus diminishing the required area to 0.8 ha, i.e. 6 % of the total area. It's worthy to bear in mind that in lower yielding environments (low fertile soils, acidic soils in arid climate, cold climates) the share of land needed to feed the horses would be greater due to lower fodder production per area unit. Changes in the annual working load has a direct impact on the total annual needs: increasing the number of working days will increase the amount of required grain feeds only (oats, barley or maize), while the needs for roughages (hay and straw) will be kept constant.

On traditional farms in Pannonian Croatia, the working horses were kept idle in winter and were often fed considerably less than in the above presented calculation. They were often fed mainly on by-products of grain crops, like pure cereal straw, maize stover and few meagre maize cobs, thus allowing to further minimize the share of land needed to produce fodder for them (Mr. Dušan Balić of the village Dalj of east Croatia, age 60, personal communication, not published data).

Therefore, the share of arable land area required to "fuel" the draught horses may be similar to the area required to fuel the diesel-engine tractor fuelled with rapeseed 1st generation biodiesel (DeDecker, 2008).

3.3.CO_2 and GHG neutrality

The production and use of biofuels, like bioethanol and biodiesel, are increasingly stimulated by many national governments because of environmental concerns, namely to reduce the CO_2 emissions to atmosphere, since the CO_2 released from fossil fuels combustion is considered a global warming contributor – as a gas with green house effect (GHG, Rathmann et al., 2010). Regarding the production of fodder for horses, it is a function of recent photosynthesis, and all of the carbon comprised in the fodder, and subjected to biological combustion in the animal, is just shortly before "caught" from the atmosphere by crop plants. Thus the *fodder crop – horse* system features the atmospheric carbon neutral function. Despite the reduction of net

CO_2 emissions by the use of bioethanol and biodiesel, there are strong doubts nowadays regarding their green house gas (GHG) neutrality. According to Crutzen et al. (2008), those agricultural crops most commonly used at present for biofuel production and climate protection can contribute to enhanced greenhouse warming by N_2O emissions. The main cause for N_2O emissions to atmosphere is the application of nitrogen fertilizers to such crops. Considering the horses' fodder, a great part of it belongs to roughages, like various hays, which are mostly produced as legume mono-crops or crop mixtures of grasses and legumes, regarded as independent of the application of artificially fixed nitrogen fertilizers (Bukvić et al., 2013), thus avoiding the contribution to N_2O emissions. Moreover, any other horse fodder may be produced organically, where the most of nitrogen is delivered to crops by biological fixation, thus further reducing the amount of N_2O emissions. Therefore, the forage-horse system of fuelling the agricultural traction may be considered as more GHG beneficial than majority of biofuels based on arable food-crops. Additionally, relatively minor soil compaction imposed by working horses (Herold et al., 2009) provides for better physical properties of the soil thus further lowering the GHG emissions from soil (Horn et al., 1995).

3.4.Soil fertility and compaction issues

Soil's fertility i.e. it's capacity to produce a yield, is a complex trait conditioned by several determinants, which are related to the soil's ability to provide a favourable environment for plants. Among the most important determinants of the soil's fertility are: bioavailability of plant nutrients, capacity to hold water and nutrients, proper drainage and aeration to roots, and richness of soil biota (Stockdale et al., 2002). Soil compaction is one of the major problems faced by modern agriculture (Hamza and Anderson, 2005) since it threatens all a.m. determinants of the soil's fertility (Soane and Ouwerkerk, 1995; Horn et al., 1995). It is well documented that one of the main causes for soil compaction is the overuse of machinery (Hamza and Anderson, 2005). The problem becomes more pronounced along with the trend to heavier wheel loads (Van den Akker et al., 2003). The increased consciousness of the soil's crucial role in environment comes from the realization that soils are a part of soil-watershed systems acting as a buffer in cases of excessive rainfalls thus mitigating or even preventing floods (Harper, 2014), and storing the water for periods of lack of rainfall, thus mitigating drought effects on yields.

Fortunately, the policy makers in the EU and worldwide recognize soil as a vital resource under increasing pressure (Van den Akker et al., 2003) and encourage the research for mitigating the soil compaction. The research is mainly focused on highly mechanized solutions and findings provide guidelines for a better management: reduce pressure on the soil, work at optimal soil moisture, reduce the number of passes by farm machinery, confine traffic to certain areas of the field (tramlines), increase soil organic matter, impose crop rotations that include plants with deep, strong taproots, and maintain an appropriate base saturation (Hamza and Anderson, 2005). Despite these all holds true, one historical option is overlooked. Namely, horses provide a tried and tested solution to prevent soil compaction (Herold et al., 2009). Although horses can under certain circumstances impose a higher ground pressure than tractor tyres, the compaction effect is limited to the top few centimetres of the soil profile because of the comparatively lower weight (Wyss, 1999) compared to modern tractors, which in the case of a light model of 54 kW (73 hp) weights as much as 3,560 kg (Filipović et al., 2011). Moreover the pression caused by the horse's hooves is limited to spots whereas tractors cause pressure stripes. And the compression effects of agricultural machinery penetrate to much deeper zones, causing subsoil compaction (Van den Akker et al., 2003) which may occur even when the soil is very dry (Trautner and Arvidsson, 2003).

Contribution of horse traction to soil's fertility is recently confirmed through the increased yield of vegetable crops after switch to horse traction from previously mechanized one (Pinney, 2003).
Contribution via horse manure production used as a fertilizer is relatively minor (about 8 t annually per 7 to 9 ha worked, Smith and Swanson, 2013), but not to neglect since our soils chronically suffer from the lack of high quality organic matter addition.

3.5.Depreciation costs

Depreciation costs of mechanical tractors strongly depend on the total area of cropland worked. E.g. a small farm producing field crops needs a tractor of at least 40 kW (i.e. 54 HP), a farmer cultivating 30 ha of cropland needs a tractor of 60 kW (80 HP), and for a 100 ha farm two tractors are required: one of 40 kW and one of 80 kW (107 HP) (Mago, 2008). The annual depreciation for a 105 HP tractor working 450 hours/year is estimated 3,096 USD/year (Lazarus and Selley, 2005) what equalled to 2,288 EUR/year (according to exchange rate of 2005) or 17,523 HRK/year. When the annual depreciation for the 105 HP tractor is calculated in relation to the area the tractor is tilling (100 ha, Mago, 2008), the depreciation rate per hectare amounts for 22.88 EUR/ha/year or 175.23 HRK/ha/year.
Regarding the horses, the depreciation can be estimated as follows: the market price for a two year old stallion or mare of the Croatian Coldblood breed is calculated by 11 HRK (about 1.5 EUR) per kg of liveweight (Mr. Vedran Vuković of Beničanci village of Croatia, a horse-breeder for meat, personal communication, unpublished data) which is in average about 600 kg, what equals to about 6,600.00 HRK (about 900 EUR) for a head, or 13,200.00 HRK (about 1,800 EUR) for a pair (i.e. team). This meat market price is estimated to represent the costs for bringing up the horse from his birth to the age of two years when matured to agricultural work. The costs of training horses for work are not included in this price since the authors were unable to estimate them. When the purchase price is divided by 12 years of employment (Randall, 2004), the depreciation of a pair of horses equals to 1,100.00 HRK annually (about 150 EUR/year). This estimation is very close to the Randall's (2004) who estimated 91.67 USD per horse annually what equals to 1,111.00 HRK for a pair (about 145 EUR) according to exchange rates in 2004. The annual depreciation rate per hectare of cropland should thus be about 79.00 HRK/ha/year (about 10.40 EUR/ha/year) for a farm example of 14 ha (Mr. Antun Mandić of Vuka village of Croatia) or about 61.00 HRK/ha/year (about 8.04 EUR/ha/year) for the Morrison's (1936, cit. Courteau, 2007) horse/area ratio of one horse per 9 ha of cropland. The presented calculus shows the draught horses annual depreciation per hectare equals to one-third to one-half of the diesel-powered tractor of 105 HP tilling 100 ha of cropland.
Nowdays, when Croatian farmers are faced with lower prices for agricultural products due to openness to the international market, with growing prices for inputs and equipment, and with poor subsidies, the horse traction may look economically reasonable to small holders, mainly due to lower depreciation, fuel and maintenance costs.

3.6.Farm-level sustainability and organic farming issues

In Croatia small farming agriculture is still very important. Farms cultivating below, or up to 10 ha of land, hold about 377,000 ha, i.e. about 37 % of a total of one million ha of cultivated land (MPRR, 2009). Small farmers are generally facing relatively high machinery costs per unit of land area (Mago, 2007) since they are over-equipped with tractor power due to their ambition to own at least a tractor and basic equipment, even when this is economically irrational. Morrissey (2009.) has concluded that horse traction under modern conditions is still suitable for small farms since it meets more sustainability criteria than the use of a diesel-engine tractor. The sustainability criteria in favour of the working horse pointed out by Morrissey (2009) were: it offers the farmers a better economic viability, it increases their self reliance, it reduces their vulnerability when facing adverse natural and socio-economic factors and it improves the quality of life of farmers who enjoy working with horses and in a natural environment. The shift to horse traction perfectly suits organic farming systems which stress the importance of a farmers' self-reliance, of natural resources, of environment protection and long term sustainability of production and society development (Rigby and Caceres, 2001). Moreover, the use of working horses is expected to improve the profile of organically produced goods, giving them a traditional image when delivered to a farmers market by a horse wagon, which is appreciated by many urban consumers. Considering the ratio of amount of added value created on-farm and off-farm in the total value of production, the horse traction enables a farmer to participate with greater share than conventional farmer, mainly by avoiding most of the off-farm expenses which the conventional farmer has to cope with.

3.7.Work capacity and employment rate

As presented above, a pair of horses may efficiently provide all the required traction for the cultivation of 18 ha of arable crops according to USA standards of 1929 (Morrison, 1936, cit. Courteau, 2007), or 14 ha of arable crops of east Croatia in the first half of the 20th century (Mr. Antun Mandić). Work capacity of a draught horse is thus estimated at about 7 to 9 ha per animal. In order to ensure the required ratio of land area per a horse, the number of animals needed increases if the cultivated area of the farm does. A similar relation applies to tractors: the bigger the farm, the more powerful the tractor (more HP). The working capacity of a horse does not limit the production capacity of agriculture. Though, using horses instead of tractors requires more human labour, since each team of horses should be lead by one man – a teamster. This statement brings another question: does the increased use of human labour benefit a nation's welfare or not? How does it correspond to Croatian employment needs? In times of increasing unemployment in Croatia, emerging employment opportunities may look promising, since unemployment has serious psychological and social consequences. For instance, unemployment brings anxiousness, depression, discontentment with life, lowered self-respect and hopelessness to affected people (Matko, 2002), and may even lead to criminal behaviour and delinquency (Nekić, 2002). If the increased employment rate is considered beneficially than the use of horses certainly would contribute to the nation's welfare.

3.8.Trade balance and foreign debt

It is well known that negative foreign trade balance, if not financed from foreign currency reserves, may lead to increased foreign debt, even to a critical level concerning the sustainability of economy. Despite the Croatian ratio of public external debt to GDP (about 30 % in 2010, derived from Statistical Yearbook 2011, Croatian Bureau of Statistics, 2012) is considered quite sustainable (when below 60 % according to Mihaljek, 2003), the ratio of gross external debt to GDP (about 100 %) may be considered as a vulnerable trait of the Croatian economy (when above 80 %, according to Mihaljek, 2003).
Croatian agriculture driven by diesel-engine tractors contributes to national foreign trade misbalance due to its diesel fuel and lubricants consumption and to imports of tractors and spare parts. At the same time, the horse traction operates without imported fuels, lubricants and spare parts, thus relieving the foreign trade misbalance. Moreover, the use of draught horses can further contribute to foreign trade balance by attracting tourists to the rural

countryside what has the same effect as exports of goods and services. The attractiveness of rural landscape for agro-tourism purposes may be efficiently improved by the appearance of horses in carriage and field works. A significant number of North-East Brandenburg farms are offering horse-boarding facilities and farm holiday activities (Lange et al., 2013), and a frequent appearance of a horse-keeping and equine service provision represents a typical urban consumer-oriented farm adaptation strategy in peri-urban areas of Berlin and Copenhagen (Zasada et al., 2011, cit. Lange et al., 2013). Thus, a partial shift to horse traction may contribute to the enhancement of rural tourism as a component of regional and national economy as well.

4. Conclusions

It appears from this research that horse traction in agriculture shows several very important indices of sustainability, even in the 21st century, and even for developed economies, what is in line with findings of Morrissey (2009), Randal (2004) and Rydberg and Jansen (2002). The most important indices of sustainability are: use of renewable energy sources for fuelling, minimization of GHG emissions, conservation and improvement of soil fertility, enabling arable soils to buffer water excesses through preventing soil compaction and thus mitigating or preventing extreme consequences like floods and crop losses due to drought, use of locally produced fodder to fuel the traction, use of locally produced "engines" since horses are self-replicating, unlimited work capacity achieved simply by adding more horses in order to keep the required land area per animal ratio, preventing adverse social consequences of unemployment through a growing need for human labour, equalizing currently negative foreign trade balance through expected increase in sales of goods and services in agro-tourism and decrease of imports of fuels, tractors and spare parts, relatively minor depreciation cost per ha of cultivated land compared to tractorised farming and improving farm economics by reducing the operation costs and off-farm expenses. The required percentage of cultivated land that has to be confined to horse fodder production, and thus excluded from cash-crop production, may be compensated by improved soil fertility and yield stability over the years in sequence of weather extremes like droughts and excessive moist. Considering farm-level economics, the obvious minor loss of area for cash-crop production may be balanced by the farmers' increased share in the added value of farm products.

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