Agriculture and the Environment: New Challenges for Engineers

Axel Munack
Institute for Technology and Biosystems Engineering
Federal Agricultural Research Centre (FAL)
Bundesallee 50, 38116 Braunschweig, Germany
Email: axel.munack@fal.de

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

As a contribution to the Special Session "Agricultural Engineering and International Development in the Third Millennium" of the XV CIGR World Congress / the 2002 ASAE International Meeting, this paper is intended to present ideas concerning the future development 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 will join the EU 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 an earlier publication, cf. Munack (2001), but in contrast to that, it does not contain material from prognoses' studies.

Mainstream needs and global trends

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

Munack, A. "Agriculture and the Environment: New Challenges for Engineers". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Presented at the Special Session on Agricultural Engineering and International Development in the Third Millennium. ASAE Annual International Meeting/CIGR World Congress, July 30, 2002, Chicago, IL. USA. Vol. IV. December, 2002.

- 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 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 programmes 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.

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.

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!

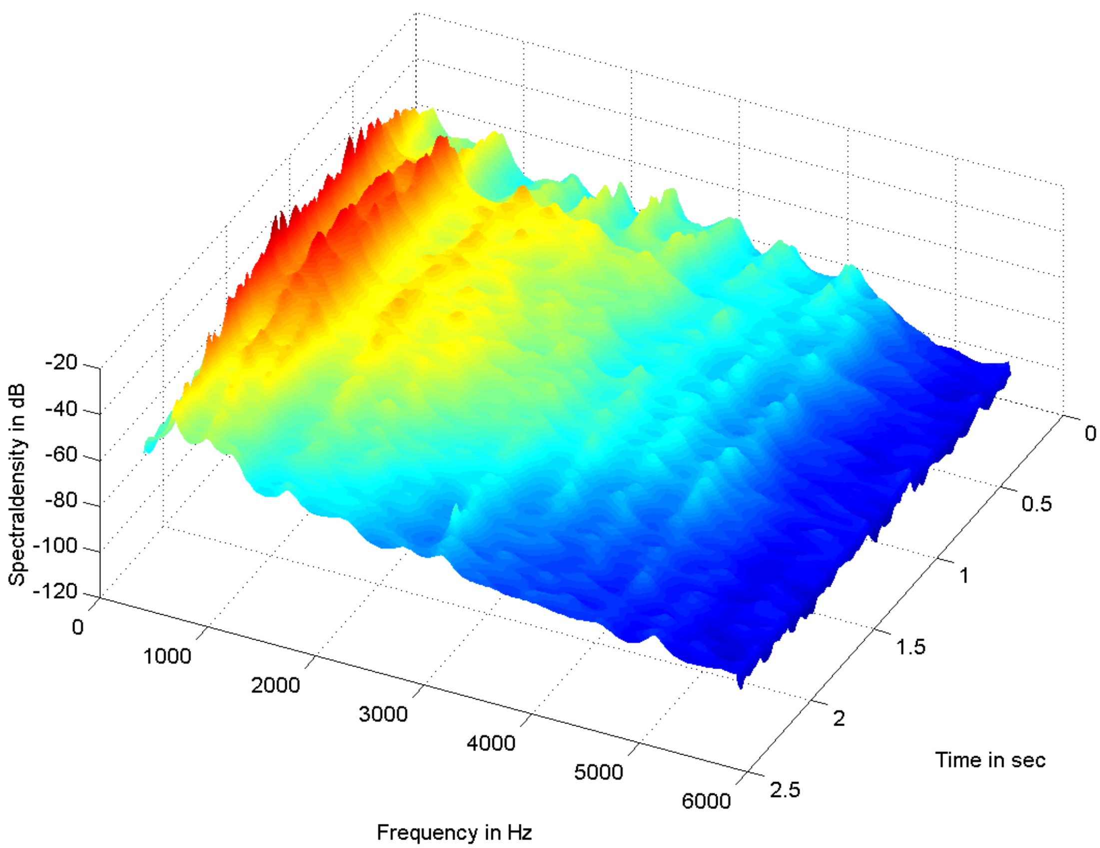

Figure 1: Spectrogram of the vocalization of a cow in case of hunger

<u>Environmental protection</u>

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 OU · m^{-3} (1 OU · 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.

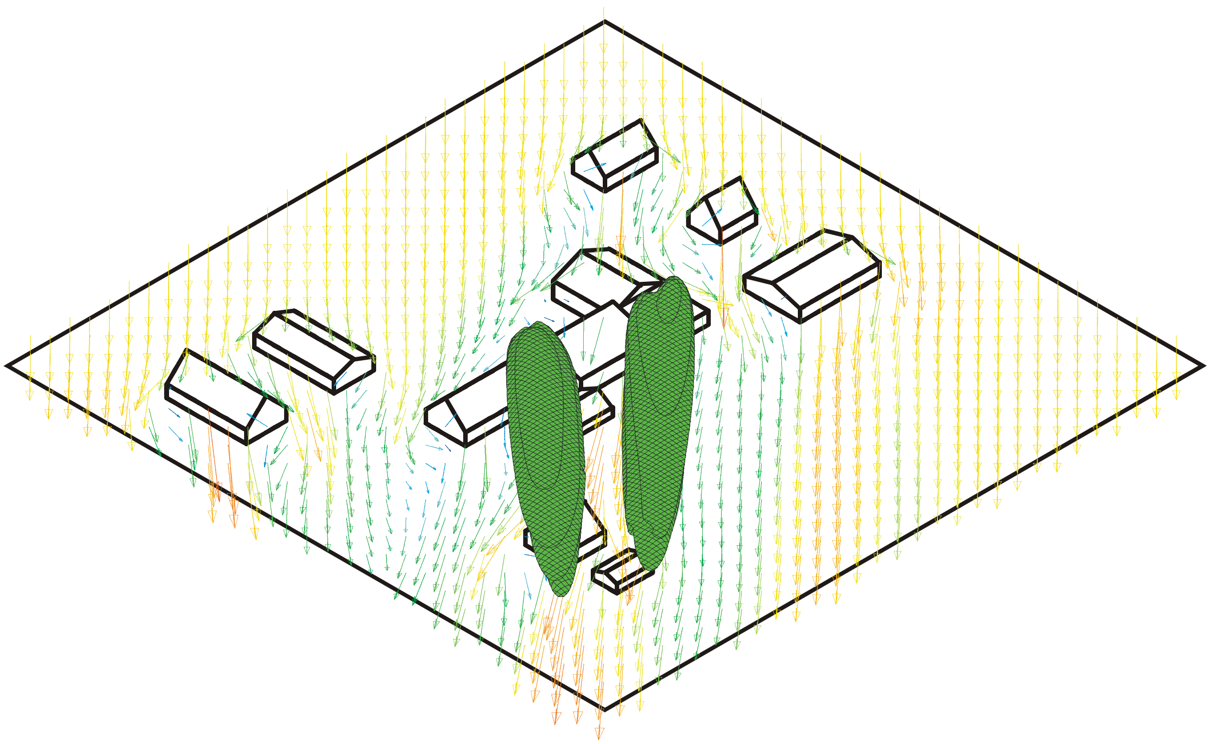

Figure 2: Immission around animal stables; the marked area is the iso-area of 3 OU · m^{-3}

Munack, A. "Agriculture and the Environment: New Challenges for Engineers". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Invited Overview Paper. Presented at the Special Session on Agricultural Engineering and International Development in the Third Millennium. ASAE Annual International Meeting/CIGR World Congress, July 30, 2002, Chicago, IL. USA. Vol. IV. December, 2002.

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 1,600 fuel stations (this amounts to approximately 10% of the German fuel stations). The price is about 8% 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 2002 was 600,000 t. During 2003, the production capacity will increase to 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 is limited to 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.

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.

References

BBE 2002. Fachkongress “Kraftstoffe der Zukunft 2002”. Dec. 04/05, 2002, Berlin. *Bundesinitiative Bioenergie, Bonn.*

Blackmore, S., H. Have, and S. Fountas. 2001. Autonomous Machinery in Horticulture: A Specification of Requirements. *Int. Conf. on Agricultural Science and Technology, Session 6 (Information Technology),* 139-147. Beijing.

Brundtland Report. 1987. Our Common Future. UNCED, Oxford.

Claessens, L., P. Huizinga, M. Huls, A. Miltenburg, J. Thelen, and B. Vanthoor. 2002. Robot Ants in Micro-Mechanization of Plant Production. *AgEng 2002*. Paper No. 02-VE-001, (8 p). Budapest, Ungarn: The Scientific Society of Mechanical Engineering (GTE).

DIN 9684 (1989-1998): Landmaschinen und Traktoren - Schnittstellen zur Signalübertragung. (DIN 9684: agricultural implements and tractors - interface for signal transmission).
Teil 1, Punkt-zu-Punkt-Verbindung (point to point connection), 1989, revised 1995.
Teil 2, Serieller Daten-BUS (serial data BUS), Jan. 1998.
Teil 3, Systemfunktionen, Identifier (system functions, identifier), Juli 1997.
Teil 4, Benutzerstation. (user station), Gelbdruck, April 1997.
Teil 5, Datenübertragung zum Management-Information-System, Auftragsbearbeitung 1 (data exchange with the management information system, task controller 1). Gelbdruck April 1997. Beuth Verlag GmbH, Berlin, 1989-1998.

Döhler, H., M. Schwab, and E. Kuhn. (1997). Perspektiven für neue Verfahren zur Behandlung und Verwertung von Flüssigmist. In *KTBL-Arbeitspapier 242*, 227-239. Darmstadt.

FAL 2002. 2. Internationale Tagung Biodiesel: Potenziale, Umweltwirkungen, Praxiserfahrungen. Sept. 16/17, 2002, Braunschweig. Sonderheft 239, *Landbauforschung Völkenrode*

FVV 2002. Workshop CO_2-neutrale Wege zukünftiger Mobilität. Sept. 09/10, 2002, Frankfurt. *Forschungsvereinigung Verbrennungskraftmaschinen, Frankfurt.*

Hahne, J., and K.-D. Vorlop. 2001. Treatment of waste gas from piggeries with nitrogen recovery. *Landbauforschung Völkenrode* 51(3): 121-130.

Ikeda, Y., G. Jahns, W. Kowalczyk, and K. Walter. 2000. Acoustic Analysis to Recognize Individuals and Animal Conditions. *The XIV Memorial CIGR World Congress.* P8206(6 p). Tsukuba, Japan.

Jahns, G., and K. Walter. 2002. Acoustic Analysis to Recognize Individuals and Animal Conditions. *Second Workshop on Smart Technology in Livestock-Monitoring.* FAL Braunschweig, Germany. (2 p; Abstract)

KOM 2001. KOM(2001)547 of Nov. 7, 2001, p. 15

Krause, K.-H., and J. Janssen. 1990. Measuring and simulation of the distribution of ammonia in animal houses. In: *Proceedings Roomvent '90. Engineering aero- and thermodynamics of ventilated room. Second International Conference*, C-7-1/12. Oslo.

Krause, K.-H., and S. Linke. 2002. Realitätsnahe Simulation von Gerüchen aus der Tierhaltung. *Landtechnik* 52(2): 124.

Munack, A. 2001. Tasks for Agricultural Engineering Research: New Challenges – New Trends? *IFAC Conference on Modelling and Control in Agriculture, Horticulture and Post-Harvest Processing,* 1-9. Oxford: Elsevier Science Ltd.

OECD. 1991. Environmental Indicators. A Preliminary Set. Paris.

OECD. 1993. Core Set of Indicators for Environmental Performance Reviews. Paris.

Stout, B. 2000. A Challenge for Agricultural Engineers. *CIGR Newsletter*, 1, 2-4.