Agricultural machinery driving force of human development

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1. Introduction

The great debate - opened by EXPO Milano 2015 "Feeding the Planet, Energy for Life" on the future of food in the world and the right of everyone to access adequate, safe and appropriate food to meet nutritional needs – clearly highlighted that world food production will have to be increased by 60-70% in the next thirty-five years.

The achievement of this goal is clearly linked to a similar increase in agricultural production and to this end, nowadays there are only two possible alternatives: increasing the average yield of existing arable lands or extending arable land surfaces.

It is quite evident that the latter solution is not feasible both for limited availability of available land and for the serious consequence in terms of further reducing the planet's green resources and the heritage biodiversity that they represent.

Therefore any future strategy to environmental sustainability of farming processes entailing the adoption of cultivation techniques that can reduce the yield per hectare is in stark contrast with the aim of ensuring adequate food supplies to feed the 9 billion people by the year 2015 as well as with the aim of protecting the world's dwindling green areas.

It is a global challenge in which we must maintain and spread the high value of crop production achieved by the most advanced agriculture, respecting the environment and preserving the planet resources. At the same time, particularly in the less advanced regions, we must provide a growing population with the means to produce the food resources they need.

In both cases, agricultural machinery and mechanization play a key role. The use of modern technologies in agricultural machinery enables the production of food in a sustainable and safe manner in industrialized countries, while the development of simple and cost-effective machines constitutes the first step in promoting food security in developing countries.

2. Road to mechanization

2.1. Driving force of human civilization

In the long course of human society, which began 10,000 years ago with the discovery of agriculture and livestock husbandry, the development of more efficient agricultural tools has been for thousands of years the main driver of growth and development.

Considering that survival and economic development were strictly connected to agriculture, the first pioneering efforts of the human mind have been totally dedicated to the creation of tools and implements such as hoes, sickle etc. able to facilitate the farming operations.

These tools allowed the increase in production capacity of the individual, making available a surplus of food that freed a workforce for the development and growth of different sectors, thus causing the gradual evolution and economic growth of society.

We can therefore assert that agricultural engineering – in its earliest and simplest forms – was the first technological innovation that radically changed the life and the structure of the human community and it may be properly considered to be the mother of all subsequent innovations that have led to the technological level in today's society.

Agricultural production and related technologies remained substantially unchanged for many thousand years and we must wait until the Middle Ages in order to see significant improvements in agricultural techniques and technologies.

In this period of time a considerable development of handcraft and iron working led to the dissemination of several technological innovations. The production of agricultural hand tools grew greatly and the plough was significantly improved – developing from the ancient symmetrical wooden plough into the mouldboard plough capable of turning over the heavy, wet soils of northern Europe.

In 1700 the advent of the Enlightenment produced a sea change in human thought which led to the birth of modern scientific thought. Reason and experience became the driving forces in the process of knowledge advancement laying the foundations of science's great journey that has so profoundly changed the men's way of life.

Equally radical was the evolution of agricultural engineering which sees a substantial transformation of the technical means evolving from simple "tools" to "machines" with mechanisms able to perform a specific task.

A major contribution to provide the basis for modern mechanization comes from the English agricultural pioneer Jethro Tull that, at the beginning of 1700s, designed the first horse-drawn seed drill able to sow seed in uniform rows and cover up the seed in the rows.

Thus began the dramatic development of mechanization of the last three centuries that led to a more than hundredfold increase of human labour's productivity, reducing employees in agriculture to 1-2% of active population in the more industrialized countries.

3 - The role of mechanization to feed the world

3.1 Mechanization after the Industrial Revolution

The extraordinary development of the last three centuries is well-known: the Industrial Revolution of the 1800s and the Green Revolution of the second half of last century have completely transformed the social structure and the agricultural production system.

This unprecedented growth of agricultural productivity on a global scale has been driven by the joint action of scientific discoveries in the agronomy field and by the development of agricultural engineering technology that has made available even more powerful and efficient machines and equipment.

Thanks to the development of mechanization productivity, human labour has increased by several thousand times (**Table 1**) with a huge progress in the quality and timeliness of agricultural field operations.

Mechanization – combined with the advancement of knowledge and technological innovations introduced by genetics and biosciences – has led to a substantial increase in the production per unit area, so to obtain an equivalent aggregate of crop production in 2012 only about 32% of the arable land needed in 1961 was required (**Figure 1**).

The experience of industrialized countries clearly shows that agricultural productivity growth is the key to overall economic growth, because it releases labour and land resources to support development in other sectors such as manufacturing, trade and services.

Advanced farming in industrialized countries highlights how the aim of gaining higher yields using fixed land and water resources can be achieved through mechanization. In 1960, one farmer in mechanized countries fed 25 people with an average arable land of 0.70 ha/person and today one farmer can feed 145 people using 0.48 ha/person of arable land.

This has led in the last 45 years to eliminate the problem of hunger in industrialized countries and to reduce from 30% to 11% in the proportion of undernourished people in developing countries, although in the meantime the world's population has approximately doubled (**Figure 2**).

3.2 Challenges for the mechanization of the next millennium

Following this uninterrupted process of growth and modernization, mechanization has reached the goal of maximizing the production capacity of human labour and it is now preparing to face the challenge of the third millennium: producing food in a sustainable and environmental friendly manner.

The 2014 Combine Harvesting World Record – recording an average throughput of 99.7 t/h with a fuel consumption of 1.12 litres per ton – gives full evidence of the huge level of efficiency achieved by the modern mechanization as well as the progressive and constant reduction of fuel consumption (**Figure 3**) that was reduced to about one third in fifty years.

The huge development of Information Technology in recent decades is gradually transforming machine from pure tools to increase work capacity of human action into "smart" devices able to know the place where they operate and to adapt to them.

Four are the key features of the new smart mechanization:

- Global Navigation Satellite System (GNSS), a satellite constellation system able to provide accurate positioning data on the field
- Remote sensing and proximal data gathering
- Electronic sensors and automation allowing automatic control systems for operating machinery and implements
- Computer science for information processing

All together they have led to the development of the so-called Precision Agriculture.

Precision Agriculture is a farming management approach based on optimization of machine operations according to the local needs and the characteristics of the crops in order to optimize the use of inputs reducing environmental impacts.

The capacity of modern machines to fit their functional parameters – while respecting with great accuracy the needs of crops and soils, thus limiting to the bare minimum the use of inputs – is a key step towards agriculture environmental sustainability.

The possibility to tailor in a site-specific way chemical and fertilizer application using prescription maps together with advanced systems of automatic machine guidance and operative control is a major step towards sustainability of agricultural production in industrialized countries.

The Variable Rate Applications may reduce fertilizers and pesticides distribution from 10% to 50%, depending on crop and conditions, while high accuracy Automatic Guidance Systems avoids overlaps between passes and increases the working speed, thus reducing by 5-10% both fuel consumption and chemical application.

Precision Agriculture methods are developing rapidly in the water management systems (Precision Irrigation) as well in order to save water, increase yields and improve quality. Spatially varying the water application across the field to match the specific soil and crop conditions allows important water saving from15% to 40%.

2.3 Mechanization for food security

No less important is the contribution that the development of an appropriate mechanization can provide to help the economic growth of the areas where there are still serious problems of poverty and undernourishment (**Figure 4**).

Well-known are the tremendous benefits that can be achieved by farm household with the help of agricultural mechanization in order to:

- Increase efficiency and productivity of agricultural production
- Reduce post-harvest losses
- Increase added value to agricultural raw material
- Maintain the integrity and quality of farm products

The experience of countries that have succeeded in reducing hunger and malnutrition shows that economic growth originating in agriculture, in particular among small farmers, is more than twice as effective for the improvement of general living conditions than what comes from all other sectors.

Many successful examples show that whenever agricultural mechanization strategies have been tailored to local needs and social conditions and integrated into broader agricultural policy approaches, they have proven successful in supporting farming and rural development.

3.4 A new approach is needed

Notwithstanding the foregoing, the present level of attention and commitment by the international organizations and governments to promote research and development in the field of agricultural mechanization, and more generally of agricultural sciences, is comparatively low.

The European Research Council (ERC), public body of EU aiming to provide Europe with the capabilities in frontier researches necessary to meet global challenges, publishes a detailed list of research sectors across all fields of sciences. Out of a total of 339 mentioned research topics, the term "agricultural" appears in only two of them, while any other terms related to agricultural science and food technology are totally missing!

This is a clear index of how the theme “Feeding the planet” has been a somewhat neglected element in research policies of the recent decades.

In light of this and of the key role that agricultural mechanization plays in ensuring sustainability in highly productive farming systems and in making farm operations more productive and efficient in developing countries, the central role of agricultural production system must be recognized and research in the area of agricultural machinery and mechanization must be considered a strategic priority.

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Table 1 – Increase of work productivity due to mechanization

	HAND	MECHANIZED	FACTOR
Soil tillage	10 m^2/h	10,000 m^2/h	x 1,000
Wheat harvesting	10 kg/h	50,000 kg/h	x 5,000

Figure 1 – To produce an equivalent aggregate of crop production (PIN=Production Index) in 2012 required only about 32% of the land needed in 1961

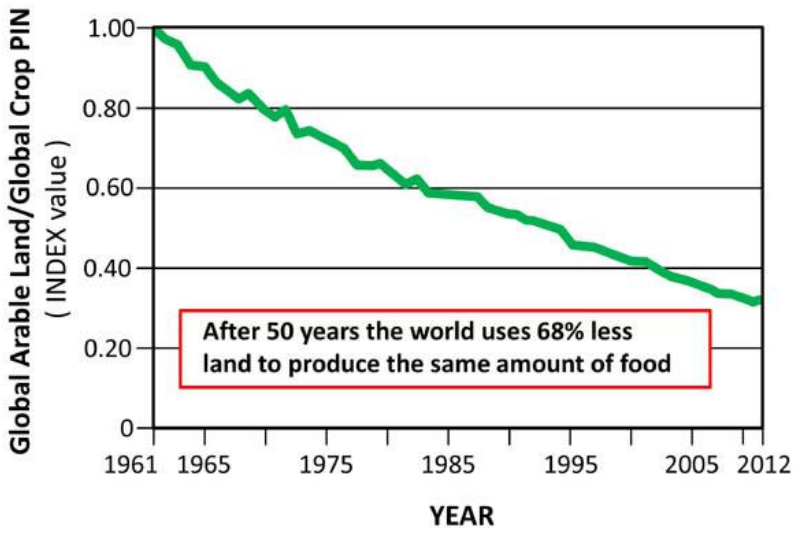

Figure 2 – Undernourished people in developing countries declined from over 30% to 11% in the last forty-five years

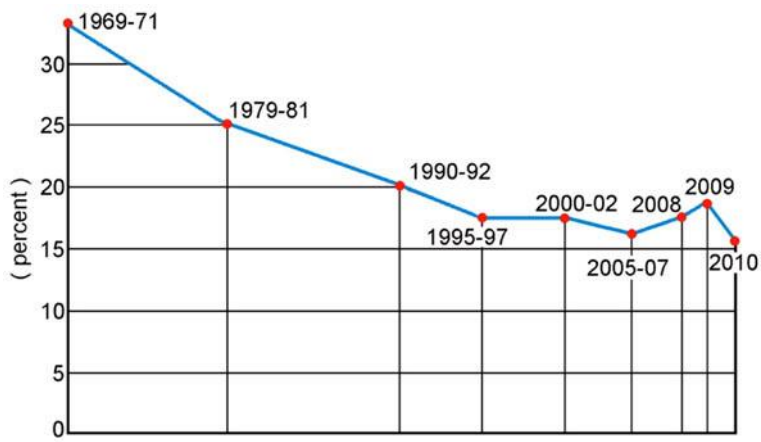

Figure 3 – From 1957 the fuel consumption per ton of wheat has fallen to one third

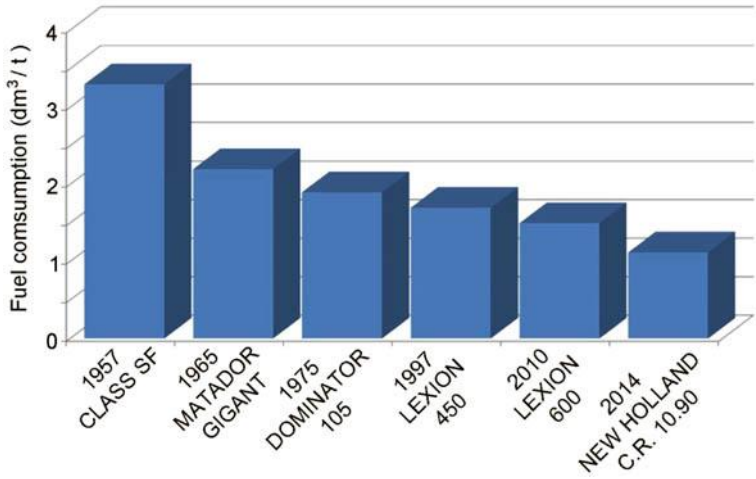

Figure 4 - The economic development of a country is always linked to the development of mechanization because it relise labour to support growth in other productive sectors