Agricultural mechanization - a key for future mankind welfare

by *Karl T. Renius*, GERMANY

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 processsing 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 develop-ment 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 unbur-dened 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 – CO_2 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

[1] **Renius, K. Th.**, 2008: 50 Jahre Agrartechnik im VDI – ein Stück Landtechnikgeschichte. (50 years of agricultural engineering within VDI – a piece of agricultural engineering history). Jubilee Lecture at University of Hohenheim 25.09.2008. Full paper in: Der Goldene Pflug **Vol. 28**, p. 4-12. Soc. Museum Hohenheim 2008.

[2] **Gavioli, G.,** 2015**:** Farm of the future. Open Meeting of the Club of Bologna "Farm Machinery to feed the World". EXPO Milan, Teatro della Terra, Sept. 21, 2015.

[3] **Fischer, A.G.B.**, 1939: Production – Primary, Secondary and Tertiary. The Economic Record **Vol. 15**, Issue June, p. 24-38.

[4] **Clark, C.**, 1940*:* The Conditions of Economic Progress. London: Macmillan.

[5] **Fourastié, J.**, 1949 and 1963: Le grand espoir du XXe siècle. Paris. German translation of the 2nd edition by K. Düll und D. Kreuz. Köln: Bund-Verlag 1969.

[6] **Pellizi, G. and M. Fiala** (Editors), 1992: Agriculture, Mechanisation and Manufacturing Facilities in 30 Countries (1970-88) - also called "Country Reports." Club of Bologna, 4th meeting 4.-5.11.1992 Bologna.

[7] **Ziauddin, A. T. M. and Z. Tasnia**, 2014: Present Status of Agricultural Mechanization in Bangladesh. AMA **Vol. 45**, No. 2, p. 30-39.

[8] **Wiesendorfer, G. at al**., 2015**:** Wirtschaftsbericht VDMA Landtechnik (Economic and financial VDMA report on agricultural machinery). Frankfurt: VDMA Landtechnik.

[9] **Kitani, O.**, 1993: Globalization of Agricultural Machinery Production through International Joint Venture. Intern. Conf. for Agric. Machinery & Process Engng. Oct. 19-22, 1993. Seoul, Korea. Proceedings p. 11-17.

[10] **Renius, K. Th.,** 2002: Global Tractor Development: Product Families and Technology Levels. Plenary paper at 30. Symposium Actual Tasks on Agricultural Engineering, Opatiya 12.-15.03.2002. Proceedings p. 97-95.

[11] **Gavioli, G.,** 2004**:** Cost benefits of the Platform Principles for Tractors and other Agricultural Machinery. Club of Bologna 15th meeting Nov. 12-13. http://www.clubofbologna.org/documents.php (p. 35-40)

[12] **Maxwell, J. C.,** 1867: On Governors. Proceedings of the Royal Society of London, No. **16**, 1867/1868, S. 270–283.

[13] **Isidori, A.**, 2012: Automatic control in agriculture. Club of Bologna 23th meeting, Nov. 9-10, 2012. http://www.clubofbologna.org/documents.php

[14] **Auernhammer, H.** 1989: The German Standard for Electronic Tractor Implement Data Communication. 2nd Intern. Conf. AGROTIQUE Bordeaux. Proceed. p. 395-402.

[15] **Auernhammer, H.,** 1993: Requirements for a Standard for Tractor Implement Communications. ASAE paper No. 93-153, St. Joseph, MI, USA.

[16] **Auernhammer, H.,** 1997: The role of electronics and decision support systems for a new mechanization. Club of Bologna 8th meeting Oct. 30 - Nov.1, 1997. http://www.clubofbologna.org/documents.php (p. 67-85)

[17] **Schueller, J. K. and B. A. Stout**, 1995: Agricultural trends and their effects on technological needs for farm equipment in the 21st century. Club of Bologna 6th meeting, Nov. 6-8, 1995. http://www.clubofbologna.org/documents.php

[18] **Auernhammer, H. and J. K. Schueller,** 1999**:** Precision Farming. In: CIGR Handbook of Agricultural Engineering **Vol. III**, S. 598-616. Edited by CIGR. American Society of Agric. Engineers, St Joseph MI, USA.

[19] **Kitani, O. et al** (Editors), 1999: CIGR Handbook of Agricultural Engineering, **Vol. I** to V. Edited by CIGR. American Society of Agric. Engineers, St Joseph MI, USA.

[20] **Munack, A.** (Editor), 2006: Preface. CIGR Handbook of Agricultural Engineering **Vol. VI:** Information Technology. CIGR and ASABE - American Society of Agricultural and Biological Engineers, St Joseph MI, USA.

[21] **Renius, K. Th.,** 2009: Tractor innovations and sustainability. Club of Bologna, 20th meeting Hannover, Nov. 8, 2009. http://www.clubofbologna.org/documents.php.

[22] **Dietrich, F.**, 2010: Europäische Abgasrichtlinie Mobile Maschinen & Traktoren - Aktueller Stand (European emission regulation for mobile machinery – present stage). Frankfurt: VDMA Referat Verkehr 18.10.2010.

[23] **Gasparetto, E. and D. Pessina,** 2013: Past and present of agricultural machinery standardisation. Club of Bologna, 24th meeting Hannover, Nov. 11-12, 2013. http://www.clubofbologna.org/documents.php.

[24] **Alt, N.:** International agricultural machinery standards for the benefit of agriculture and industry. Club of Bologna, 24th meeting Hannover, Nov. 11-12, 2013. http://www.clubofbologna.org/documents.php.

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

- Milking machine …….……..…….....	*factor* 15
- Two horses ploughing ………………….....	25
- Small tractor ploughing ...…………….....	50
- Multi purpose tractor mowing ……...….	500
- Large tractor ploughing …………….....	1000
- Large combine …………………………..	4000

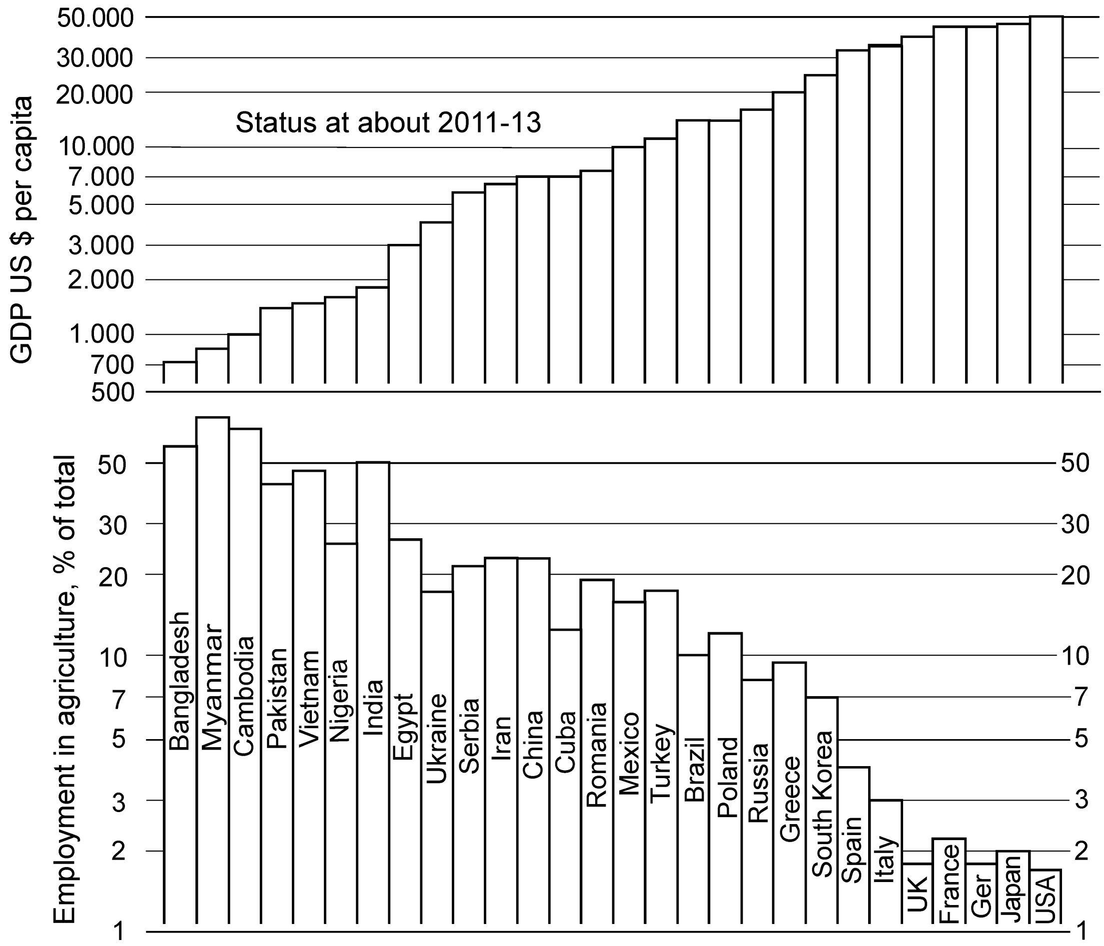

GDP US $ per capita
50.000
30.000
20.000
10.000
7.000
5.000
3.000
2.000
1.000
700
500
Status at about 2011-13
Employment in agriculture, % of total
50
30
20
10
7
5
3
2
1
Bangladesh
Myanmar
Cambodia
Pakistan
Vietnam
Nigeria
India
Egypt
Ukraine
Serbia
Iran
China
Cuba
Romania
Mexico
Turkey
Brazil
Poland
Russia
Greece
South Korea
Spain
Italy
UK
France
Ger
Japan
USA

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.

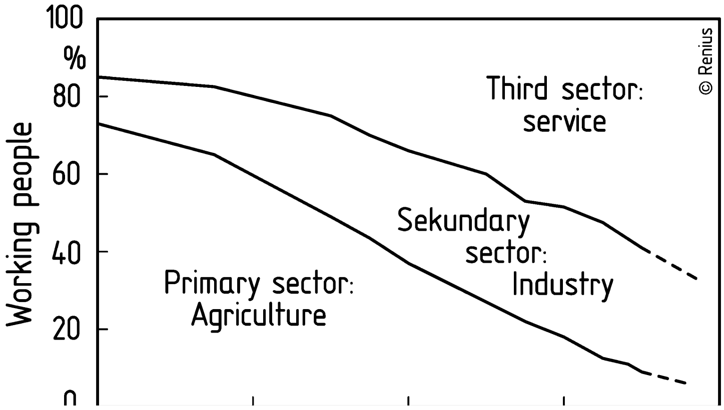
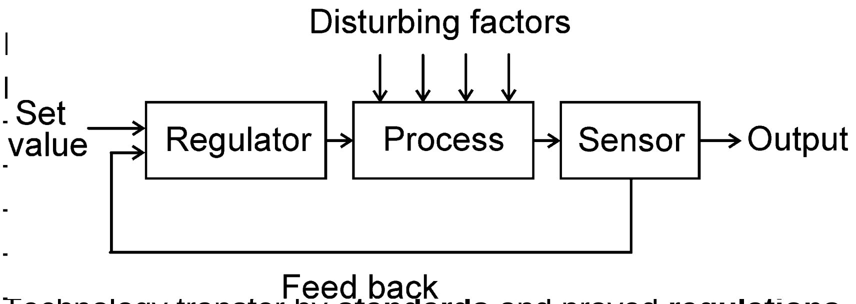


Table 2: Consequences of a low level in agricultural mechanization

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

- 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 3: Lower technology levels: Seven key points for supporting agricultural mechanization in developing countries – proposed as a continuing mission of the *Club of Bologna*



- Technology transfer by **standards** and proved **regulations**

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

	Nominal engine power			Wheel drive			Diesel engine					Drive transmission					PTO			Hydraulics				Cab			Elec-tronics		
Technology level	Low	Medium (40–80 kW)	High	Only rear-wheel drive	Four-wheel drive opt.	Four-wheel drive stand.	1 Cylinder	2 Cylinder	3 Cylinder	4 Cylinder	6 Cylinder	Very simple	Simple	Partial power shift	Full power shift	Infinitely variable	540/min	540 and 1000/min	3 or 4 speeds	Rear 3-point hitch	Remote Control	Rear & front 3-p. hitch	Load Sensing circuit	No cab	ROPS / low cost cab	Comfort cab	Not existing	Low cost concepts	High tech concepts
I	X			X			X	X		X		X					X			X				X			X		
II	X	X			X			X	X	X	X		X					X		X	X			X	(X)		X	(X)	
III		X	(X)		(X)	X			X	X	X			X				(X)	X	X	X	X			X	(X)		X	(X)
IV		X	X			X			(X)	X	X			X	X				X	X	X	X	X			X			X
V		X	X			X				X	X					X			X	X	X	X	X			X			X

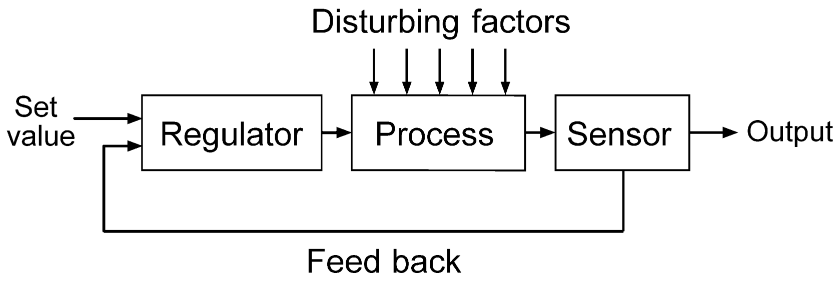


Figure 3: Closed loop control as a key technology for automation in agriculture

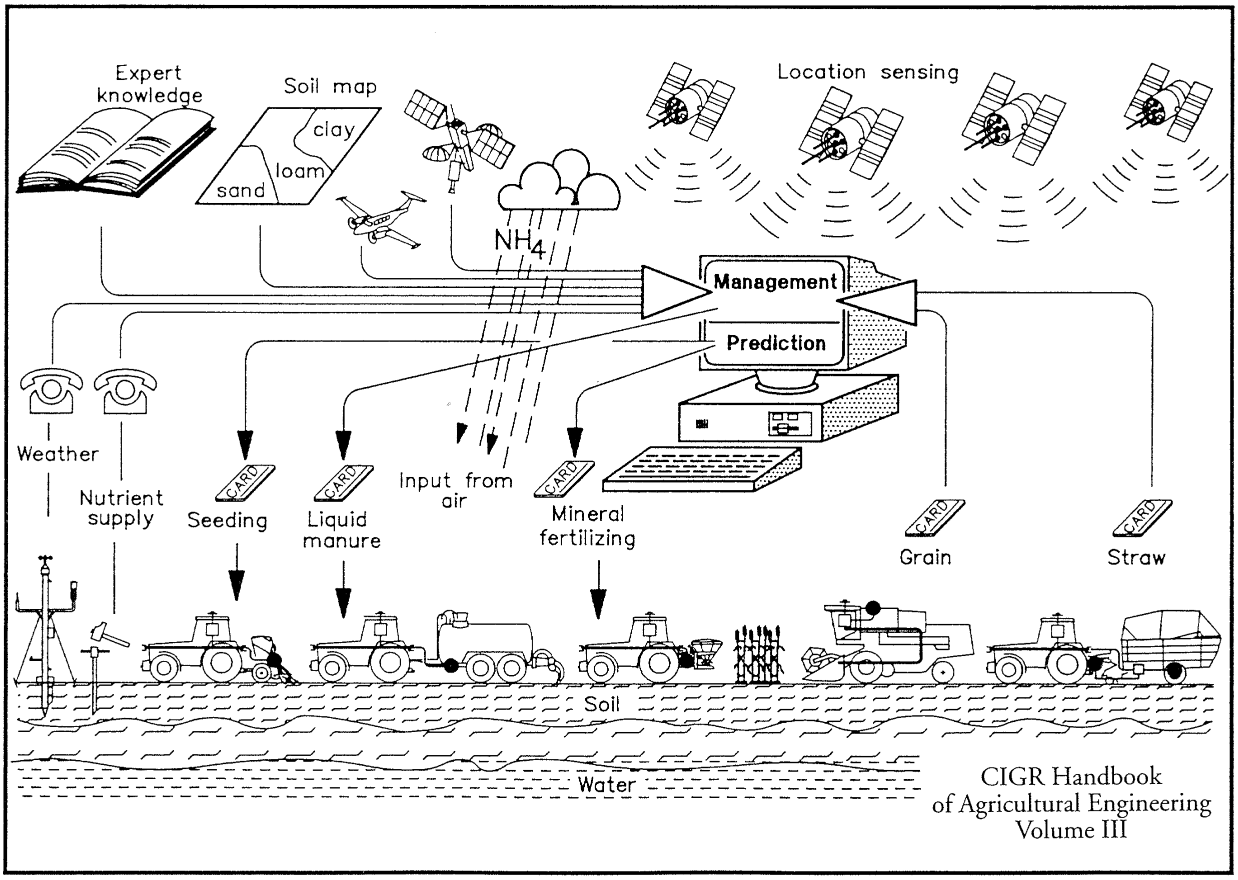


Figure 4: Integrated farming system with IT penetration, vision of Auernhammer and Schueller, documented for example 1999 in [18]