Agricultural mechanization - a key for future mankind welfare

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1. Agricultural mechanization and its economic roles

1.1 Enlarged responsibilities

Besides the very important function of feeding the world in the future there are additional strategic aspects of agricultural mechanization – leading in total to the following three important roles [1]:

- The classical role: mechanisation of plant and animal production, storage and processing in order to feed the planet (can also include aquaculture)
- The recently added environmental role: mechanisation of raw material & clean energy production and landscape maintenance in order to safeguard the planet
- The strategic role: mechanization to increase labour productivity in agriculture in order to free labour power for developing other areas within national economies

1.1.1 The classical role

Agricultural mechanization influences two very basic farming factors: land productivity and labour productivity.

Influence on land productivity is not dominating, however one of several important factors:

- Breeding
- Fertilizing
- Irrigating
- Plant protection
- Post harvesting methods
- Mechanization

Mechanization benefits are – for example – improved yields, higher quality levels, reduced input materials, reduced human work loads and reduced losses. The old methods of harvesting cereals (as still used in many developing countries) have often losses of 20 or even 30% (FAO) while the losses of a modern combine figure only about 1% under usual conditions.

Importance of mechanization for labour productivity is considerably higher – it is even by far dominating in this case. The impressive factors of Table 1 made it possible, that world market prices for basic agricultural products could be kept very low as compared to the labour costs and prices of many other goods. In highly developed countries, people spend today only about 10-12% of their income for buying food (beverages excluded). This figure has never been that low and food has never been offered in such a good quality – both mainly thanks to agricultural mechanization.

1.1.2 The recently added environmental role

Factors affecting a production increase of energy and raw materials are more or less similar to those mentioned above for food – with some exceptions or adjustments.

The problem is that the production of these goods reduces the available production area for food – in addition to the extra needed area for feeding animals.

These trends have led to forecasts that the total plant production increase must be higher than the population increase. Example: while an increase from 7.1 to 9.5 billion people (as expected from 2014 to 2050 by FAO) means 34%, several experts estimate a demand increase in plant
production of rather 60% or more. Gavioli states in his parallel paper only 50%, but this in case of substantially reduced losses and additionally reduced food being wasted [2].

1.1.3 The strategic role

This is the third field of responsibility of agricultural mechanization not being addressed so often, as it has nothing to due with feeding, raw material or energy, nor with animals – but it is nevertheless also very important.

The key point is that agricultural mechanisation usually can reduce the number of working people in agriculture making possible that they can become productive in other areas of the national economy creating additional added value. This leads to an increased GDP, Figure 1.

Agricultural mechanization is therefore in almost all developing countries the key technology to overcome poverty, suffering, low expectation of life, high illiteracy, high infant mortality, low level of infrastructure etc. Unfortunately political instability hampers the progress in many of poor countries, sometimes also along with religious conflicts. But nevertheless the strategic role is clear:

A low level in agricultural engineering usually means a high level of poverty.

This important relationship can be explained well by the so called Three Sector Model as initially addressed by Allan G.B. Fischer [3] and Colin Clark [4] and directly after World War II also by Jean Fourastié [5].

Some data from Fourastié (1963) have been extracted and formed in a diagram by Figure 2 for the US economy [1]. It indicates that around 1820 more than 70% of the working population had been engaged in agriculture in the United States – being now below 2% (Fig. 1).

Material of FAO, the “Country Reports” of the Club of Bologna [6] as well as international statistics and many publications confirm the message of the Three Sector Model for many countries, for example recently by a case study for Bangladesh [7].

Summarizing the future challenges I would like to underline “THE MILAN CHARTER” but expanding it to all the three mentioned roles of agricultural mechanization, Table 2.

If an adequate political stability is on hand in a developing country, the Club of Bologna can deal with key activities as summarized from my viewpoint by Table 3.

One important item of the list is technology transfer. A special highlight of the past Club activities was its role when creating the “Agricultural Handbook of Agricultural Engineering” - under the auspices of CIGR, edited by members of the Club of Bologna, printed by ASAE in USA (in six volumes). Vol. III (Plant Production Engineering) is available even in Chinese.

2. Globalization of agricultural machinery manufacturing

2.1 Expanded strategies for product development

The total turnover of the worldwide agricultural machinery production (including tractors) is estimated to be about 100 Billion € as an average of the recent years [8].

Along with the globalization, agricultural machinery business has become more and more international. This resulted in new strategies of increased world wide networking and co-operation as – for example – already 1993 addressed by the Club of Bologna [9].

While Henry Ford could capture the world market with only one tractor model – that was his famous FORDSON F (1917-28) – today’s numbers of tractor types are legion. Same for other agricultural machinery.
The extremely wide span of demanded specifications cannot be covered by a few models. This was the reason to consider and to present a classification of worldwide demanded specifications – in a first step for the example “tractor” [10]. Table 4. Five levels have been settled from “very simple” to “high sophisticated”. The challenge for the product development is to cover these “technology levels” with a minimum number of components respective a minimum number of living parts by standardized platforms and interfaces. According to my considerations of now about 15 years, a split in at least two groups of platforms is necessary. Cost benefits of platforms have been reported to the Club of Bologna for example by Gavioli for CNH [11]. Further progress seems to be necessary mainly regarding developing countries.

2.2 Upper technology levels: from simple manual control to automatic closed loop control

The “cybernetic principle” as early addressed by Maxwell 1867 [12] has been reviewed at the Club of Bologna meeting in 2012 [13], Figure 3. It defines a closed loop control in which the actual value of a process is all the time measured and fed back to enable an adjustment to a given target. This type of control is usually more productive than a manual open loop control, saves energy and offers – in addition – a higher comfort level as the driver is unburdened from the duty of permanent human action. The strong technical trend in this direction is typical for the upper technology levels. It enables modern “precision agriculture”, based on:

- The enormous general progress in digital IT technologies regarding functions, costs, availability and reliability [13 - 18].
- New IT-friendly components with interfaces for digital CAN BUS control and information systems [17].

A vision of completely integrated IT technologies in agriculture has been demonstrated around 1995 by Club of Bologna members Auernhammer and Schueller, for example documented 1999 in the CIGR Handbook Vol. III [18] on page 599, Figure 4.

The tremendous IT penetration offers basic holistic benefits for the farmer regarding:

- Productivity
- Process quality
- Product quality
- Traceability
- Environment protection
- Energy efficiency – CO2 reduction
- Safety and comfort
- Farm management

Because of this megatrend in agriculture and agricultural mechanization, the well known CIGR Handbook, Volume I to V [19] was completed in 2006 by Volume VI [20] offering a comprehensive survey on all important aspects of information technology in agriculture.

2.3 The role of legal acts and standards

Some legal acts have been very successful safeguarding human health - three examples may be listet [21]:

- The introduction of rollover protection structures which could reduce the number of fatalities in Germany by about 95% – similar in other countries.
- The noise reduction at driver’s ear within cabs could be reduced from about 100-105 dB(A) to now only 70-75 dB(A) for full power/OECD - eliminating the risk for hardness of hearing which has been before a huge problem.
- Diesel engines of tractors and mobile machinery which could arrive in 2015 at almost “zero emission” within EU and USA [21, 22].
ISO standards replace more and more national standards [23, 24] thus being able to better support global progress of agricultural mechanization in several aspects:

- by improving international *machinery development* (distributed production)
- by improving international *machinery use* due to better *compatibility* for the farmer – even often when combining old and new machinery (PTO, 3-point hitch, drawbar, …).
- by *technology transfer* to developing countries (large know how tank).

The *Club of Bologna* has been working on all these items for now 26 years – supported by UNACOMA and later on by FederUnacoma. The Club could develop basic recommendations and guide lines for agricultural mechanization and a comprehensive global network simplifying any kind of co-operation.

3. Conclusions

Agricultural mechanization has been and still is a key driving force of human civilization. The huge reduction of labour costs could keep the prices low for staple food such as cereals. In addition, whole economies could benefit from increased labour productivity as people could be transferred for value adding outside agriculture reducing poverty and increasing national welfare in all areas of the economy. This is still an important goal for developing countries and underlines the mission of the *Club of Bologna*.

The era of production surplus ended more or less with the 21st century – further population increase must now be met by food production increase. This must even be higher than the population growth due to expected higher proportions of meet, energy and raw materials and expanded duties of environmental protection as addressed by THE MILAN CHARTER. Facing the dramatically widened required technologies and power levels within the past decades, product planning and production of machinery has to be structured globally meeting the wide span of locally needs by appropriate technology levels and platform strategies.

References


Table 1: Increase factors of productivity by mechanization, status 2008 [1]

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Factor</th>
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</thead>
<tbody>
<tr>
<td>Milking machine</td>
<td>factor 15</td>
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<tr>
<td>Two horses ploughing</td>
<td>25</td>
</tr>
<tr>
<td>Small tractor ploughing</td>
<td>50</td>
</tr>
<tr>
<td>Multi purpose tractor mowing</td>
<td>500</td>
</tr>
<tr>
<td>Large tractor ploughing</td>
<td>1000</td>
</tr>
<tr>
<td>Large combine</td>
<td>4000</td>
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</tbody>
</table>
**Figure 1:** Employment in agriculture in relation to the total number of working people and corresponding GDP. Sources: FAO, World Bank, publications, personal contacts and estimations.

**Figure 2:** Economy development of the United States by sectors [1] - data from Fourastié [5]

**Table 2:** Consequences of a low level in agricultural mechanization
- high level of poverty
- low food quality, high prices
- low fresh water availability/quality
- low level of general infrastructure
- high illiteracy, low level of education
- low expectation of life
- high infant mortality
- low interest of investors
- high risk of emigrations

Table 4: World wide demanded specifications for agricultural tractors, classified by five technology levels, proposal Renius 2002 [10].

<table>
<thead>
<tr>
<th>Technology level</th>
<th>Nominal engine power (40–80 kW)</th>
<th>Wheel drive</th>
<th>Diesel engine</th>
<th>Drive transmission</th>
<th>PTO</th>
<th>Hydraulics</th>
<th>Cab</th>
<th>Electronics</th>
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<tbody>
<tr>
<td>I</td>
<td>Low</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>II</td>
<td>Medium (40–80 kW)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>III</td>
<td>High</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>(X)</td>
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<td>V</td>
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Figure 3: Closed loop control as a key technology for automation in agriculture.

Figure 4: Integrated farming system with IT penetration, vision of Auernhammer and Schueller, documented for example 1999 in [18].