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Agriculture in the 3rd millennium : new challenges and current trends in the agricultural engineering profession

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Agriculture in the 3rd Millennium: **New Challenges and Current Trends in the Agricultural Engineering Profession**

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Abstract. *Agriculture is embedded into global trends, national legislation, and public demands. The paper starts with a collection of mainstream needs and global trends. Furthermore, the demands on agriculture, formulated by different groups, are compiled. Agricultural engineering can contribute to sustainable (competitive, protecting the environment, socially compatible) production techniques by design of intelligent machinery (mechatronics) and applications of biological engineering. Some examples from animal husbandry (voice analysis; computerized air flow simulations) are presented. Applications in communication and energetic use of agricultural products are addressed, too.*

Keywords. Agriculture; environment; future development; European viewpoint; communication; energy from biomass.

Introduction

This paper is intended to present ideas concerning the future development of the Agricultural Engineering profession from the viewpoint of an inhabitant of a nation of the European Union (EU). This viewpoint is both quite different from those of other developed regions as well as of developing regions. The European, or EU, way may be characterized by a high degree of striving for sustainability, quality of products, animal protection, and a high technological standard.

Of course, there exist differences among the member countries of the European Union, and large differences are observed in comparison to the candidate countries that joined the EU most recently or will do so during the next years. However, these topics cannot be addressed in detail here. Moreover, the paper deals with the main current EU aspects and, in particular, some specific German topics. Before going into these details, global trends will be addressed, and demands on agriculture will be deduced from these. To some extent, the presentation follows earlier publications, cf. Munack (2001) and Munack (2002).

Mainstream needs and global trends

Main demands from the human society concerning agricultural production are the following:

- production of food, energy, and raw materials for a growing world population with growing demands,
- application of sustainable technologies,

- assurance of high quality within the whole production chain.

Besides these direct, or mainstream, needs there exist various global trends that also have a large impact on agricultural production. These are:

- rural production becomes more industrialized,
- capital, production, and trade are becoming more and more globalized,
- information technology is becoming used in all areas of life,
- a technological shift is happening through biotechnology and genetic engineering.

The latter two trends have already opened new facilities for production processes, are in the process of doing so, or will influence future production. Of course, a big impact of these new technologies on agriculture-related research could be observed during recent years, too. The first trend influences the technology of production processes as well as their location, capital-intensity, and throughput capacity – also the amount of labor that is needed for production. The globalization is a trend that less affects the research area but more the development and production of machinery. However, new research programs of the EU encourage to combine the research work of different national organizations in order to found real or virtual European research centers or networks of excellence.

Demands on agriculture

In the following, the demands on agriculture that are imposed by different groups will be collected and discussed.

The society asks agriculture for competitiveness, protection of the environment, and social compatibility. Although the weights associated with these three aspects may be different, one can state that the combination of these aspects is commonly referred to as sustainability. The first commonly accepted definition for sustainable development was given by the Brundtland commission: *"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs"* – Brundtland (1987). For an assessment of the degree of sustainability of a process or a whole process chain, indicators are needed. These are currently elaborated and discussed, based on the existing environmental indicators, e.g. the OECD Pressure-State-Response (PSR) Indicator System, cf. OECD (1991/93).

The consumers want qualitatively excellent products at low prices, all over the year; palatable, healthy and nutritious food; nice landscape with no disturbance by noise or odor. Some of the consumers prefer products that can be traced back to their origin. The percentage share of consumers who are willing to pay for traceability is not clear. However, in case of health problems caused by food, the consumers take such a trace-back opportunity for granted.

The industry's demands on agricultural production can be summarized as: high-quality, low cost, food and raw materials; renewable resources (for energetic and material use); pharmaceutical products (GM plants and animals). The different shares of the addressed agricultural products (foodstuff, energy, and raw materials) will depend on market demands and profitability. In order to feed the growing world population, the non-food sector could globally become less attractive in the future. In Europe, however, where over-production of agriculture is a major topic, the energy sector is highly attractive since it offers an opportunity to reduce the emissions of greenhouse gases.

Which are the demands of farmers? They want a participation in general increase of income; labor safety and reduction of working time; clear and reliable legal principles for further development of the farm.

The demands of politicians on agriculture can be stated in case of the German government (a red-green coalition) as follows: promotion of organic farming (where a share of 20 % in food production is striven for); high standards for animal protection; raising food security and food quality (protection of consumers); securing environmental protection; promotion of sustainable production processes in farming, fishery and forestry.

Global politics, as e.g. pronounced by the FAO, demand for securing the feeding of the growing world population and a reduction of emissions of greenhouse gases.

The European Union demands for much of the above stated and puts a stress on environmental protection, in particular reduction of the trans-border nitrogen transport. For the latter, nitrogen flows (through the air as NH_3) are calculated and plans are made to tax these flows. Furthermore, a decoupling of the amount of subsidies from the production quantity is going to be realized.

The above exemplary and incomplete compilation shows that the demands on agricultural production are manifold and cannot be summarized in a few short headlines. Nevertheless, an attempt will be made in the following to demonstrate suitable technical means for agricultural production and environmental protection in order to meet the majority of the demands.

Technical means for agricultural production and environmental protection

Plant production

The most advanced technical tool for plant production is site-specific treatment. This is a bundle of measures which can be collected under the topic "Precision Agriculture" (or "Precision Farming"), and it refers to preparation, sowing, fertilization, irrigation, weed and pest control, and harvesting. The future technical realization is not yet clear. It could evolve into large gantry-type systems that carry small subsystems, which perform all the sensing and acting tasks. Other prognoses are in favor of small autonomous vehicles with one tool each that drive across the field, cf. e.g. Blackmore et al. (2001) or Claessens et al. (2002).

Animal production

The second part of Precision Farming lies in animal production. In former times, when the farmer knew each single animal of his herd, animal-specific treatment was the usual way of husbandry. This was lost while enlarging the herds and employing more staff. Now, animal-specific husbandry can be re-installed by means of microelectronics. The main tasks performed are feeding, weighing, milking and milk inspection, optical inspection, and health care. For the latter, there exists a very ambitious research direction, i.e. sound or voice analysis for animals, cf. Ikeda et al. (2000), as well as Jahns and Walter (2002).

A spectrogram of the vocalization of a cow in case of hunger is shown in Figure 1. The characteristic frequencies of the cow can easily be seen at the lower frequency spectrum. They remain constant for the whole course of the call. For an interpretation of the meaning of the call, a detailed analysis of the time course of the spectrum is necessary. Hidden Markov Models have proven to be a powerful tool for modeling and interpretation. Details can be found in the references. A future application may lie in opportunities for rapid detection of diseases, leading to reduction of prophylactic medication. A further application – if possible – is the control of animal transports. Whether this aim can be reached is very uncertain, since in this case calls of unknown animals must be interpreted, leading to the fact that no training data are available. However, it's a real challenge!

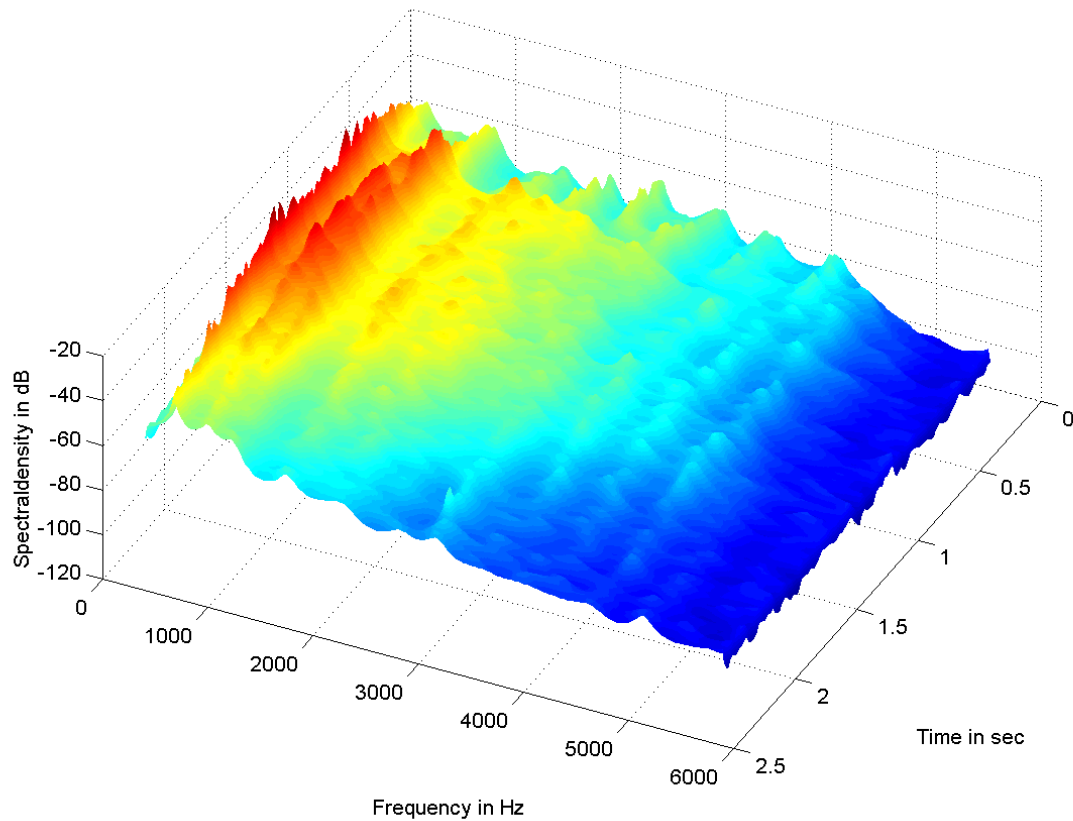


Figure 1: Spectrogram of the vocalization of a cow in case of hunger

Environmental protection

In animal production, the reduction of gaseous and dust emissions, as well as corresponding immissions is a further urgent task. Contributions to solutions are possible from various sides. Precision feeding with reduced nitrogen content is such a possibility. Technical means are the construction of the housing system with emphasis on low emissions, cf. Krause and Janssen (1990); filtering of outlet air, cf. Hahne and Vorlop (2001); covered manure storage, see Döhler et al. (1997); manure distribution close to the ground, see Döhler et al. (1997), too.

The above cited technical means mainly refer to reduction of emissions. However, with respect to immissions, the contour of the surrounding of the animal house, the wind direction, speed, and turbulence class must be considered in addition. This necessitates CFD (computerized fluid dynamics) simulations of the farm and its surrounding. Figure 2 shows such a simulation for one situation of wind conditions; more detailed information can be found in Krause and Linke (2002). The marked area is the iso-area of odor recognition threshold, i.e. $3 \text{ OU} \cdot \text{m}^{-3}$ ($1 \text{ OU} \cdot \text{m}^{-3}$ is the detection threshold). Without such (still) time-consuming simulations, in many cases an extension of agricultural activities would become impossible, in particular in central Europe with its high density of population.

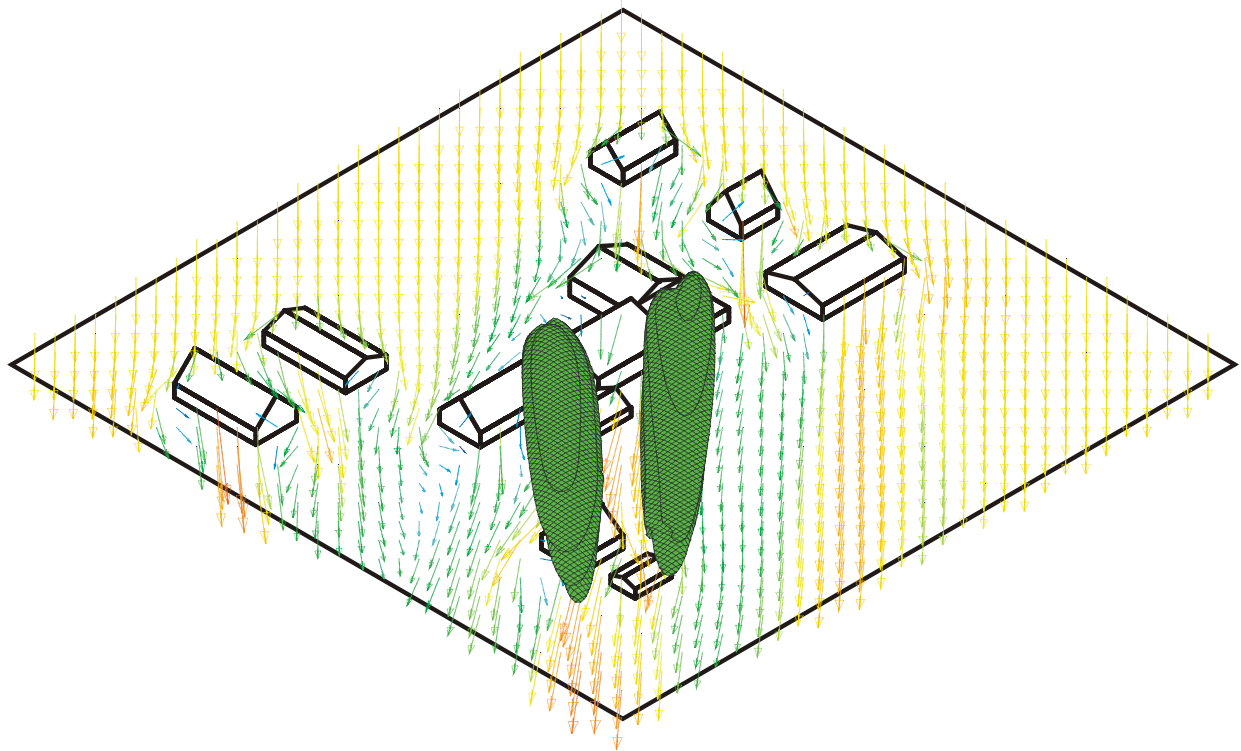


Figure 2: Immission around animal stables; the marked area is the iso-area of $3 \text{ OU} \cdot \text{m}^{-3}$

Communication

A high amount of information flows that is associated with product flows makes necessary a compatible data exchange. This was developed in Germany several years ago as agricultural bus system (LBS) and its standard is documented within DIN 9684 (1989-1998). It includes the standard for the physical connector and the transport protocol; standardized system functions, services, and messages (the network management); a flexible standard for a human/machine interface; and it includes a standard for the information exchange with a management information system. In the meantime, an ISO working group is formulating a corresponding international standard, ISO 11783. This work is of outstanding importance for compatible data exchange among subsystems from different manufacturers and has comparable dimension as the standardization of the three-point hitch some decades ago.

Energetic applications

Agriculture can contribute to reduce the energy dependence from fossil sources. Today, mainly the fuel substitution by ethanol (Brazil) or the application of diesel fuel substitutes derived from plant oil have become industrial reality. In Germany, biodiesel consists of rapeseed oil methylester (RME) that is sold as neat fuel (B100) at more than 1,700 fuel stations (this amounts to approximately 10% of the German fuel stations). The price is currently about 10% lower than that of fossil diesel fuel, which is partly compensated by a slightly higher fuel consumption of 4 to 6% when using biodiesel. The overall amount of RME sold in the year 2003 was more than 650,000 t. During 2003, the pro-

duction capacity was increased to more than 1,100,000 t per year. If this capacity would be used completely, 4% of the German diesel fuel consumption could be substituted. The maximum will be attained at about 6%, due to limited agricultural cultivation area and the necessary crop rotation.

Further energetic use of whole plants (not only oil seeds) could increase the contribution of agriculture to fuel supply. Possible pathways are:

- fast-growing wood plantations,
- bio-ethanol,
- bio-gas,
- synthetic fuel from synthesis gas ($H_2 + CO$), derived from pyrolysis of plant material,
- hydrogen.

The latter will still need some time for development of technology – at least until it can influence the traffic and mobility sector by a larger extent. The first three are in a state of rapid development, and the fourth was intensively discussed during recent conferences (FAL, 2002; FVV, 2002; BBE, 2002). The use of fuels from renewable resources is heavily supported by the EU. The members agreed to increase the share of such fuels to 5.75 % in 2009 (KOM 2001). Moreover, today no fuel tax is imposed on fuel from renewable resources; this also holds true for the corresponding share in blends.

The national potential concerning agricultural production of bio-energy (as Fischer-Tropsch fuels (FTF), biogas, bio-ethanol, and biodiesel) is limited to about 25% of the actual German fuel consumption, as shown in Table 1 (Munack and Krahle, 2004). This amount could be increased if further agricultural products from abroad, like sugar from sugar cane, substitute domestic products, such that the agricultural area for cultivation of energy plants becomes larger.

Table 1: German potentials and actual utilization as fuel for different biogenic materials

Raw Material	Calorific Value [PJ/a]	Fuel Yield [PJ/a]	Utilization [PJ/a]
lignocelluloses containing biomass	wood, straw 752 - 803	FTF 188 - 281	≈ 0
	energy plants* < 333 - 422	FTF 83 - 148	
oil, sugar, or starch containing biomass	winter rape* < 308	RME 120	RME 21 rapeseed oil 0,2
		FTF 26 - 36	
	winter wheat* < 285	bio-ethanol 120	
		FTF 36 - 51	
	sugar beet* < 195	bio-ethanol 195	
residues	organic residues 222 - 288	biogas 110 - 202	≈ 0
	energy plants* < 236	biogas 118 - 165	

*Cultivation on 2 million ha; only one of the alternatives is realizable.

Concluding remarks

Agricultural engineering research has by far moved from nuts and bolts to broader tasks that are of high relevance for the society: more and higher quality of food, reduction of world poverty, help poor farmers raise their income, pollution control, resource conservation, a safer workplace, and reduced drudgery, cf. Stout (2000). The growing world population will put new challenges on food production, and increasing prosperity will enable more people not only to look after their daily food but consider its quality, too. At the same time, there is an increasing awareness of the fact that we need to apply sustainable technologies also in agricultural production processes. All these mainstream needs offer wide fields of work for agricultural engineers. Information technology and biotechnology present themselves as advanced tools to tackle complex problems. We are urgently asked to contribute to related work with our professional expertise, and not to leave these fields to other professions.

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