VĚDECKÝ ČASOPIS

ZEMĚDĚLSKÁ TECHNIKA

5

AKADEMIE ZEMĚDĚLSKÝCH VĚD ČSFR
ÚSTAV VĚDECKOTECHNICKÝCH INFORMACÍ
PRO ZEMĚDĚLSTVÍ

CONTENTS

OBSAH

TAE 92

TAE 92 je zkratka anglického názvu Trends in Agricultural Engineering 1992, což volně přeloženo znamená Trendy v zemědělské technice 1992 - název, pod kterým se skrývá konference pořádaná ve dnech 15. až 18. září 1992 na technické fakultě Vysoké školy zemědělské v Praze. Konferenci připravovala skupina pracovníků této fakulty více než rok pod záštitou československého národního výboru C.I.G.R., pana Karla S c h w a r z e n b e r g a a rektora Vysoké školy zemědělské v Praze prof. ing. Jiřího P e t r a , DrSc. Na konferenci se registrovalo 135 účastníků, z toho 65 ze zahraničí (celkem ze 16 států).

Jednání konference probíhalo v pěti samostatných sympoziích s dvěma zvláštními a jedním nezávislým pracovním setkáním. Témata těchto akcí reprezentoval i název konference: Ekologické aspekty zemědělské techniky, Vlastnosti, kvalita a zpracování zemědělských produktů, Kvalita strojů, Současné zemědělské stroje a hospodaření s nimi, Hospodaření v podmínkách neprodejných přebytků a Růst životnosti strojů v podmínkách intenzívního opotřebení. Konference byla doplněna výstavou zemědělských strojů, exkurzí do zemědělského závodu a celou řadou dalších programů. Proběhlo také několik jednání v menších skupinách, např. o společných projektech, o podrobnostech 5. mezinárodní konference s názvem Fyzikální vlastnosti zemědělských materiálů, která se bude konat příští rok v Bonnu, byla založena nová mezinárodní konference ISASE, sdružující pracovníky z oblasti nauky o zemědělských materiálech apod.

Myšlenkovou osu konference tvořilo šest plenárních přednášek, jejichž text vzhledem k opožděnému zaslání rukopisů nemohl být zařazen do třídílného konferenčního sborníku. Redakční rada časopisu Zemědělská technika umožnila tyto významné přednášky uveřejnit v tomto čísle v plném rozsahu. Předpokládáme, že syntetické práce přednášejících autorů (G. P e l l i z z i , H. H. H a r m s , B. C h e z e , M. D e b r u y c k e r e , J. R. O ' C a l l a g h a n , A. H. Ž a l u d o v á) budou zdrojem inspirací pro čtenáře.

Doc. RNDr. ing. Jiří B l a h o v e c , DrSc.

TRENDS IN AGRICULTURAL ENGINEERING

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FRAME OF REFERENCE

Agricultural Engineering is the application (G a r r e t t et al., 1992) of the concepts, methodologies, analyses and design capabilities inherent to engineering itself to the processes and mechanisms related to biological systems and their derivatives.

Consequently, these applications take the form of a „service" rendered to: life and the development of vegetable and animal production; their preservation and processing. As time has passed, this role has grown and developed. Today, its primary objectives are to: minimize production costs; protect the health and safety of agricultural workers and animals; optimize product quality, protect the environment and maximize production flexibility.

In order to optimize these functions, measures must be taken independently of the certain, highly diversified, conditions of the various countries such as: socio-economic, structural, climatic, pedological, productive and market factors.

However, when implemented within the various contexts, engineering technologies applied to agriculture should be used in different ways in order to achieve the objectives mentioned above. The result of this is that if these objectives are to be attained, changes must be made, in many cases fundamental changes, to those technologies, whilst maintaining their basic physical-mechanical characteristics, in order for them to be appropriate to the local conditions.

The application of the engineering science and techniques to agriculture in terms of objectives to be reached and problems to be solved is also directly related to the evolutionary stage of the agricultural system on a worldwide scale.

If we consider to what extent agriculture has changed on the planet over the centuries, its evolution may be divided into 4 main successive periods, as represented in Fig. 1 (P e r i , 1992). Agricultural engineering has played a specific and increasingly important role in each of these.

As the figure shows, the mere management of natural resources has been progressively abandoned and the emphasis has moved gradually towards increasing yields. Since the end of years 20 of the last century, agricultural processes have continuously speeded up. In the industrialized countries, and even today in a large part of the developing world, from the 1820 until the end of the Second World War, the problems and goals of agricultural development (generally labour intensive) were dealt with in reductionist terms. This means essentially that biological, chemical and physical techniques were studied and applied to the individual elements of the system, each independent of the other.

Agricultural engineering was of growing but still marginal importance to development over that period (Fig. 2). Irrigation and drainage techniques, important since the Middle Ages, became more sophisticated as did post-harvesting technologies within the farms. In contrast, little or no account was taken of certain problem areas: ergonomics and worker

safety; animal health; energy sources. Mechanical development, which remained virtually at a standstill since the beginning of the last century, begun to make new progress. Over that period, a growing number of new discoveries was patented. However, these machines were designed to replace labour by man and animals in the slowest and most burdensome tasks of crop growing. Finally, in the area of buildings, research and technologies developed even more slowly and the first dedicated studies only began in the twenties of this century.

In the Third World, this evolution took place even more slowly. In many of these countries, the least advanced, agriculture is still based on management of natural resources (shifting agriculture). Only the most developed countries have begun to experiment relatively recently with new forms of management and engineering technologies.

From the early 40s until the 80s, whilst maintaining a reductionist approach to solving the various problems, there was a gradual move in the industrialized world towards integrated management of resources. At the same time, there was a progressive increase in production rationalization and in productivity.
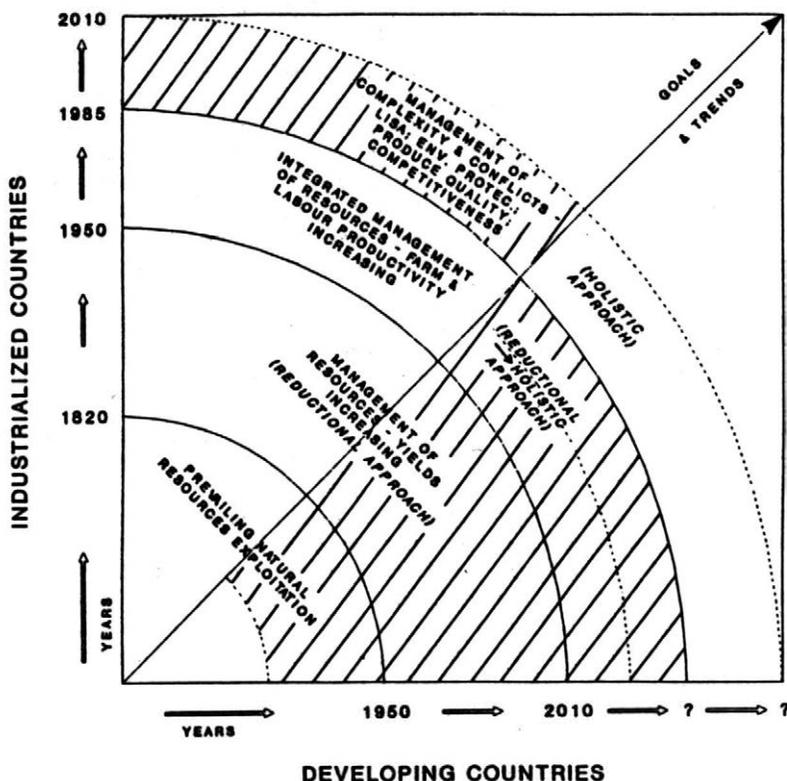
1. Evolution of agriculture: goals and trends

The agricultural sector in the developed nations has progressed more and more rapidly towards: capital intensive agriculture; trading with international markets; an holistic (or systemic) approach towards the problems. The growth of agricultural engineering in all its various applications has deeply contributed towards these changes.

However, only the most advanced countries in the developing world are now adopting this approach (Fig. 1). The others are still at the lowest levels of engineering applications, with the sole exception, perhaps, of irrigation and drainage.

In general terms (C r o s s o n , 1989) we still generally think of agriculture as a set of activities by which societies use land, labour, fertilizers, pesticides, seeds, farm machinery and other resources to satisfy the demand for food and non-food products. Only over the last decade we have begun to recognize that the way we manage these resources inevitably affects the supply of a variety of other values that societies consider important. These concern particularly environmental aspects whose economic value is frequently ignored by farmers; the progressive globalization of markets and trade; the fact that a shrinking proportion of the population produces biological raw materials for the majority.
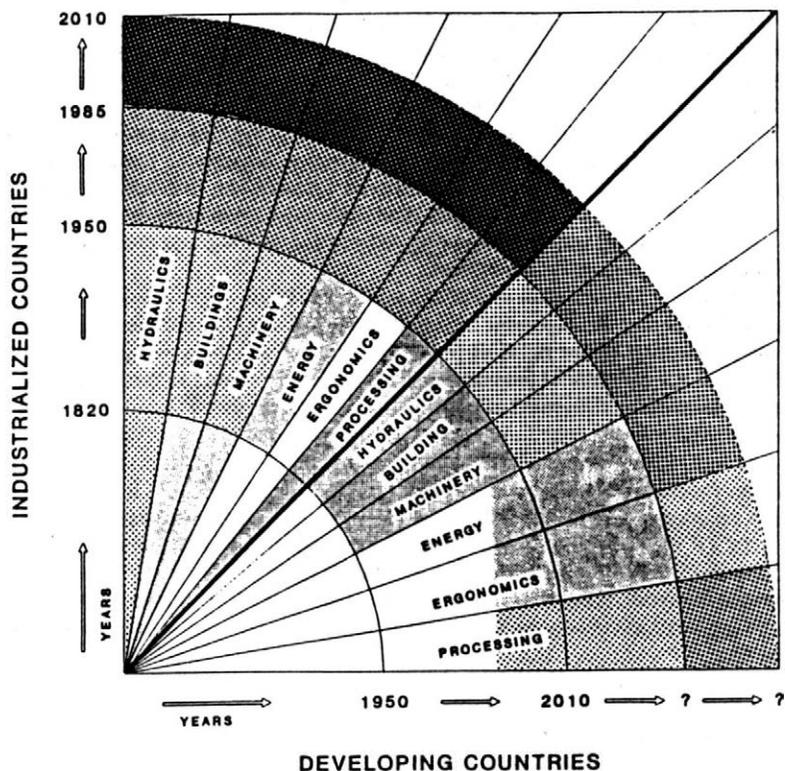
2. Agricultural engineering development related to the agricultural evolution

These factors have influenced the research and development in the various fields of agricultural engineering. In the last 40 years, this has progressed, albeit displaying a remarkably innovative spirit, along the reductionist road i.e. whereby study and research have been concentrated on single isolated areas with no concession to a cross-disciplinary approach.

For some years now (Fig. 1) we have given the year 1980 for the industrialized countries but it will be 2000 for the Third World there has been a growing awareness of the need for a different agricultural management style which takes into consideration the (environmental, social, economic and market) complexities and conflicts within the system and in relation to the outside product consumption systems and the geographical territory. Consequently, the need exists for a prevalently holistic approach to solving the various problems and this approach will develop in the future.

At the same time, in the primary sector too, there has been a growing need for dematerialization (P o r t e r , 1986; G r u e b l e r , N o w a t n y , 1990; G a l l i , 1991). In other words, this means a reduction in the role of materials used and the energy embodied in favour of a growing use of immaterial and cultural resources and the growing impact of information technology.

Studies on L.I.S.A. (Low Input Sustainable Agriculture) on controlling harmful emissions, protection of the agricultural environment, product quality and hygiene, product competitiveness and land conservation, the growing need for production flexibility to meet rapid changes in the market are a clear example of this trend.

The application of engineering sciences to this new type of system has obviously followed this trend and in the future it will continue to do so to an even greater extent. As a result, alongside predominantly reductionist research, the first holistic type studies started. These have been possible thanks to modern calculation systems and the progressive (but still marginal use) of monitoring sensors and will become more important and have a significant impact on the system.

Therefore, the identification of future goals and strategic objectives for agriculture in terms of the rational management of complexities and conflicts represents the basis for the development of future fields of research - intended as „the art of prediction" - and development for agricultural engineering. This is directly related to the study of specific advanced technologies revealed as essential by strategic analyses once a clear classification of the various decisions to be taken has been achieved (K a y , 1986).

As a result, agriculture is obliged by the growing complexity of the problems concerned to use an increasing amount of information and technology (Fig. 3). It must constantly be in a position to implement specific choices (Fig. 4) in the various decisional areas (L a z z a r i et al., 1991): strategic planning, leading control, operational management.

In the short term, every effort must therefore be made to:
- increase the farmer's knowledge, update management methods, appreciate technologies to be applied individually or in combination and manage these using strictly rational criteria;
- develop research and development programmes bringing together the understanding of the system and the analysis and definition of its needs and objectives using advanced technologies aimed at meeting those needs and objectives.

The progressive globalization and deregulation of agricultural markets will have an increasing impact on this overall situation allied to a growing need to perceive farming as a „social" use of natural areas (environment-services sector). On the one hand, this

will require awareness of cost analysis and management factors and increasing flexibility of production systems.

On the other, it will give rise to specific problems of: production quality; environmental protection; expansion of areas managed using minimum sustainable and eco-compatible criteria.

As a result, a different concept of the agricultural professionals will arise and this figur will develop along four main lines (S e v i l a , B a y l o u , 1991):
- the farmer - supplier of food and non-food products, in the industrial context - strictly linked to downstream industrial processing;
- the farmer-craftsman producing high added value speciality products for both food (e.g. so-called organic products to be distributed fresh to the market and typical processed products) and non-food (extracts, cosmetics, pharmaceuticals, fibres, etc);
- part-time farmer who generates the majority of his income from nonfarming pursuits but with an irreplaceable social and environmental function;

THE FARMER

FORCED TO SATISFY INCREASING NEEDS FOR

| ECONOMIC COMPETITIVENESS | IMPROVEMENT OF THE PRODUCE QUALITY | ENVIRONMENT PROTECTION | HEALTH & SAFETY OF WORKERS |

IS FORCED TO

USE INCREASING QUANTITIES OF

COMPLEX INFORMATION AND TECHNOLOGICAL INNOVATION
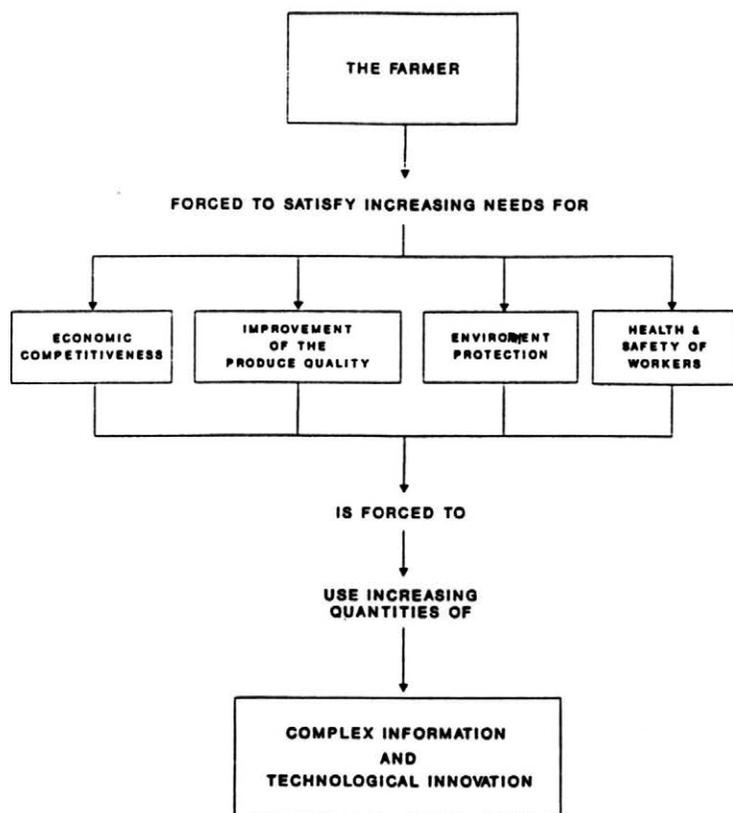
3. Farmer's needs

- businessman-farmer providing maintenance and monitoring of the environment-services sector for leisure pursuit of non-rural populations.

This system must be underpinned by widely differentiated, targeted structures: the first two targeting cost reduction and product quality; the second two, environmental protection.

The conclusion to be drawn here concerns the need to establish frames of reference and strategies consistent with these various situations but primarily meeting the desired goals. This will obviously affect the technological choices to be made whether they be biological, computer-related, physical-mechanical, etc.

Under each set of circumstances, one aspect will prevail over another in the choice of technologies although they must all be taken into. To take an example: whilst the priority objectives for the type of farming which supplies raw materials to industry must be ones of economics and quality, the primary considerations for part time agriculture will be comfort and worker safety. Environmental monitoring will also become an aspect of foremost importance and its main purpose will be to provide a range of real time data for: development, pathologies and needs stages for plants, animals and soil, optimizing the various crop yields and their biological cycles with the minimum of intermediate consumption; properties of soils; climatic trends; air, water and soil pollution levels, etc. (A n o n y m o u s , 1986).

The final conclusion is therefore that:
- given that great changes will occur to agriculture and its management, the world of research will bear the considerable responsibility of knowing how to interpret the development of agricultural engineering for applications in the next millennium;
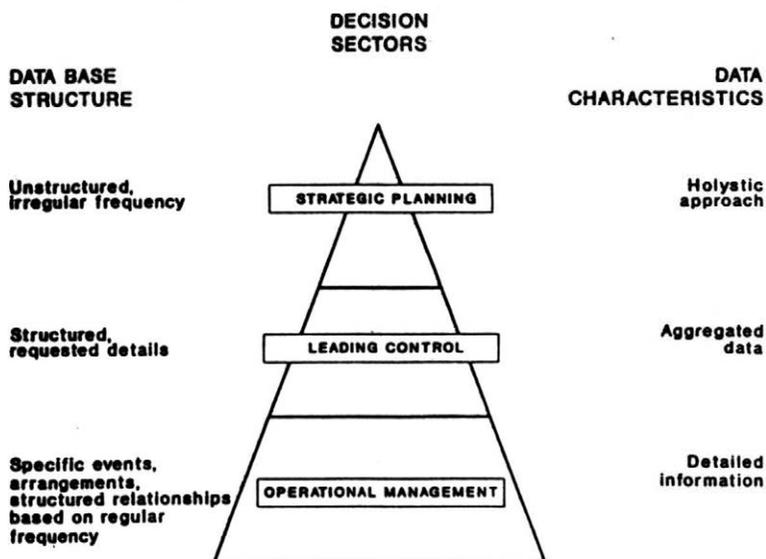
4. Decision sectors for the management of the agricultural engineering system

- agricultural engineering will have to be implemented in numerous areas developing, highly original hard and soft solutions with increasing rapidity;
- the link with the outside world will have to be closer with increased application of replaceable advanced and de-materialized engineering technologies;
- greater recourse to the acquisition and use of new advanced physics based technologies has to be done;
- closer links must be developed between the research, manufacturing and agriculture worlds with the aim of establishing objectives and the means to attain them, methods and the results to be achieved thereby;
- there will be a growing need for extension services to farmers arising out of the greater need for information.

This is true of the overall agricultural sector in its widest sense. If we wish to express the concept in its baldest terms we could refer to the flow diagrams given in Fig. 5 and 6 (P e l l i z z i , 1984). They seek to show close existing relationships and the need to develop research and manufacturing structures in each country, in parallel to the agricultural sector with the aim of: producing technologies appropriate to the system concerned;
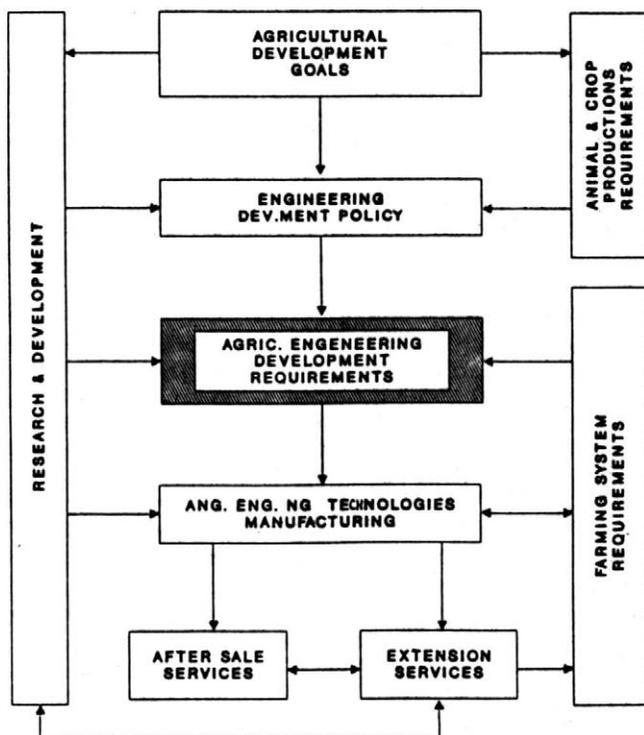
5. Integration between agricultural goals, agricultural engineering requirements and manufacturing facilities

providing continuous and effective technical support; interpreting the various factors which manifest themselves and their development.

THE FUTURE ROLE OF AGRICULTURAL ENGINEERING

If on the basis of these premises, we attempt to identify the main lines along which Agricultural Engineering will develop in the future, we must consider the problem looking to the various fields concerned. These could initially be divided into the six classic disciplines of Agricultural Engineering and therefore the six CIGR sections (Soil and Water Use; Building and Environment, Mechanization, Energy, Ergonomics and Safety, Product Processing). However, the question arises as to whether these six sections have a de facto justification both at present, and even more importantly, in the future. Or indeed whether they should be divided according to different criteria or have some transversal, complementary functions.

If systemic logic is the valid option, and will continue to be so, there can be no doubt that this particular division must be reviewed. This will cause obvious repercussions, not only on the research system but also on that of the university one. Consequently, it will
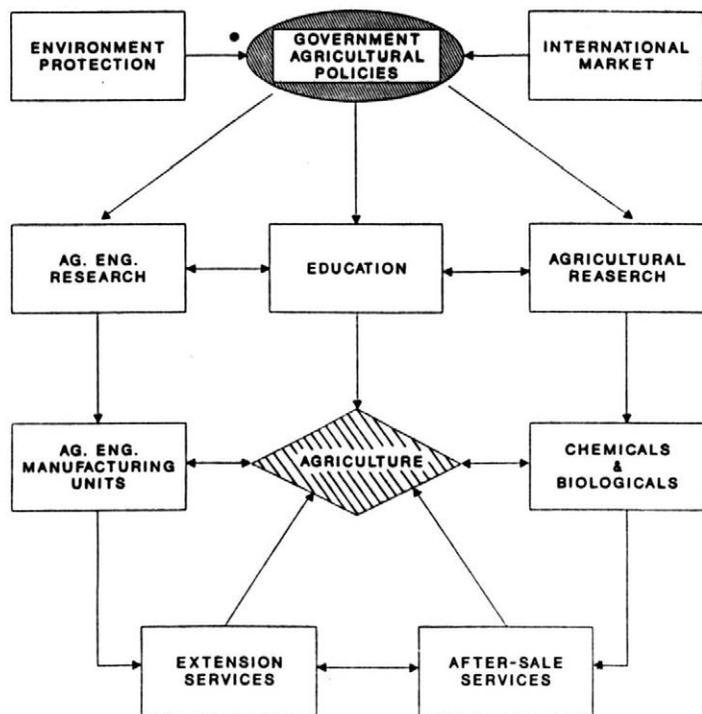
6. The government agricultural policies influence the educational and agricultural systems

no longer be sufficient to speak of hydraulics, mechanics, buildings, energy, ergonomics, postharvest technologies as independent and unrelated disciplines.

It must first be established: what form will the agriculture of the future take; what this will entail in terms of complexity and conflict management; what roles will be played by dematerialization and information science; how important will the following problems be: quality, hygiene and production cost minimization; production flexibility; market demands and barriers; environmental protection, and so on.

Clearly, this does not mean abandoning completely the reductionist approach to problem solving and indeed this approach has generated significant technical, economic and social benefits over the last 40 years. It entails the contemporary need to identify and develop strategic analyses aimed primarily at: finding the correct areas of application for these technologies and their sub-systems; identifying the specific areas where action must be taken as a priority.

Let me show you a couple of examples. The „arable farms" system where the objectives are: to reduce costs; to improve product quality; to protect the environment. These objectives must clearly be attained whilst respecting the considerations of worker comfort and safety, a transversal problem.

As reported in Fig. 7, in addition to the „transversal" sectors connected with work organization, ergonomic aspects, sensing, information technology and environmental protection, these are also a range of „peak" areas which must be defined on the basis of an economic analysis of importance to and impact on production costs. The aim here is to decide what is possible to do, the areas where action must be taken, what contribution can be made by engineering and physical sciences to reducing production costs.

One significant example worth remembering in this instance is the analysis (ECCAEA, 1989) developed by the European Community Club of Advanced Engineering for Agriculture for cereals. This analysis identifies 5 areas of action on the issue of cost containment: seed bed preparation techniques; fertilizer and seed applications; herbicides and pesticides distribution; product harvesting and transport; drying. New technologies for reducing soil compaction and new seed-bed preparation methods, optimizing irrigation methods and tractor-equipment combinations, using electronics applied to various machines can reduce current average cost levels by around 25%. Additionally, further savings can be made in areas such as: use of fertilizers and seeds; crop management using information technology and decision making support systems. This would give a further 15 - 20% cost reduction. But, it is interesting to discover that improving drying techniques only create a 5 - 8% cost saving on that particular operation (which in itself accounts for only 20% of total costs), while new methods of cultivation and seed bed preparation can reduce relative costs by 50%, similar to the harvesting and transport processes. Research efforts must therefore be concentrated in these latter two areas which together account for 35% of total costs.

A second example is concerning the „dairy farms" where the main objectives to be attained concern: cutting production costs, improving product quality, animal health and environmental protection. Here too, account must be taken of the agricultural worker's comfort and safety. In this context, the whole farm system organization comprises three main mutually dependent sub-systems (Fig. 8): forage; feedstuffs; breeding.

The first (Fig. 9) includes all crop production aspects taking into account the climatic and soil conditions and including technologies related to: seed bed preparation; irrigation; cultivation and product improvement techniques; fertilization; weed control. Here the valuation system based on the application of the various technologies must take as its

point of departure the incidence of forage types (fresh, hayed, siled) on total milk production costs. In this way, the production cost of „milk feed unit" can be calculated and the incidence of each of the sub-factors mentioned above can be calculated within this overall cost. From this, it can be determined which of these accounts for the highest
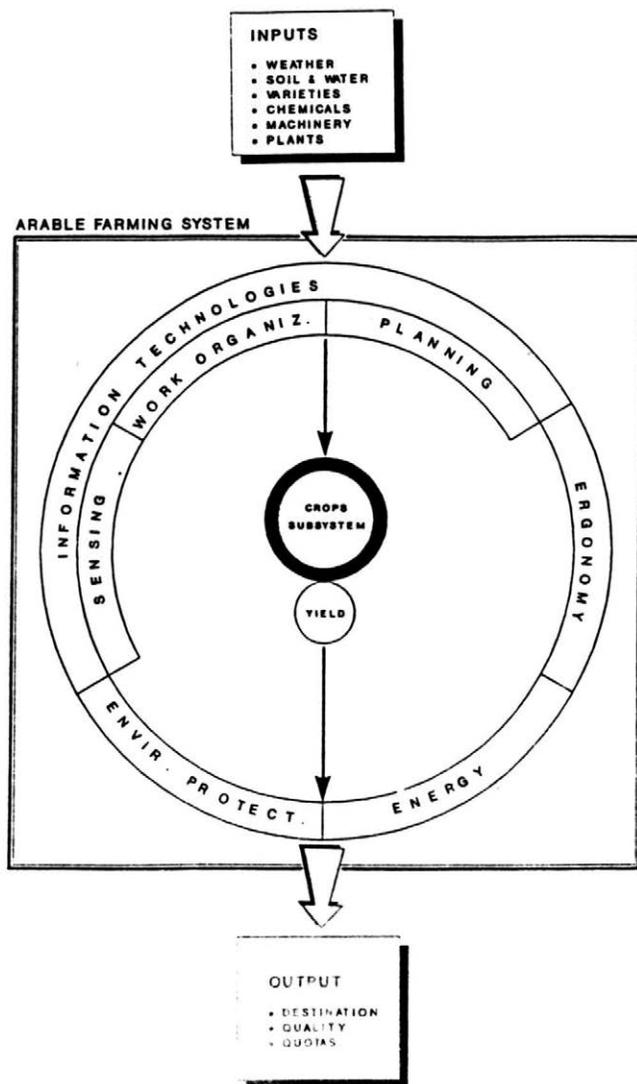
7. The „arable farms" system

proportion in terms of cost composition and therefore it is a priority area to be considered. Other factors must also be taken into account: the effect that fertilizers (chemical or organic) and herbicides have in terms of soil and water pollution; the physical-mechanical properties of the soil and consequent compaction problems; and what yield the soil should give (affecting irrigation and fertilization) with the aim of maximizing the cost-benefit ratio. It is only at this point that any decision may be reached in terms of the technologies
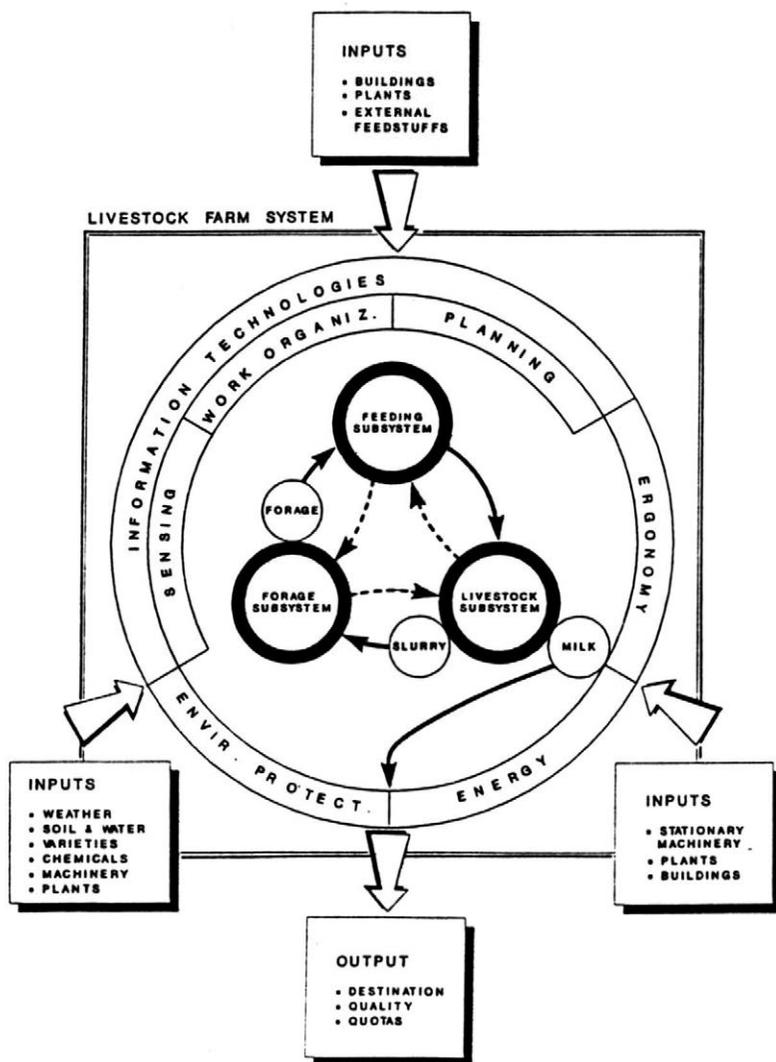
8. The „dairy farms" system

and changes to implement. Generally speaking, the optimization of the following areas becomes a priority objective:
- irrigation and drainage systems and technologies; water and soil quality monitoring systems;
- technologies connected with pre-harvest operations (less compaction; less energy consumption; less use of fertilizers and herbicides);
- harvesting technologies (reaping, partial drying in the fields; harvesting and baling; product handling) taking account of production functions.

All these factors, have to be considered within the context of crop monitoring systems (meteorology, crop requirements, development stages and pathologies, water quality, etc.), and require: a sensing-based system; regulation and electronic control of machinery; appropriate simulation programmes and management models.

The second sub-system is closely correlated with this (Fig. 9) and concerns the conservation and production of feeds. This is linked with: upstream, harvesting methods of various forages; downstream, the breeding system. The main problem areas are: shape and size of buildings; monitoring of conservation and production stages; appropriate mechanical technologies.

Within an overall context of cost minimization and production quality this affects: building design; contribution of electronic aids; choice of materials; the application of artificial intelligence; sensors; robots; use of electric machinery, etc.
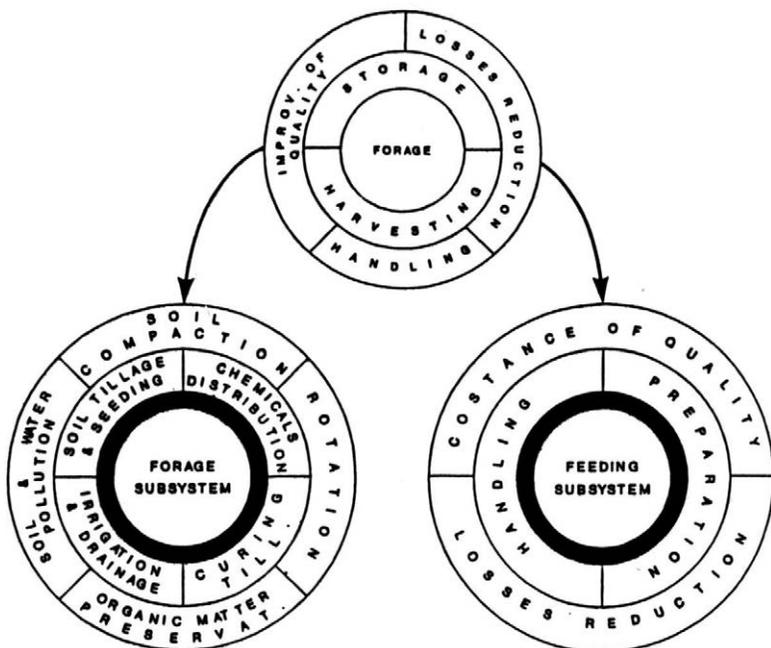
9. Correlation between forage and feeding subsystems

The third subsystem concerns breeding (Fig. 10). This involves all aspects of building, relative plant and machinery and mechanization for: distribution of animal feeds (linked upstream with their preparation); stable cleaning and slurry management (affecting downstream the forage subsystem); milking quality and cooling of milk; animal health.

As far as buildings are concerned, the main aspects to consider are the optimization of: role of plants and machinery; reduction of harmful emissions into the air and soil; animal health; de-materialization without forgetting the main objective of cost-benefit minimization.

Depending on diet types, animal feed distribution technologies must be based on: optimum working capacities; loss minimization; quality consistency, distribution uniformity and quantity control of feeds.

The cleaning of the building and slurry management include the following aspects: removal; storage and treatments; environmental protection (air and water); spreading on fields.

Milking requires the optimization of: technologies for real time control of animal health and milk quality; work productivity; milk cooling and potential for heat recovery, etc. These factors must all be considered within an overall context of building rationalization, optimizing use of machinery and human resources.

The following aspects are of particular importance to this subsystem (ECCAEA, 1989):
- monitoring of environment, animals and machinery and therefore development of appropriate sensors and electrotechnologies;
- robots and automation;
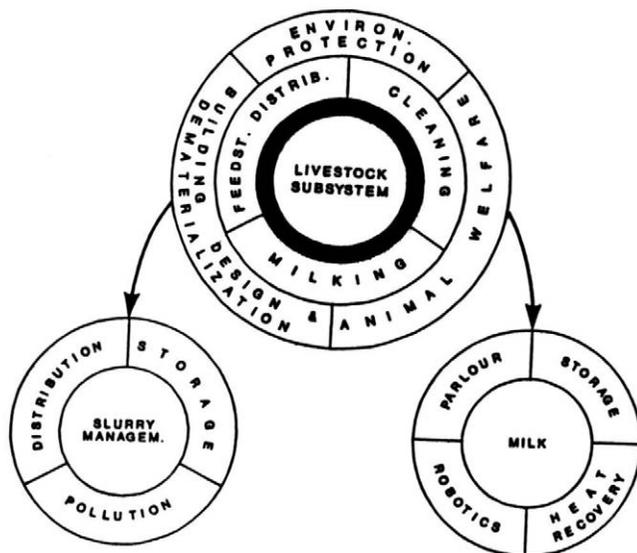
10. The livestock subsystem and its correlations

- image analysis and vision systems;
- energy savings and dematerialization, developing low cost, rapid obsolescence animal houses;
- models, information systems, computerized control systems.

Finally, the circle must be closed in terms of slurry management in the forage subsystem. Similarly, it is evident that the considerations of work organization, ergonomic and safety are fundamental to the entire system.

Let me offer, at this point, two final considerations. The first concerns the need to evaluate what contribution each subsystem and each technology makes in terms of marginality. This affects production choices (more or less intensive, size, etc.), feeding methods and determines the choice and development of the various technologies. The term marginality means „incremental modification - increasing or decreasing - at the limits of a certain function".

This concept (K a y , 1986) has been applied for some time to the production function, correlating, for example, the variation of inputs and outputs in physical and economic terms and thereby giving rise to: marginal physical products, marginal revenues and marginal costs.

However, it is virtually unknown and almost never applied when developing new technologies where it is essential to determine at the outset what benefits these will generate (outputs) and the costs they will entail (inputs). This kind of evaluation produces the curves shown in Fig. 11. It can be applied to machinery for example.

In terms of crops, economic output may be increased by improving the production capacity of a machinery and therefore its size and speed. If we are considering the harvested product, this is generated by reducing losses and improving product quality. If, finally, we are referring to inputs distribution, action must be taken in terms of using more sophisticated machinery to reduce consumption. However, this being the case, none is able to say with any certainty: whether the attainable benefits offset and to what extent, the higher costs; what importance the time factor has; to what extent this is correlated with higher costs and so on.

TR = TOTAL REVENUE
MC = MARGINAL COST
MR = MARGINAL REVENUE
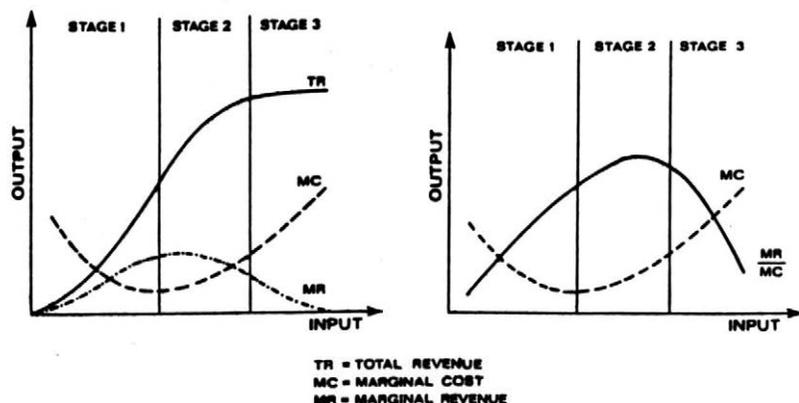
11. The main production functions

Efforts, for example, by producers of combine harvesters to reduce losses entail higher machine costs (electronic regulation, sensors, display systems, information technology). The question therefore arises as to whether the higher costs are offset by returns when on average 1% less wheat loss means a marginal return no more than of US$ 10/hectare. The same goes for robotics, automation, building and animal treatment: do better animal health and well-being and improved milk quality offset the higher costs? Do crop monitoring with sensors and the use of artificial intelligence produce a positive balance between marginal costs and revenues or not? To what extent should one pursue the objective of lower land compaction?

I have no answers to these questions and I am merely raising some queries where further research is necessary.

The second and final consideration concerns the question of how to ensure that the agricultural system sufficiently flexible in terms of production both to move from one solution to another within the same system depending on market conditions and to modify production depending on the market situation or, more generally, on political decisions. This comes back to the issue of dematerialization in the sense that technologies must be developed and implemented so not to impose rigidity on the agricultural system and as such paid for and replaced over a limited number of years. This is a highly innovative approach and it is in sharp contrast with current trends in the technology production sector. Indeed, manufacturers market their products proclaiming the fact that they will last for many - too many - years. The progress made in materials science and modern computer-aided design and production systems should provide the tools and support needed to invert this trend. These latest developments must be improved upon and efforts should be made to use them throughout the production sector. This too, is an area in which agricultural engineering must become involved.

CONCLUSIONS

This study has sought to examine new problem within the context of current and future needs of the agricultural sector. The hypotheses it puts forward may in some instances appear ambitious and futuristic. However, in my view, they are sufficiently based on the probable future needs of this sector, in turn driven by a world undergoing fundamental social and economic change.

Leaving aside the fact of the overall validity of the reductionist approach to developing agricultural technologies for use in the developing world, this is no longer the case for the industrialized countries. It is therefore the obligation and duty of everyone involved in agricultural engineering to attempt to understand the general problems and the form they take before taking decisions in technological terms. We must understand the various categories and their inherent sub-systems, the bottlenecks to be unblocked, without allowing ourselves to be distracted by adapting models used in other sectors and economically unproven. It is only in this way that Agricultural Engineering will play a key role and have a truly essential function in the world's various agricultural systems in the future too.

References

ANONYMOUS: Office of technology assessment. Technology, Public Policy and the Changing Structure in American Agriculture - U.S. Congress Office of Technology Assessment Press, Washington D.C., 1986.

CROSSON, P.: Agriculture and environment in the world of tomorrow: the challenge to science and policy. Proc. Int. Congr. Agric. Environ., Bologna, 1989, pp. 29-42.

European community club of advanced engineering for agriculture, 1989 - Agriculture and engineering: new technological opportunities - ECCAEA, 6 pp.

European community club of advanced engineering for agriculture, 1989 - The contribution of engineering and physical science to input cost reductions for cereal crops - ECCAEA, 4 pp.

GALLI, R.: Globale/Locale. Torino, Isedi ed., 1991, pp. 1-37.

GARRETT, R. E. et al.: Improvement of competencies of agricultural and related biological engineer - Dept. Agric. Engng Univ. California, Davis, 1992, pp. 143.

GRUEBLER, A. - NOWATNY, H.: Elements of an emerging new growth phase and possible development trajectories. Int. J. Technol. Mgmt, 1990, No. 4, pp. 22-37.

LAZZARI, M. - MAZZETTO, F. - PELLIZZI, G.: Quality and innovation in agriculture. In: The total quality system applied to agricultural mechanisation, Fiat Geotech Press, 1991, pp. 77-145.

KAY, R. D.: Farm management. McGraw-Hill Book Co., NY, 401 pp.

PELLIZZI, G.: General outlines for the development of agricultural mechanisation and the organisation of allied facilities - Riv. Agric. Mechanisation and the Organisation of Allied Facilities - Riv. Agric. Tropicale-Subtropicale, 1984, No. 1, pp. 16-32.

PERI, C.: Nuovi ordinamenti didattici per le Facolta di Agraria del 2000 - Riv. Dott. Sci. Agrar., Roma, 1992, No. 3, pp. 9-17.

PORTER, M.: Competition in global industries - Harward Business School Press, Harward, 1986.

SEVILLA, F. - BAYLOU, P.: Who and what will be the 21st century rural professional - Rep. ASAE Winter Meet., 12, Chicago, 1991.

World Bank, World Development Report. New York, Oxford University Press, 1989.

PELLIZZI, G. (Institut mechanizace zemědělství, Univerzita Miláno, Itálie): *Trendy v mechanizaci zemědělství.* Zeměd. Techn., *38*, 1992 (5): 255-270.

Byl analyzován vývoj zemědělství jako celku ve světě, přičemž je věnována pozornost rozdílům mezi rozvinutými a rozvojovými zeměmi. Jsou posuzovány nové možné oblasti rozvoje. Je zdůvodněna větší potřeba rozvoje zemědělství v rozvojových zemích a potřeba řešení přebytků v zemích rozvinutých. Z technických řešení jsou jako perspektivní uváděny: prostředky používané pro sledování prostředí, rostlin a živočichů a mimo jiné i techniky samotné, různé senzory, roboty, automaty, systémy pro analýzu obrazu a systémy vidění, soustavy umožňující spořit energii, snižovat náklady, avšak i informační soustavy.

rozvoj; rozvinuté země; rozvojové země; přebytky; technologie; informatika; automatizace; prostředí

VÝZKUM A VÝVOJ ZEMĚDĚLSKÉ TECHNIKY V ZÁJMU OCHRANY ŽIVOTNÍHO PROSTŘEDÍ

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Podobně jako ve směrech rozvoje v jiných oblastech techniky je dodnes také v zemědělské technice obrácena hlavní pozornost na zvyšování produktivity práce a produktivity na jednotku plochy (plošné produktivity). Zvyšování plošné produktivity, tedy zvyšování výnosů na jednotku plochy např. cíleným šlechtěním a optimalizovaným nasazením hnojiv a chemických ochranných prostředků, stálo v popředí na počátku industrializace.

Současné 1,5% roční přírůstky v Německu se mohou podle odhadu (S c h ö n , 1989) v důsledku biotechnologických změn v příštích deseti letech dokonce ještě zdvojnásobit, což znamená zoufalé výhledy pro ceny obilí v rámci ES!

Po druhé světové válce byly v Německu ve velkém množství prodávány a nasazovány traktory, později též sklízecí mlátičky a sklízecí řezačky. Tím se značně zvýšila produktivita práce (např. plocha obhospodařovaná jednou pracovní silou nebo počet zvířat na pracovní sílu). Nasazení nejmodernější techniky způsobilo, že se produktivita práce v západoněmeckém zemědělství v posledních 40 letech osminásobně zvýšila. Současně klesl počet pracovních sil pracujících v zemědělství na plný úvazek zhruba na jednu šestinu (S c h ö n , 1989). Další vývoj bude muset brát ohled na dostupné energetické rezervy a na ochranu životního prostředí, což ještě před několika lety hrálo podřadnou roli.

Ještě v 70. letech bylo pouze váhavě přiznáváno ochraně životního prostředí a otázce plýtvání energií patřičné postavení. Svou roli jistě sehrála varující a zpočátku zlehčovaná slova „zelených" a „Římského klubu", avšak skutečně věřit jim tehdy nechtěl nikdo. Snad je ještě známé, že se počátkem 70. let v mnoha firmách a ve vědeckém světě pilně pracovalo na konstrukci mobilní sušičky, pomocí níž měla být zelená píce ihned na poli zcela vysušena. Jeden z těchto strojů nesl příznačný název Apollo. Ropná krize roku 1973 učinila každému takovému vývoji rychlý konce.

Z toho lze vyvodit závěr, že ve svobodném a tržním hospodářství je regulátorem v první řadě trh; ten však může být ovlivňován politikou.

Obecně se technika a životní prostředí - jak ukazují stále patrnější a hrozivější katastrofy posledních let - dostávají v našem moderním světě stále více do vzájemného konfliktu. Průmysl, zemědělství, doprava a městské aglomerace přispívají každý svým dílem k ničení krajiny a životního prostředí. Emise jsou vzduchem a vodou přenášeny do velkých vzdáleností a způsobují odumírání lesů, ničí ozónovou vrstvu naší Země, zvyšují obsah CO_2 v atmosféře a vyvolávají skleníkový efekt, který táním ledových pokrývek pólů způsobí změnu mapy světa. Zemědělství, které je ostatně právě v Německu největším příjemcem subvencí, je zde často stavěno do role největšího hříšníka, i když zdaleka není hlavní příčinou tohoto vývoje. Pokud by se měla atmosféra Země skutečně oteplit, pak bude zemědělství zasaženo jako první, protože příroda představuje pro zemědělce základní kapitál.

Navzdory všem černým výhledům má zemědělství a spolu s ním i průmysl zemědělských strojů a traktorů pouze tehdy šanci na přežití, pokud zůstane i při respektování

potřeb ochrany životního prostředí konkurenceschopným ve vztahu k zemím s nižší citlivostí k těmto potřebám. Konstruktéři zemědělských strojů musí pro zemědělství hledat, zkoumat a vyvíjet takové prostředky, které zároveň snižují náklady i zatížení životního prostředí. To však nesmí vést k úplné industrializaci zemědělství, která by např. znamenala zemědělské závody s mnoha statisíci brojlerů a mnoha desetitisíci prasat v živočišné výrobě nebo monokultury na obrovských plochách v rostlinné výrobě.

Změny trhu

Vyjdeme-li z těchto skutečností, tak nás nepřekvapí, že vývoj trhu zemědělské techniky vychází z údajů, které uvádí obr. 1.

● Urychlení strukturních změn do roku 2000:
  - méně zemědělských závodů v západní Evropě (1991: 6 miliónů, odhad 2000: 4 milióny),
  - vzrůst obhospodařované plochy na jeden závod,
  - trend k širokému pracovnímu rozpětí/kapacitám (více nájemných podnikatelů/strojní okruhy).
● Vývoj příjmů bude mít rostoucí tendenci pouze u závodů s velikostí nad 50 ha pod podmínkou tržního řízení.
● Odbyt na trhu zemědělských strojů bude dále klesat:
  - malé stroje budou poklesem silněji zasaženy,
  - kapitalizace se u větších jednotek zlepší.
● Otevření východního trhu přinese částečné oživení trhu (u větších strojů).

Údaje na obr. 1 znamenají zesílené strukturní změny v zemědělství, což se současně a bezprostředně promítne do vývoje zemědělské techniky. V důsledku těchto strukturních změn je třeba vycházet z toho, že se v regionech se ztíženými podmínkami pro zemědělskou výrobu sníží plocha zemědělsky využívané půdy. Zbylé plochy budou obhospodařovány mnohem komplexněji a výkonnějšími stroji s podstatně menší časovou a personální náročností. To znamená, že se pozornost nebude zaměřovat ani tak na získávání základních dat, např. pro řezání píce nebo slámy, protože zde ušetříme na výkonu pouze několik procent, ale mnohem více na zlepšení celkového nasazení stroje, např. použitím moderní komplexní elektroniky a hydraulických systémů. Je zřejmé, že tyto strukturní změny musí pro zemědělce přinést nákladná racionalizační opatření, která se zase projeví v oblasti zemědělské techniky tak, že zemědělec bude stále více vyhledávat půjčování strojů v tzv. strojních okruzích (obdoba bývalých strojních družstev) nebo najímat podnikatele, kteří svými stroji provedou požadované práce, nebo bude sám stroje pronajímat. Tím vzroste doba provozu strojů, zvětší se prostor jejich nasazení, porostou
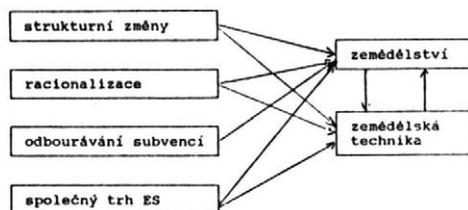
1. Faktory vlivu tržního vývoje na zemědělskou techniku - Factors of the effect of market development on farm machinery (S c h ö n , 1992)

požadavky na účinnost a na snadné ovládání. Zároveň rostou požadavky ergonomické, hygienické a na redukci vedlejších činností, např. optimalizaci údržby.

Tyto strukturní změny budou rovněž určovány odbouráváním subvencí, které je podmíněno všeobecným nedostatkem finančních prostředků. Tím se příjmová situace zemědělců ještě dále zhorší. Pouze větší závody, které jsou řízeny na tržně ekonomických základech, mají šanci přežít jako závody, jejichž hlavní náplní je zemědělství. Počet prodaných zemědělských strojů musí nutně dále klesnout, což bude mít negativní dopad hlavně v případě malých strojů. Silné robusní stroje vhodné pro pronájem si svůj podíl na trhu zachovají. Otevření vnitroněmecké hranice a východního trhu přináší pro západoněmecké výrobce u některých strojů oživení trhu, na druhé straně se muselo mnoho výrobců poučit z vyšší provozní doby strojů podmíněné obrovskými plochami. Kromě toho není bez problémů platební schopnost nových zákazníků. Společný trh ES bude mít také silný vliv. Především rozdílné bezpečnostní předpisy členských států přinesou průmyslu zemědělských strojů velké těžkosti.

Reakce na potřeby trhu

Ve střednědobém výhledu se změny trhu projeví přechodem k podnikům, které jsou vedeny tržně ekonomicky a pracují pokud možno bez subvencí. Produktivita práce stroje musí být tedy dále zvyšována. Ve všech oblastech průmyslu bude tento cíl prioritní.

Lze nalézt mnoho příkladů, jak může být zvýšena produktivita, i když každé zvýšení produktivity nemusí nutně znamenat zvýšení spotřeby energie, a může tedy znamenat i přínos k ochraně životního prostředí.

Využití přírodních zdrojů

Vedle zvýšení produktivity práce musíme v budoucnosti klást stále větší důraz na zlepšení produktivity energie, tzn. na lepší využití dostupného energetického potenciálu. Energetické rezervy jsou k dispozici pouze v omezeném rozsahu, proto musíme s těmito zdroji zacházet opatrně. Nízká spotřeba energie je zároveň znamením, že se příslušná země nachází v bídě a nouzi. Z obr. 2 je patrné, že zhruba dvě třetiny celkových emisí CO_2 pocházejí ze šesti zemí. Samozřejmě může zemědělství ve vztahu k energetické technice ovlivnit pouze marginální část, ale dává možnost stát se dodavatelem průmyslově zpracovatelné biomasy jako suroviny a zdroje energie, a tím se stát spotřebitelem vlastních produktů např. spalováním řepkových metylesterů v traktorech a sklizňových strojích místo nafty. Potřebné výzkumy v tomto směru jsou uzavřeny. Pro nadcházející období se

2. Energeticky podmíněné emise CO_2 - Energetically conditioned emissions (S c h ö n , 1990)

ostatní svět   USA
Velká Británie   SNS
Japonsko   Německo   Čína

vztaženo k roku: 1986
celkově: 20 miliard tun
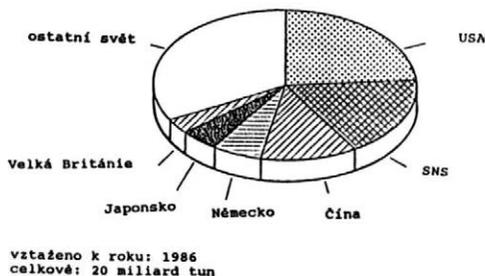
očekává změna příslušných daňových zákonů v Německu a schválení příslušných norem, poté můžeme vycházet z toho, že se plochy řepky v Německu dále zvětší. ES si dalo za cíl do roku 2005 zvýšit podíl technických plodin na celkové spotřebě energie na 5 % (A u e r n h a m m e r , 1990).

Obecně však existují právě pro zemědělskou techniku další možnosti. Dlouhodobé perspektivy mají vedle řepky také další obnovitelné zdroje energie, které jsou všechny prvotně podmíněny využitím sluneční energie, jak ukazuje obr. 3. Je pravdou, že jiné zdroje energie nedosahují výhřevnosti fosilních paliv, k jejich fosilaci je však potřeba 10^3 a 10^8 let. Kromě toho stoupá náročnost investic podle toho, čím příměji má být využita sluneční energie. Tak je např. přímé využití sluneční energie pomocí kolektorů při nízkém zisku energie velmi drahé. Vedle využití vodní a větrné energie nabízí stále se obnovující biomasa ekonomicky výhodný kompromis se srovnatelně velkým ziskem energie a únosným růstovým cyklem.

Zemědělství je právě předurčeno (W e l s c h o f , 1991) stát se velkým dodavatelem biomasy jako zdroje surovin a energie, neboť:
- metody sklizně biomasy jsou celosvětově vyzkoušeny;
- přechod na produkci obnovitelných průmyslových surovin může být uskutečněn v relativně krátké době (W e l s c h o f , 1991).

Samozřejmě je pro každý produkt třeba vedle ekologické stránky posuzovat ekonomickou stránku celého procesu, aby byl zvážen skutečný význam jednotlivých technologií. V této souvislosti je třeba ještě jednou citovat (W e i z s ä c k e r , 1992): *Komunismus ztroskotal, protože jeho ceny neodpovídaly ekonomické skutečnosti. Kapitalismus ztroskotá, pokud jeho ceny nebudou odpovídat ekologické skutečnosti.*

Pokud tedy zákonodárce odstupňuje pomocí daní ceny energie podle ekologického měřítka, může být zemědělství velkým dodavatelem zdrojů energie. Na základě několika příkladů lze ukázat některé výzkumné a vývojové linie.

Příklady pro sklizeň biomasy jako suroviny a zdroje energie

Předpokladem pro sklizeň biomasy, která má být např. využita pro získání tepelné energie, je rychlý růst s co největším hmotným objemem. Tato biomasa však musí být nějakým způsobem dopravena do spalovacího zařízení. Proto je třeba, aby byl přepravovaný objem co nejmenší, tedy aby biomasa byla co nejhutnější. K tomuto účelu poskytuje vhodný základ kompaktní svinovací lis vyvinutý Matthiesem. Princip činnosti tohoto lisu ukazuje obr. 4.
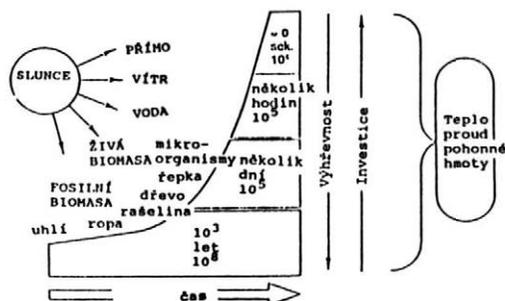
3. Využitelný podíl sluneční energie - Utilizable portion of solar energy (W e l s c h o f , 1991)

4. Princip činnosti kompaktního svinovacího lisu s kontinuálním provozem - The principle of the activity of compact coiling press with continuous operation (M a t t h i e s , 1991)
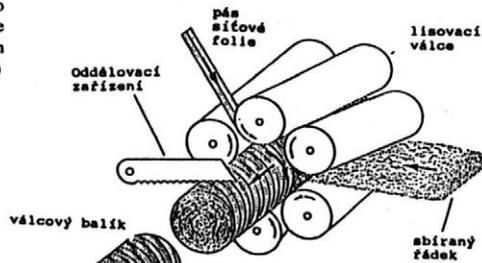
Řádek sbíraný ze země je stlačován v komoře tvořené rotujícími válci. Za účelem vytvoření vytěsňovací složky jsou stlačovací válce odkloněny od osy komory. Aby byly vytvořeny pevné jednotky, ovíjí se válec slámy v okamžiku axiálního posuvu, kdy se nachází pod radiálním tlakem, samovolně síťovým pásem (obr. 4). Po axiálním vytěsnění ze stlačovací komory je rotující válec slámy rozřezán na jednotky libovolné délky.

Nově vyvinutý systém kompaktních svinovacích lisů poprvé umožňuje kontinuální stlačování slámy pomocí jednoduchých rotujících součástí. Tento systém se vyznačuje v praxi dosud nedosaženým stlačením na 350 až 450 kg/m^3 (podle charakteru stlačované hmoty) při relativně nízké spotřebě energie 3 a 4 kWh/t při výkonu až 16 t/h. Tyto údaje se vztahují ke stacionárnímu svinovacímu lisu, který byl testován na institutu v Braunschweigu a který má průměr lisovaného válce pouze 25 cm. V porovnání s konvenční stlačovací technikou jsou výkony kompaktních svinovacích lisů velmi dobré (tab. I).

Vzhledem k těmto vlastnostem se systém kompaktních svinovacích lisů nehodí pouze pro zemědělství jako tradiční oblast nasazení této techniky, ale též se velmi dobře uplatní sklizeň zemědělsky vyrobené biomasy určené pro průmyslové využití. Uvážíme-li velké dopravní vzdálenosti k elektrárnám a obrovská množství hmoty, kterou je potřeba skladovat, nabízí technika kompaktních svinovacích lisů přednosti, které jiné techniky nemají.

Kompaktní svinovací lisy se používají ve všech oblastech nasazení obdobných lisů v zemědělství, a nadto dávají možnost využití ve zcela jiných oblastech. Nesmíme však zapomenout, že se technika kompaktních lisů nachází teprve ve stadiu vývoje a že všechny své přednosti pro zemědělskou praxi bude muset z pohledu technických a ekonomických ukazatelů teprve prokázat.

Pro sklizeň biomasy se nabízí možnost využít pěstování rychle rostoucích rostlin s vysokým výnosem na jednotku plochy. V současnosti se velmi diskutuje např. o *Miscanthus sinensis*,

I. Charakteristiky různých způsobů stlačování - Characteristics of different ways of pressing

Princip stlačování	Průchodnost (t/h) sláma	Hustota (kg/m^3) sláma	Spotřeba energie (kWh/t) sláma
CRP-250 - kompaktní	7..... 16	250...350	3 4
GB - svinovací lis	6..... 12	110...120	2 3
GB - pístový lis	14..... 22	150...170	2 3
HD - pístový lis	8..... 12	120...140	2 3

známém pod jménem čínská tráva nebo čínský rákos. Pro úspěšné pěstování těchto rostlin je nezbytné podporovat základním výzkumem vývoj technologie sklizně.

Nebezpečí plynoucí ze zemědělské výroby pro životní prostředí

Obnovitelné zdroje energie však nemohou samy o sobě vyřešit problémy zemědělské techniky. Našim úkolem je pamatovat na ochranu životního prostředí. Pokud je půda vystavena nasazení těžkých strojů nebo častému přejíždění v průběhu vegetačního období, vede to ke sníženému růstu, resp. k erozi půdy a k vyplavování živin z půdy. Pro ochranu vody a vzduchu je v první řadě nutné cílené a pokud možno minimální použití hnojiv a ochranných chemických prostředků. Zde se otevírá další pole působnosti pro uvědomělou ochranu životního prostředí u zemědělců, zahrádkářů, soukromých domácností, ale též v oblastech odbytu.

Pro ochranu půdy a kořenového systému při pokosu je rozumné používat žací stroje, které jsou speciálním závěsem připevněny před traktor tak, že žací lišta půdu pouze minimálně poškodí. Protože okamžitý pól přední hrany žací lišty je shodný s průsečíkem závěsů, vzniká dopředu orientovaná složka rychlosti, když např. žací stroj překonává půdní nerovnost nebo jinou překážku (obr. 5) a je přitom tlačen traktorem.

Teprve jakmile se okamžitý pól nachází v oblasti před a nad žací lištou, může se lišta bez větších těžkostí vyhnout směrem vzhůru. Tím se chrání kořenový systém a je umožně-
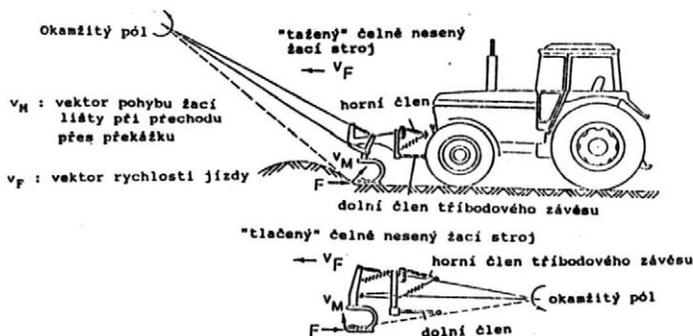
5. Možnosti umístění žacího stroje - Possibilities of location of mower (A u e r n h a m m e r, 1990)
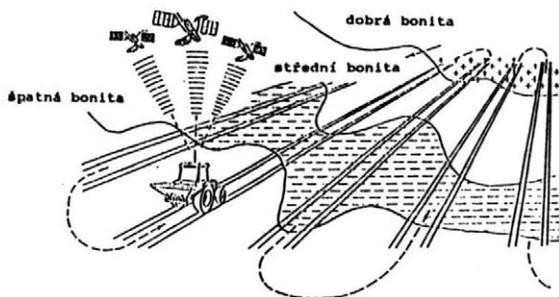
6. Zjištění polohy rozmetadla při nasazení na poli - Finding the position of distributor during operation in the field

no rychlejší dorůstání trávy. Tento způsob upevnění se nazývá „tažený" čelně nesený žací stroj.

Půda je však ohrožována také kontaminací oleji a mazadly. V německém zemědělství připadá ročně zhruba 8000 t minerálních olejů na mazání ložisek a řetězů, k tomu se připočte ještě 4000 t připadajících na zájmové využití. Tento olej se zpotřebuje při údržbě a ošetřování strojů a nakonec zůstává v nějaké formě na poli. Zde se ukazuje jako bezpodmínečně nutné stále více používat nativní mazadla chránící životní prostředí. Domníváme se, že řepkový olej jako náhrada za minerální olej v hydraulických zařízeních se začne ve větší míře používat až za několik let, protože dosud nejsou uspokojivě vyřešeny otázky stárnutí a změny vlastností v závislosti na teplotě.

Tendence snižovat používání průmyslových hnojiv a chemických ochranných prostředků demonstruje, že zemědělská technika musí pracovat s nejmodernější elektronikou. Jako příklad uvádí obr. 6 rozmetadlo hnojiv, které se pohybuje po poli s rozdílnou bonitou půdy. Pokud je okamžitá bonita půdy známa, může být na právě přejížděnou půdu pomocí zařízení se zpětnou vazbou rozmetáno právě tolik hnojiva nebo chemického prostředku, kolik je nezbytně nutné a kolik mohou rostliny skutečně absorbovat. K tomu je pouze nutné znát okamžitou polohu traktoru a sdělit ji regulačnímu článku. Za tímto účelem se zvažuje využití systému GPS (Global Positioning System), který byl vytvořen pro vojenské účely (obr. 6). V současné době se pracuje na vytvoření map, které by byly podkladem pro tuto metodu. Přitom se pomocí sklízecí mláticky podchycují i údaje o vý-

7. Nasazení výpočetní techniky - Introduction of computers (M e r t i n s , T a b r i t z , 1992)
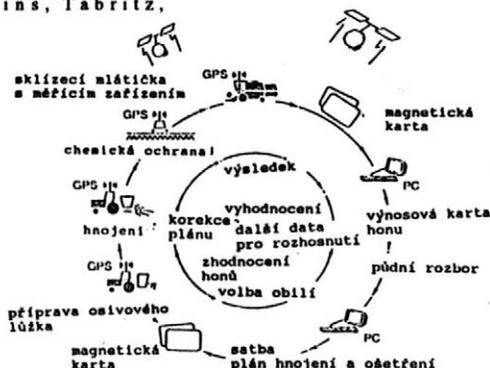
8. Rizika zemědělské výroby - Risks of agricultural production (W e l s c h o f , 1991)
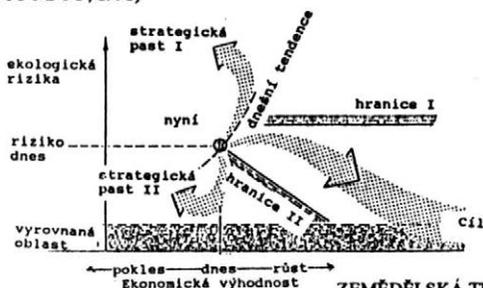
nosech, kterých se v daném místě skutečně dosahuje; tyto údaje pak slouží jako podklad pro příští hnojení. Možnosti vyplývající z paměti výpočetní techniky jsou velmi rozmanité. Malý přehled ukazuje obr. 7.

Technici musí nabídnout zemědělcům takové optimální stroje a postupy, aby životní prostředí bylo vystaveno pouze nejnutnějšímu zatížení. Pokud nebudeme brát dostatečný ohled na ekologická rizika a překročíme hranici I (obr. 8), zničíme naše životní prostředí sami. Pokud nedosáhne zemědělství ekonomické výhodnosti, tak se vystavujeme nebezpečí, že naše zemědělství ztratíme. To by změnilo i naši krajinu. V zemědělské technice tedy nejde o optimalizaci jediného komponentu, ale o optimalizaci celého systému.

Z němčiny přeložil dr. Pavel P o l á k .

Literatura

AUERNHAMMER, H.: Landtechnische Entwicklungen für eine umwelt- und ertragsorientierte Düngung. Landtechnik, *45*, 1990, č. 7/8, s. 272-278.

MATTHIES, H. J.: Die Compactrollenpresse. Landtechnik, *46*, 1991, č. 5, s. 225-229.

MERTINS, H. H. - TABRITZ, K. A.: Elektronik immer professioneller. Agrartechnik, *71*, 1992, č. 4, s. 14-26.

SCHÖN, H.: Landtechnik für die Landwirtschaft der Zukunft. [Přednáška.] 1989, Franfurkt am Main, Agritechnica.

SCHÖN, H.: Schutz der Erde. 3. Bericht der Enquete Kommision des 11. Deutschen Bundestages „Vorsorge zum Schutz der Erdatmosphäre", Dtsch. Bundestag, 1990, č. 19.

SCHÖN, H.: Futtererntemaschinen - ein schwieriger Markt. Agrartechnik, *71*, 1992, č. 3, s. 38-41.

WEIZSÄCKER, E. U. VON: Was geht uns Wissenschaftler die UNO - Umwelt-Konferenz an? [Přednáška.] Techn. Univ. Brauschweig, 15.5.1992.

WELSCHOF, G.: Landmaschinen und Traktoren. Landtechnik, *46*, 1991, č. 12, s. 590-595.

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The market conditions the development and progress as well. We ourselves are creating the market for agricultural products. Unfortunately, generally speaking, we are not prepared to pay for 1 kg of biologically cultivated potatoes more, however ideal this would be. Regrettably, there are many swindles on the side of producers, so we cannot believe in all eulogies. We, as engineers, have to offer to the farmers such optimum machine and procedures, to expose the environment only to the necessary loading and to require to sell us 1 kg of potatoes as far as possible without subsidies for the same price as imported from Brazil, where we had to cut out the tropical forest at first. However, we are standing on the narrow edge in the farm machinery - as shown in Fig. 8. Unless we will not respect the ecological risks and we shall break the limit I, we ourselves shall destroy our environment. Provided that agriculture will not achieve an economic prosperity, we are faced the danger that we shall lose our agriculture. This would change also our landscape. I cannot hope that this industrial society would like to live in the steppe. To prevent this, we need functional agriculture. In farm machinery this is not the case of optimizing the only component, but of optimizing the whole system.

LIVESTOCK HOUSING AND ENVIRONMENT - AMMONIA EMISSION AND ODOUR NUISANCE

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Due to the non-ground bound character of intensive livestock breeding nowadays, animal rearing is posing severe strains on the environment. Two of these problems have been looked at a bit closer in this paper: the ammonia emission and problems related to odour nuisance. Several corrective solutions to reduce the NH3 emission and the odour problems have been tried with varying results. Preventive measures often involve treatment of the manure to prevent the formation or the release of NH3 and odorous components. Often the solutions are very expensive and technical difficult to achieve. More research has to be performed to find effective and economical solutions for the odour problem.

agricultural engineering; livestock; animal housing; environment; odour hindrance; odour abatement

Although environmental pollution induced by agricultural activities does exist already for quite a long period, it was only in more recent years that steps have been undertaken in this field to control the contamination by ammonia and noxious odours. Especially animal husbandry has proved to be one of the main contributors to a general deterioration of the environment due to ammonia emission. For example: it is estimated that the ammonia emission, for which agriculture is the main source, has increased by about 50% since 1950 in Europe. In certain regions, this level was even considerably higher (A p - s i m o n , K r u s e - P l a s s , 1990).

The reason for the environmental problems induced by agriculture can be found in the altered practices in livestock breeding. The small mixed farms, where crop and animal producing where harmoniously combined, have made way for large industrial operations with a better labour efficiency and higher yields. Improved climate control techniques and equipment allow much higher densities in the houses. Systems to reduce labour such as the application of slatted floors combined with litterless housing are common practice since many years. Due to all these factors, livestock units are no longer in a normal proportion to the farm area. Since feed is brought onto the farm from external sources, the physical relation between the herds and the land is limited to the space the animal houses occupy. These distorted relations have imposed a severe burden on the environment (D e b r u y c k e r e , 1973): odour nuisance, ammonia emission and dung surpluses. Furthermore, due to historical and economical factors, there is often a not uniform distribution of farms. Very high concentrations of animals occur in certain regions, which leads for example to excess waste dumping on farmland resulting in pollution of ground and surface water.

Although the general rule that the degree of environmental pollution is proportional to the concentration of animals in a certain area, differences can be noticed. With the actual size and composition of the livestock, cattle and swine contribute more to ammonia pollution than poultry and other farm animals in Western Europe (W e e r d h o f , 1988). The physical location where the ammonia emission occurs, varies also considerably. For example, veal calves, due to their young age, have a very low contribution to the general ammonia emission, which then, mainly, occurs when their manure is spread on the land. Cattle on the other hand contributes much more, and depending on the season, in different places: during the pasturing period, the ammonia emission takes place immediately outside, while in winter time, the emission comes from the animal house or in spring from applying manure on farmland. Ammonia emission and odour problems from animal houses are noticeably higher in summer than in winter time. Due to the higher temperatures the biochemical decomposition of manure is faster while ventilation rates are higher too.

As will be shown further on, differences in ammonia emission and odour pollution are not only related to the age and animal species, but also to the composition of the feed, the housing system itself and especially the manure handling system. Although the problem of excess manure production is very real in most industrialized countries, we will not deal with it specifically in the scope of this paper. In the following chapters, we will focus only on the problems of ammonia emission and odour hindrance.

ANIMAL HUSBANDRY AND AMMONIA EMISSION

Effects of NH₃ emissions on the environment

Emitted ammonia affects the environment in several ways. First of all, there is the direct interaction with the atmosphere and secondly, there is an action of NH_3 on the plants and the soil.

NH_3 which penetrates into the clouds, greatly affects the natural cloud chemistry. In particular, the oxidation processes of SO_2 by ozone and hydrogen-peroxide are distressed. Under normal circumstances sulphur-dioxide is oxidated in cloud droplets. This process facilitates removal of SO_x in precipitation. The oxidation of SO_2 by H_2O_2 is strongly pH dependent and negatively influenced by NH_3. Ammonia forms ammonium aerosols in the atmosphere, a.o. $(NH_4)_2SO_4$, which do not only reduce visibility but which also have an extremely strong acidifying potential for soils (A p s i m o n , K r u s e - P l a s s , 1991).

In weakly buffered ecosystems a high deposition of ammonium leads to acidification and nitrogen enrichment of the soil. As a consequence many plant species characteristic of poorly buffered environments disappear. In forest ecosystems, a high input of ammonium leads to leaching of K^+, Mg^{2+} and Ca^{2+}. This results in a reduced growth of symbiotic fungi and a lower uptake of potassium and magnesium by the root system of the plants.

Experiments have shown that coniferous trees absorb NH_4^+ through their needles. The combination of magnesium and potassium deficiencies and nitrogen stress, leads to a premature shedding of the needles. It also makes trees more susceptible to other stress factors such as drought, frost and fungal diseases. Most probably not only coniferous trees are affected in this way, but other plants as well.

Finally, another more visible effect, be it less widespread, occurs in cold climates, such as in northern Scandinavia. A direct impact on the vegetation from airborne NH_3 can be noticed: coniferous trees colour red and reddish brown. Due to the low temperatures, the ammonia detoxification capacity of the plants is very limited (R o e l o f s, H o u d i j k , 1991).

NH_3 emission from animal houses can be estimated by measuring the NH_3 concentration in the exhaust ventilation air and by measuring the air flow rate. The mathematical product of those two entities gives a close estimation of the ammonia emission from the animal house (G u s t a f s s o n , O l d e n b u r g , 1989).

Ammonia concentrations can be determined on a continuous basis or by taking momentary samples. The latter is often done with the use of Dräger tubes. Although this method may give a fairly good first indication of the NH_3 concentration in the stable, the technique is susceptible to errors and the accuracy is usually limited to about ± 15% (O l d e n b u r g , 1989; G r o o t K o e r k a m p et al., 1990). The Dräger tube method is therefore not recommended for comparative or scientific research.

A number of other discontinuous methods are used such as the wet chemical technique (using Nessler reagens, or the indophenol method) while continuous methods have also been developed. The latter are often based on opto-acoustic or photo-acoustic principles, IR-detection and conductometric systems. More details about these systems can be found in the literature. General precautions need to be taken to protect the equipment from the high concentrations of dust and moisture which frequently occur in animal houses.

The ventilation pattern in the animal house has often an outspoken effect on gaseous concentrations. There may be gradients in NH_3 concentrations. Therefore determined NH_3 concentrations need to be interpreted carefully and should be verified at the animal level (H o e k s t r a , 1988).

The ventilation rate of mechanically ventilated buildings can easily be measured. In the most frequently applied method, a registration fan is installed in the ventilation air exhaust duct. The airflow can be estimated from the revolutional speed of this dummy ventilator. Some caution is required though at low ventilation rates. The accuracy of this technique is between 10 to 15% of the range (G r o o t K o e r k a m p et al., 1990). Mechanically ventilated buildings with an overpressure system often pose additional problems due to air leakage (O l d e n b u r g , 1989).

It is extremely difficult to gauge the ventilation rate of naturally ventilated facilities. The ventilation rate is often calculated indirectly from the heat balance or from the changing concentration of certain gases (tracer gas, CO_2 or NH_3). Often, the results are not reliable enough and presently research is done to develop more accurate techniques.

As conclusion, the importance of accurate measurements needs to be stressed. Several researchers have discovered deficiencies in the N balance using some of the measurement techniques described above (E l h a r d t , 1988). Therefore further research for reliable ammonia emission detection systems which can be used on the farm is necessary (Tab. I).

I. NH₃ emission from livestock in the Netherlands (%)

	Housing	Spreading manure	Animals on pastures	Total
Cattle	19	31	10	60.0
Pigs	12	15	0	27.0
Poultry	7	5	0	12.0
Veal	0	1	0	1.0
Total	38	52	10	100.0

General methods to reduce NH₃ emission

Ammonia emission from livestock occurs at different stages in the production cycle for different kinds of animals. When the N-cycle in animal husbandry is fully understood, it is possible to take action to reduce ammonia emission. This can be done on two levels: firstly, the total amount of N released into the environment can be lowered and secondly, the concentration of NH_3 emitted can be decreased. For example, the nitrogen cycle for an average fattening pig can generally be analyzed as shown in Fig. 1. From a 100% N intake, only about 34% N is used for production, while 66% N is redeposited in the environment through faeces and urine, mainly in the form of uric acid. About 13% is them emitted into the atmosphere as NH_3 from the animal house or the manure storage facilities. Another 13% contributes to ammonia emission during the spreading of the manure on farmland. Hence, only about 40% of the initial nitrogen can contribute to fertilization of plants (S p r e e u w e n b e r g , 1990).

From this example, it is quite obvious that feed has a very important role: the minerals which are not taken in by the animal through the feed, cannot be excreted in the faeces or the urine (S p r e e u w e n b e r g , 1990). Therefore it is important that the digestion of feed is fully understood and that a correct and complete insight is obtained in the nitrogen digestion and the essential amino acid requirements of the animals. The latter will lead to a reduction of the overall protein content of feed and the addition of essential
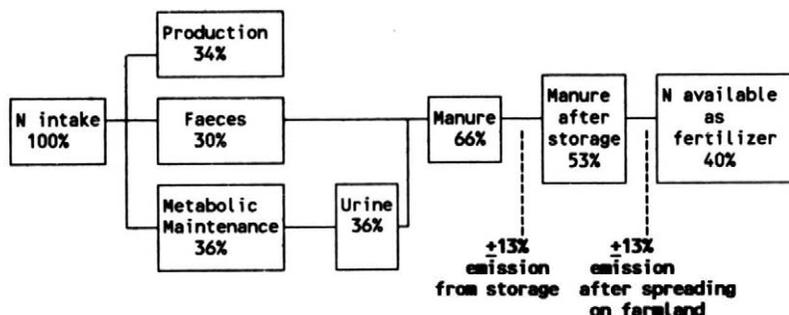
1. General N digestion in fattening pigs

amino acids. Besides the total N content of the feed, other components which are used, need to be given attention as well. Feed for pigs and poultry contains a high amount of seeds of leguminosae such as beans (*Phaseolus* spp.) peas (*Pisum sativum*) and others (*Glycine max, Vicia faba* etc.). These seeds contain a number of anti-nutritious factors (ANF) which have a negative effect on N digestion. The first important group of ANF's consists of protease inhibitors (PI). PI's are proteins which bind trypsin and chymotrypsin with the immediate effect of diminished protein digestion. At the same moment PI's induce an increased excretion of endogenous protein through hyper-secretion of pancreas enzymes. The second group of ANF's are lectin proteins. These compounds affect the animal in different ways pending on their chemical structure and functional properties. Finally, tannines are the third group of ANF's which reduce the digestibility of proteins in the food by forming H-bridges and hydrofobe interactions with the latter. Certain of these ANF's can be removed from the feed by pretreatment of the seeds (e.g.soybeans and *Phaseolus* spp.), while the amount of other ANF's in certain seeds has proven to be subject to genetic variability. Therefore, selected species, with a low ANF content, may be preferred to supply the basic ingredients for animal feed (J a n s m a n et al., 1990). Although the possibilities to decrease the total N intake through adjusted feed composition look promising, there are limits imposed by economic factors (L e n i s , 1989). At this moment, synthetic amino acids are already implemented in feedstuff for piglets and broilers which make further reduction of total N nearly impossible if a one - sided source of base components is to be avoided.

Phased foddering, i.e. supplying feed with a composition based on the animal's requirements in function of its age, can also improve N digestion and therefore contribute to reduced ammonia emission.

As it is not possible to remove N completely from the faeces and urine, measures need to be taken to reduce the NH_3 emission inside the animal house as well. Ammonia is produced by microbial decomposition of the nitrogenous compounds in the manure. This is an aerobic process, where a number of different bacteria are involved. Several systems try to reduce one way or another bacterial activity in the manure, especially if the manure is to be stored inside the animal house for a considerable amount of time. Temperature, moisture content and pH are important factors here. Other techniques consist of removing the slurry from the house, as will be seen further on.

The influence of temperature has been demonstrated through seasonal fluctuations of the NH_3 emission from manure storage facilities in relation to aerial temperature (H a r - t u n g , 1990). However, a high technical and costly effort is required to keep temperatures low during summer time under practical farm conditions.

Cattle and ammonia emission

Determining ammonia emissions from cattle and dairy facilities has proved to be quite difficult because most stables are naturally ventilated. An indirect measuring method by use of the Lindvall box has been developed, however, there is still disagreement on the precise application of this technique (O o s t h o e k et al., 1991; B o d e , 1991). Most research, presently going on, is performed in the Netherlands. Different flushing systems and floor scrapers combined with flushing systems are being investigated. The main problems with these methods are the increased slurry volume and recycling of flushing

liquid. With respect to these problems special constructions: sloping floors and urine gutters are being studied as well.

Extracting air from above the manure will prevent ammonia to penetrate into the animal house through the slatted floor, but this will not reduce the total ammonia emitted into the atmosphere (G r o o t K o e r k a m p et al., 1990).

Several manure treatment systems are also under study to find a practical method with acceptable results. In an aerobic environment, the N present in different organic compounds of cattle dung can rapidly be converted to mineral nitrogen. If sufficient carbon is present, the N is fixed in bacterial protein by micro organisms. This process continues until the C and N level in the manure is almost the same as in the micro organisms. Further digestion will lead to release of carbon dioxide and ammonia. Normally, ammonium nitrogen is in equilibrium with ammonia. When storage tanks are not covered, the ammonium concentration remains fairly constant. This can only be explained by further decomposition of organically bonded nitrogen. In covered tanks however, the ammonia cannot volatize and the ammonium concentration increases. Hence the manurial value of this slurry is higher.

The storage tanks can be covered with different materials. Cattle dung forms a weak crust after about 1.5 months, but this crust is not weather resistant and thus does not really reduce ammonia emission. Adding chopped straw to the manure, approximately 5 kg per square meter tank surface, leads to the formation of crust with reduction coefficients up to 78%. Several other covering systems have been tested: a floating cover, a tent and an expanded polystyrene cover. All had even better results that the straw crust: up to 90% reduction NH_3 emission.

Finally, ammonia emission can also be reduced by mixing additives to the manure. A commercial system has been developed and used in the Netherlands with fairly good results. The principle is based on reducing the pH of the slurry to about 4.6 by adding a.o. HNO_3. The main result is a considerable improvement of the climate inside the animal house and the amelioration of the manure which can be used as a truly NPK fertilizer (W o u d s t r a , 1990).

Swine and ammonia emission

Ammonia emission from pig housing facilities cannot only be reduced by a carefully selected diet, as illustrated earlier, but also by implementing specific techniques for handling and storing the manure as well as by applying specific ventilation techniques.

Most modern swine houses are equipped with slatted or partially slatted floors under which manure is stored for a certain time. Frequently, air leakage from the manure channels or storage area through the slatted floor into the shed is the main contribution for high concentrations of ammonia. It is recommended to install shutters in manure channels going out from the stable, to prevent these canals to work as air inlets in the case of exhaust ventilation systems. The air movement near or above the manure also affects the release of ammonia into the animal house. Therefore it is recommended to install a „breathing" ceiling which allows very low air velocities. Low exhaust systems, preferably through the manure channel, have a better effect on ammonia concentrations in the house than high exhaust systems. Comparative research has shown that it is possible to reduce the concentration of NH_3 25 to 30% (G u s t a f s s o n).

Another important factor for the release of ammonia, seems to be the size of the surface area of manure and urine stored inside the building. However, researchers have different opinions on this subject. A comparative study of three fattening pig houses has shown that there is no significant difference in ammonia emission between a stable with a manure storage with a large surface area, a stable with a shallow manure storage area which was emptied weekly or a stable with a direct run-off system for urine and daily removal of faeces. These researchers conclude that „quick removal of manure, a low amount of slurry stored in the house, and even the immediate separation of urine fail to provide solutions to the problem of NH_3 emissions from fattening pig houses" (O o s t h o e k et al., 1991). Presently, research is being done on flushing systems. This are systems where manure is washed out of the animal house at regular intervals. Depending on the applied technique, the flushing liquid can be obtained from the slurry itself after aeration and sedimentation. During the aeration process, ammonia is converted to nitrate which in its turn is converted into nitrogen. Although the experiments are not yet concluded, some provisional results are already available. Flushing systems whereby faeces and urine are collected in a layer of flushing liquid achieved reduction of ammonia emission of 60 to 70% in comparison with fully and partially slatted floors (O o s t h o e k et al., 1991).

Finally, a number of experiments with ammonia binding additives are under way. A frequently encountered problem is a shift from NH_3 emission to non acceptable health risks (e.g. adding formaldehyde) or towards burdening the environment with an excess of other harmful components (e.g. super phosphate - $NH_4H_2PO_4$) (V e r d o e s , 1990).

Ammonia emission from poultry houses

Although the total ammonia emission from poultry is ranked behind the emission from cattle and swine breeding, it is still quite an important factor. About 2/3 of the total ammonia emission from poultry is released from the housing and manure storage facility, while 1/3 is liberated from spreading the manure on fields and farmland.

Washing NH_3 from ventilation air or removing it though chemical or biological filtering is possible but too expensive. Moreover, this system would not contribute to the general amelioration of the environment in the animal house. High concentrations of NH_3 (20 ppm) have proved to cause damage to the respiratory tract of laying hens and broilers, resulting in higher infection risks, less efficient breathing and hence an increase in feed conversion. A lower egg production - although the eggs tend to be somehow larger, and more cases of keratoconjuctivitis have been noticed in these situations (C a r l i l e). Therefore, it is important not only to reduce the NH_3 contents in the (ventilation) air, but to prevent the formation of ammonia from the manure within the shed.

As approximately 75% of the ammonia emission by poultry is caused by broilers (E l h a r d t , 1988), most methods to reduce the conversion of uric acid to NH_3 have been designed for broiler facilities. With an adjusted diet, low in protein (19.8%) and high in fat, the total amount of N in the manure can be reduced considerably (E l h a r d t , 1988). Another way to prevent the production of ammonia is by adding antibiotics in the food to lower microbial activity in the manure. Successful results were obtained with thiopeptin (C a r l i l e), but careful selection of antibiotics is required to avoid health risks (W i t , E l h a r d t , 1988). This problem is even more outspoken by the mixing of formaldehyde or paraformaldehyde, chemical substances which prevent the lease of NH_3 by fixating it, in the manure. The health risks involved are, however, due to the cancerous nature of the chemicals, not acceptable.

Reducing the pH of the litter will slow down bacteriological activity and thus NH_3 production. Therefore acetic or propionic acid can be added to the litter. This method is only successful during the first weeks of the production cycle, after which treatment has to be repeated (W i t , E l h a r d t , 1988), which is considered a very cumbersome task by most farmers.

The use of zeolite, in particular clinoptilolite, has proved to be quite successful, but this too, requires periodical adding and mixing clinoptilolite with the litter. A possitive side effect of the use of clinoptilolite is the reduction of foot pad burns and the increased egg production with laying hens. When used as sole source of litter, clinoptilolite caused dust problems and augmented the overall mortality rate. The product could eventually be mixed with the food but more research has to be conducted in this area (C a r l i l e).

Reducing the humidity of the litter has proved to be a quite effective means of lowering NH_3 emission. This effect can be obtained by properly constructed building and appropriate equipment such as drinking nipples instead of a drinking gutter and other open water systems. The choice of material used as litter has also some influence: fresh long straw remains dryer than wood shavings (E l h a r d t , 1988). Avoiding condensation on cold floors helps to keep the litter dry, therefore insulation in combination with floor heating has given fairly good results. Designing ventilation for an acceptable NH_3 level and relative humidity level between 60-75% will enable farmers to keep the litter dry enough to reduce ammonia emission considerably. Ventilation control based on NH_3 is at this stage not yet commercially available due to the lack of reliable ammonia sensors. Certain farmers have, however, obtained acceptable results both from the point of view of ammonia levels and heating costs, with a standard temperature based control system combined with periodical increased ventilation rates.

ANIMAL HUSBANDRY AND ODOUR NUISANCE

Animal husbandry and odour problems have always been related. However, as mentioned earlier, due to the very intensive livestock operations, odour pollution has often become a real nuisance in densely populated areas. Therefore, attempts are made to reduce odour emission from animal production units. Fortunately, odour associated problems only occur in a fairly close range around the animal house, the manure storage area or the fields where manure is applied. The latter is in most cases even, only a temporary problem. Research has shown that even at very close distances (50 to 100 m in certain cases) the scent had reduced to a level of „faint odour detectable" (K o w a l e w s k y et al., 1990). The classification of odour levels is a subjective matter. Presently, no objective method for the measurement of odour intensity is available yet (K o w a l e w - s k y et al., 1990; M i n e r , H a z e n , 1969). A considerable amount of research is performed to develop accurate and reliable measurement techniques for odours components. Two methods are commonly used and being refined: gas chromatographic analysis and olfactometric measurements (V o o r b u r g , 1985; H a r t u n g , 1991). For the latter, research has lead to a set of „Recommendations on Olfactometric Measurements" (V o o r b u r g , 1990), which are continuously being updated and improved. One of the major problems encountered is the very low quantities of certain odourants. Often, the concentrations of compounds, sulphur components in particular, are too small to be detected by mass spectrometry or regular gas chromatography while they do have a distinct influence. Different methods for collecting air samples and special gas chroma-

tographic techniques have been developed to determine these low levels (M i n e r, H a z e n, 1969; K o w a l e w s k y et al., 1990; S c h a e f e r, 1990).

Most researchers do agree on the fact that nearly all the odorous components are released by decomposition of manure. Especially anaerobic digestion of slurry tends to release a considerable amount of odourants (B a n w a r t, B r e m m e r, 1975; W i l l s o n, 1971). Although suggestions that a number of odorous components may be direct products of animal metabolism have been made (H a m m o n d, J u n k). A list of components contributing more or less to odour from livestock farming is available, amongst which the most common are phenol, para-cresol, indole, ethylphenol, skatole, acetic acid, propionic acid, butyric acid, short chain alcohols and a number of sulphur compounds (A k i o Y a s u m a r a, K i i c h i r o F u w a, 1983; A k i o Y a s u m a r a et al., 1984). Not all of these components have the same importance, in all cases. While the presence of skatole and indole, two alkaloids with a strong harsh odour was found in poultry and swine manure, assumptions were made that there would be a correlation between malodours of livestock and these components. The appearance of these two components in air from swine houses is so low that not only a correlation cannot be established, but that neither can be considered an important odour constituent of swine manure (T r a v i s, E l l i o t, 1977). Several researchers have attempted to establish a relationship between one or more of these chemical components and odour levels. K o w a l e w s k y et al. (1990) who investigated odour dispersion of swine and poultry houses, states that NH_3 is fairly well correlated with the sensory odour levels. M i n e r, H a z e n (1969) discovered that ammonia emitted from a hog house can be discovered at concentrations below reported threshold-odour levels and thus concluded that odour producers have an additive effect. J o n g e b r e u r, K l a r e n b e e k (1990), on the other hand, declared that complex odours, such as emanating from livestock facilities, cannot be characterized by a single or even a few components. Instrumental analyses of odour emissions should only be considered suitable for screening purpose and not for reliable odour determination (J o n g e b r e u r, K l a r e n b e e k, 1990). This indicates that still a lot of work needs to be done before objective standards for quantification of odour from livestock can be established. Although profound knowledge and understanding of the compounds and their interactions that form malodours is essential to control odour emission, a number of production techniques have proved to reduce the problem to a certain extent.

Odour dispersion from animal houses is fairly similar to industrial odour dispersion. The main difference occurs from the much lower points of release (M e j e r, K r a u s e, 1985). Therefore high chimneys could be erected, but these are aesthetically not desirable. The application of vertical not covered exhaust chimneys has proved to be useful to increase the effective discharge height. Planting trees around the animal facilities may provide a better dilution because of added turbulence, but the real effectiveness still needs further investigation (M e j e r, K r a u s e, 1985). Filtering dust from the exhaust air has proved to reduce odour emission up to 65% from swine houses (H a r t u n g, 1985). Filtering dust is not always a practical solution, although different systems have been tried: a water misting system in a baffled duct of a laying hen house was quite successful and did not require too much maintenance (W i l l s o n, 1971). As about 85% of the dust in a stable originates from the feed, wet feeding is recommended to reduce the dust problem (H a r t u n g, 1985). In situations where it is nearly impossible to control dust or when dust is not the main problem, deodorants and other additives may be mixed to the manure to reduce odour emission or to mask the malodour.

Successful trials have been made by mixing potassium permanganate ($KMnO_4$) with cattle manure in open feedlots (U l i c h , F o r d , 1975). Masking odours, i.e. adding products with a stronger, but more agreeable scent, have been proved to be quite successful for the treatment of poultry manure, while digestive enzymes were the least effective. No research has been done, however, on the effect of these chemicals on the soil where treated manure is spread (B u r n e t t , D o n d e r o , 1970). Experiments with dried bacteria have had mixed results. When very carefully selected they do have an odour reducing effect on swine and poultry manure (C o l e et al., 1975; B e r g d o l l , 1975).

There is a general agreement that keeping the manure aerobic, will reduce the overall odour emission. A number of installations based on this principle are already actively used. Flushing systems for laying hen facilities with an aeration tank have given promising results. An overall amelioration of the climate inside farrowing facilities was obtained by aeration of the manure which was stored underneath the slatted floor. Not only the odour emission was lower, but there was also a significant reduction of faecal streptococci. Recent developments are aimed at simplifying and optimizing the design for aerobic treatment of organic sludge. Beside the aeration of manure, experiments during which poultry manure collected on belts in laying hen batteries was dried, have shown a reduction of triethylamine in the air with approximately 60% and hence also a reduced odour emission (A n o n y m o u s , 1979-1981). Biofilters and bioscrubbers have to be mentioned here as well since they may become more important in the future. These systems are known and have been applied since many years. However, due to the high costs related to the treatment of huge volumes of exhaust air from animal houses, the difficulties of conditioning the effluent water with regards to nitrogen and the fact that on farm installation often do not perform up to expectations, biofilters and scrubbers are not frequently used (S c h o l t e n s , D e m m e r s , 1990). New designs adjusted for operation in livestock buildings (S c h i r z , 1990) and further research for treatment of the nitrogen rich effluent water will have to provide economically justified solution for biofilters. Finally, oligolysis has to be mentioned too. This electrolytic treatment, where small quantities of metal ions (especially Cu ions) are discharged in the slurry, has given good results concerning reduced odour and ammonia emission on a lab scale level (C o l a n - b e e n , N e u k e r m a n s). Further investigation is required to determine whether this system can be applied on farm scale.

CONCLUSIONS

Due to the non-ground bound character of intensive livestock breeding, nowadays animal rearing is posing severe strains on the environment. Two of these problems have been looked at a bit closer in this paper: the ammonia emission and problems related to odour nuisance.

Several researchers have proved that high ammonia concentrations in the atmosphere (or the animal house) have a negative effect not only on men and animals but in general on the environment. Ammonia is released into the atmosphere at different points in the animal production cycle. First there are emissions from the animal houses and manure storage facilities, second the NH_3 release from spreading manure on farm land and third, particular for cattle, there is the emission during the outdoor grazing period. Preventive actions were aimed at reduced total N excretion into the environment by adjusted diets. Corrective actions range from properly constructed shelters to proper manure treatment.

When livestock breeders apply the correct treatment, ammonia emissions from livestock breeding can be reduced considerably.

Intensive animal production often causes odour nuisance as well. One of the difficulties encountered here is the lack of objective and clear standards to quantify and characterize odour. Research has been done to identify the odorous components and most scientists agree that these compounds are mainly released by the decomposition of manure.

Several corrective solutions to reduce the odour problems have been tried with varying results. Preventive measures often involve treatment of the manure to prevent the formation or the release of odorous components. Often the solutions are very expensive and technical difficult to achieve. More research has to be performed to find effective and economical solutions for the odour problem.

References

AKIO YASUMARA - KIICHIRO FUWA: Isolation and analysis of odorous components in swine manure. J. Chromatogr., 1983, No. 281.
AKIO YASUMARA - KIICHIRO FUWA - MASAYUKI JIMBU: Identification of odorous components in fresh and rotten swine manure. Agric. Biol. Chem., 48, 1984, No. 12.
ANONYMOUS: Indirect reference to a not specified issue of the Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent. The article was based on research performed by the Centrum voor de Studie van het Stalklimaat, 1979-1981.
APSIMON, H. M. - KRUSE-PLASS, M.: The role of ammonia as an atmospheric pollutant in odour and ammonia emissions from livestock farming. 1990; 1991.
BANWART, E. L. - BREMMER, J. M.: Identification of sulphur gases evolved from animal manures. J. Environ. Qual., 1975, No. 3.
BERGDOLL, J. F.: The use of dried bacteria cultures and enzymes to control odor and liquidify organic waste found in hog, dairy and poultry producing units as well as lagoons. Proc. 3rd Int. Symp. Livestock Wastes, 1975.
BODE, M. J. C. de: Odour and ammonia emissions from manure storage in odour and ammonia emissions from livestock farming. 1991.
BURNETT, W. E. - DONDERO, N. C.: Control of odors from animal wastes. Transactions ASAE, 1970, No. 14.
CARLILE, F. S.: Ammonia in poultry houses. Lit. Rev. Wld's Poult. Sci. J., 40, pp. 99-113.
COLE, C. A. - BARTLETT, H. D. - BUCKNER, D. H. - YOUNKIN, D. E.: Odor control of liquid dairy and swine manure using chemical and biological treatments. Proc. 3rd Int. Symp. Livestock Wastes, 1975.
COLANBEEN, M. - NEUKERMANS, G.: Mestbehandeling door oligolysewerking. Landbouwk. Tijdschr. (in druk).
DEBRUYCKERE, M.: Livestock housing and environment. Proc. CIGR Meet. Agrartechnik und Umwelt, 1973.
EHLHARDT, D. A.: Ammoniakproduktie en - emissie van schlachtkuikenstallen in Kontaktdag primaire sector. 1988.
GROOT KOERKAMP, P. W. G. - VERDOES, N. - MONTENY, G. J.: Naar stallen met beperkte ammoniak-unitstoot. Deel 1, 1990.
GUSTAFSSON, G.: Reduction of ammonia in swine houses.
HAMMOND, E. G. - JUNK, G. A. et al.: Constituents of swine house odors. J. Pap. N^{o}j-7748 Iowa Agric. Home Econ. Exp. Stat.
HARTUNG, J.: Dust in livestock buildings as a carrier of odour in odour prevention and control of organic sludge and livestock farming. 1985.
HARTUMG, J.: Influence of housing and livestock on ammonia release from buildings in odour and ammonia emissions from livestock farming. 1990.
HARTUNG, J.: Sampling of odorous air for olfactometric measurement, in odour prevention and control of organic sludge and livestock farming. 1991.
HOEKSTRA, W. K.: Balans tussen ammoniak, vocht en temperatuur. Pluimveehouderij, 1988, No. 40.
JANSMAN, A. J. M. - HUISMAN, J. - POEL, A. F. B. van der - KEMPEN, G. J. M. van: Mogelijkheden tot de reductie van uitscheiding van stikstof via mest en urine door eliminatie van antinutritionele factoren in veevoedergrondstoffen in Mestproblematiek: aanpak via de voeding van varkens en pluimvee. 1990.
JONGEBREUR, A. A. - KLARENBEEK, J. V.: Odour measurement research in intensive livestock production units. Proc. 4th Forum Appl. Biotechnol., 1990.

KOWALEWSKY, H. H. - SCHEU, R. - VETTER, H.: Measurement of odour emissions and immissions. Proc. 4th Forum Appl. Biotechnol., 1990.

LENIS, N. P.: Lower nitrogen excretion in pig husbandry by feeding current and future possibilities. Netherl. J. Agric. Sci., 1989, No. 37.

MEJER, G. J. - KRAUSE, K. H.: Dispersion models for emissions from agricultural sources in odour prevention and control of organic sludge and livestock farming. 1985.

MINER, J. R. - HAZEN, T. E.: Ammonia and amines: Components of swine-building odor. Transactions ASAE, 1969.

OLDENBURG, J.: Geruchs- und Ammoniak-Emissionen aus der Tierhaltung. KTBL-Schrift, 333, 1989.

OOSTHOEK, J. - KROODSMA, W. - HOEKSMA, P.: Ammonia emission from dairy and pig housing systems in odour and ammonia emissions from livestock farming. 1991.

ROELOFS, J. G. M. - HOUDIJK, A. L. F. M.: Ecological effects of ammonia in odour and ammonia emission from livestock farming. 1991.

SCHAEFER, J.: Development of instrumental methods for measuring odour levels in intensive livestock buildings. Proc. 4th Forum Appl. Biotechnol. 1990.

SCHIRZ, S.: Practical application of bioscrubbing technique to reduce odour and ammonia, odour and ammonia emission from livestock farming, 1990.

SCHOLTENS, R. - DEMMERS, T. G. M.: Biofilters and air scrubbers in the Netherlands, odour and ammonia emission from livestock farming, 1990.

SPREEUWENBERG, W. W. M.: Het voer op het individuele bedrijf in relatie tot dé mestproblematiek in Mestproblematiek: aanpak via de voeding van varkens en pluimvee. 1990.

TRAVIS, T. A. - ELLIOT, L. F.: Quantitation of indole and skatole in a house swine unit. J. Environ. Qual., 4, 1977, No. 6.

ULICH, W. J. - FORD, J. P.: Malodor reduction in beef cattle feedlots. Proc. 3rd Int. Symp. Livestock Wastes. 1975.

VERDOES, N.: Naar stallen met beperkte ammoniakuitstoot. 1990.

VOORBURG, J. H.: Standardization of olfactometric measurements in odour prevention and control of organic sludge and livestock farming. 1985.

VOORBURG, J. H.: Achievements of the odour group in odour and ammonia emissions from livestock farming. 1990.

WEERDHOF, A. M.: Pluimveehouderij kan NH₃ uitstoot verlagen in Pluimveehouderij. 1988, No. 37.

WILLSON, G. B.: Control of odors from poultry houses. Livestock Waste Management, 1971.

WIT, W. de - EHLHARDT, D. A.: Ammoniak vormt een groot milieuprobleem. Pluimveehouderij, 1988, No. 3.

WOUDSTRA, J.: Vermindering van de ammoniakuitstoot op het rundveebedrijf met ammoniakbindende additieven in Dierlijke Mest problemen en oplossingen. 1990.

V dnešní době chov zvířat vzhledem k svému intenzívnímu půdou neomezenému charakteru tvrdě zatěžuje životní prostředí. Podrobněji se autoři v tomto článku zabývají emisí amoniaku a problémy, spojenými s pachy.

Několik výzkumníků dokázalo, že vysoké koncentrace amoniaku v ovzduší (nebo ve stájích pro zvířata) měly negativní vliv nejen na lidi a na zvířata, ale všeobecně na životní prostředí. Amoniak se do ovzduší uvolňuje v různých okamžicích produkčního cyklu zvířat. Za prvé to jsou emise ze stájí a z objektů pro skladování hnoje, za druhé je to uvolňování NH₃ při rozhazování hnoje na zemědělských plochách a za třetí, a to platí zvláště u dobytka, jsou to emise během pastvy. Prevence má za cíl omezení celkové exkrece dusíku do životního prostředí. Jde o komplex problémů od správně vystavěných hnojišť až po správné zpracování hnoje. Jakmile chovatelé dobytka zavedou správné zpracování, emise amoniaku vyskytující se při chovu dobytka se výrazně sníží.

Intenzívní živočišná výroba je často také příčinou zamoření pachy. Jednou z obtíží, se kterými se zde setkáváme, je nedostatek objektivních a jasných norem pro kvantifikaci a charakterizování pachů. Byl dokončen výzkum směřující k identifikaci složek pachů a většina vědců souhlasí s tím, že tyto sloučeniny se uvolňují hlavně při rozkladu hnoje.

Několik způsobů, jak omezit problémy spojené s pachy, bylo vyzkoušeno s různými výsledky. Preventivní opatření často zahrnují zpracování hnoje s cílem zabránit tvorbě nebo uvolňování pachových složek, jsou často velice nákladná a těžko dosažitelná z technického hlediska. Musí proto proběhnout ještě další výzkum, zaměřený na nalezení efektivního ekonomického řešení uvedené problematiky.

THE MACHINERY SYSTEM

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Agricultural machinery is one of the inputs which the farmer uses in the exploitation of solar energy through crop production. The availability of solar energy completely dominates when to plant, what crops to sow, how they develop and when they are ready for harvesting. Usually when conditions are right, the different operations have to be carried out quickly and correctly in order to create the best environment for crop growth or to harvest the produce at its optimum quality. In traditional agricultural production systems crop production has been associated with three great peaks of labour demand: for cultivating the soil and sowing the seed, for removing weeds, which were competing with the crop for solar radiation, water and nutrients, and at harvest. These short periods of hectic work, needing casual labour, were followed by long periods of little activity.

The early stages of agricultural mechanisation can be traced towards an attempt to substitute machinery for labour in order to reduce the peaks of labour demand during the farming year and to provide a better match between the work load and the labour force. A second stage of mechanisation is directed towards substitution of machinery for labour in order to reduce the costs of production. The rate at which this substitution proceeds depends on the relative costs of machinery and labour and also upon the opportunities for alternative employment in the economy usually outside agriculture. A third stage is to seek economies of scale in the utilisation of both machinery and labour through the amalgamation of agricultural holdings into larger production units.

MODELS OF THE PRODUCTION PROCESS

There are several ways of looking at the production process depending on whether one is interested in the physical operation of converting a set of inputs into an output as an end in itself or whether one is further interested in the production process as a business venture which yields a profit. In crop production, husbandry is concerned mainly with the physical/biological processes of converting a set of inputs, in the form of land, labour, seeds, fertilizers and machinery, through the cycle of growing a crop to maturity into an output, which is expressed in a yield of so many tonnes per hectare. In machinery manufacture the physical model is the engineering processes which allow resources of labour, ferrous and non-ferrous metals, machine tools and factory premises to be converted into, say, tractors.

A business model takes the discussion a step further by allocating costs to the inputs and prices to the output so that the objective is not just yield but the profit which can be achieved by maximizing the difference between the price of the output and the cost of the inputs.

The physical model

In crop production, the physical model is a description of how a crop develops from a seed at the time of sowing into a crop canopy which harvests solar radiation and converts the energy into biomass which matures to a stage at which it can be harvested. The physical model must take account of how yield is influenced by the availability of nutrients and water, by the competition of weeds and by the effects of disease at different stages of growth.

The effectiveness of the transformation process has been increased enormously through the efforts of scientists and engineers in many disciplines, e.g.
- plant breeders have given us plants that are more efficient, converters of the inputs, and especially ones that partition a higher proportion of the biomass into saleable products;
- chemists and engineers have given us fertilizers, which relax the constraints imposed by soils that are deficient in plant nutrients, and chemicals, which control weeds, pests and disease;
- engineers have provided water for irrigation and machinery to carry out cultivations, spraying and harvesting at the correct time.

It is worth emphasising that the transformation process is of long duration, that it is driven by solar radiation and that the attainment of a successful product in terms of both quantity and quality is critically dependent on the delivery of the right mix of inputs at the correct time. One of the great achievements of agricultural machinery is the way it contributes to certainty of performance by improving the timeliness of cultivations, planting, delivery of water, spraying and harvesting. However, for the future, demands on machine performance are likely to increase in order to provide more stringent control over inputs in order to satisfy tighter environmental requirements and to make better use of the inputs. We are also likely to see major changes in our understanding of the transformation process as a result of the advances in molecular biology for controlling and modifying the behaviour of plants.

A representation of the physical process is given by:

$$Z = g\,X$$

where: Z - the yield of the crop (usually the economic yield);
X - $(X_1, X_2 \ldots X_n)$ is the quantity of resources used in growing crop;
g - a production function.

The relationships between the product and the inputs are not simple because of the large number of processes, which take place during a crop cycle from sowing to harvest, the way in which the processes are affected by changes in the environment and the fact that many of the processes are operating near their limits where non-linear and second-order effects cannot be ignored.

The business model

Agronomists, in both research and practice, tend to interpret the Physical Model in terms of yield per unit area, without paying too much attention to the costs of the inputs that are necessary to produce the yield. However for the farmer, who sees the transfor-

mation process as the basis of a business, it is necessary to convert the Physical Model into a value process by assigning prices, both to the product which is marketed, and to the resources used to produce it.

A model of the value process is given by:

$$V = p(Z) - h(X)$$

where: $p(Z)$ - the value of the product;
$\quad\quad\quad h(X)$ - the cost of the resources;
$\quad\quad\quad V$ - the net value of transforming resources X into product Z.

The fundamental business problem can be represented as a constrained optimisation problem: maximize $V = p(Z) - h(X)$; subject to the constraint $Z < g(X)$.

However this formulation can only be solved when the value of the output and the cost of the resources can be measured on the same scale and the constraints can be quantified. Due to their inherent complexity, and the effects of a variable environment, it is very difficult to quantify the production functions in agricultural processes. In this situation many farm business analysts have concentrated on the value equation

$$V = p(Z) - h(X)$$

without reference to the constraints. In a further simplification it has been proposed that the value equation could be resolved into either of two problems:

(i) Regarding Z and hence $p(Z)$ as fixed, with the result that maximizing V became equivalent to minimizing $(h(X)$. Small scale projects were presumed to fall into this category in which the system was expected to meet specified standards at minimum cost. Since machinery is one of the resources used in crop production with a cost which should be minimized, it is necessary to emphasise at this stage how erroneous it would be to uncouple machinery cost from yield. From the point of view of the cost of using a machine, cost decreases with utilisation; the more hours and the longer the season during which the machine is used, the lower will be the cost per hour. However there are critical time periods for crop growth and development, with the result that if certain operations like planting and harvesting are not completed in time, there will be a reduction in yield. If the owner of a machine attempts to harvest too great an area with the machine, a stage is reached at which the crop gets over-ripe before the machine can harvest it, with the result that the loss of crop such as wheat through shedding is greater than the reduction in the costs of the machine through utilisation. The „timeliness factor", in such operations as planting, irrigating, spraying, and harvesting has such an effect on yield that is not possible to consider utilisation independently of yield.

The trade-off between machine capacity and „timeliness" is one of the problems of machinery selection. When a farmer invests in a bigger machine he incurs bigger costs in owning the machine. However, with a bigger machine, the losses in yield as a result of not carrying out the critical operation at the correct time should decrease. Adding the two costs together, produces a resultant cost which shows a minimum. This is the level of machine capacity for which the farmer should plan in order to minimize the total machinery cost of that operation.

(ii) Regarding the package of resources $h(X)$ as fixed, so that maximizing V is equivalent to maximizing $p(Z)$ and consequently Z. Large scale investments such as irrigation

and roads would fall into this category, where the optimisation problem becomes one of constructing a maximum package of development within a fixed budget.

The operational model

The level of inputs that would be chosen by the Business Model in order to maximize the net value (V) of the process will always be less than the level of inputs that would be chosen by the Physical Model in order to produce maximum yield because it is usually uneconomic to produce the last increments of yield. However, production processes in agriculture are not steady state ones for which it is possible to calculate or measure a unique package of inputs. The farmer through his experience, responds to the demands of the crop and tries to meet them. One of the targets of mechanisation must be to provide a measure of feedback control, as shown in Fig. 1, into the transformation process so that the inputs can be manipulated more effectively to exploit changes in the environment and give a crop output of more predictable quantity and quality.
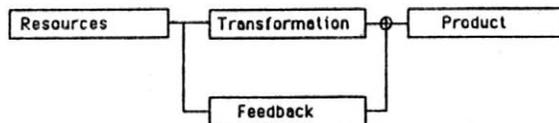
In farm mechanisation we have become used to developments in „hardware" to the point where we now have a mature machinery industry in which the rate of innovation has become slow. In common with other industries, there is a shift towards „software" solutions which depend on sensors to collect data and computer algorithms to calculate optimum strategies for carrying out the processes. In such applications as engine management systems, it is possible to automate the process without involving the owner or operator. However, this is only tackling part of the system, the real gains will be made through designing optimum strategies for whole crop production processes which involve soil analysis controlled distribution of fertilizers according to need and predictions of crop response, identification of local targets for spraying etc., and production of a final product to meet more exactly the specification of the market.

INVESTMENT PLANNING

The big „make or break" decisions in any business are the decisions about strategy and investment. Once an entrepreneur has committed himself to a „large" investment relative to the size of his enterprise, he is committed to that machine, process and activity until he has paid off the investment. In all probability he has locked himself into the activity for at least five years and possibly for the remainder of his working life.

Because planning is a ˋpaper exercise' it is cheap and fairly invisible. It is about setting objectives and particularly about taking up a position in regard to future possibilities and outcomes. Most of these factors are difficult to quantify, depend to some extent on the

specific constraints of the individual firm, require assumptions about conditions several years hence and involve making estimates of future markets, competition, rates of return and rates of inflation, as well as the performance of the different kinds of equipment that could be purchased. Planning has none of the high visible profile of „hands-on, trouble-shooting" but it is the cheapest way to avoid such excitement in the future. While it is easy to change a decision at the planning stage, it almost always involves financial loss to make a change when the equipment has been purchased.

For most farmers the decision to purchase a new tractor or combine harvester is a large investment, and machinery costs are now a large fraction of a farmer's production costs. Reequipment should be an occasion to reassess the total farm plan over a 5-10 year horizon rather than a succession of piecemeal decisions. Should the farmer own the machine at all or should he share expensive equipment with another farmer? The contractor solution has much to recommend it, for it gives access to the latest equipment at a reasonable hire: it provides skilled operators and offers the opportunity of high load factors for the owners of the machines.

MACHINERY COSTS

The costs of owning a machine can be considered as the sum of four components:

fixed costs + variable costs + labour costs + performance costs

The fixed and variable costs are associated directly with a particular machine while the labour and performance costs are dependent on the system of mechanisation as well as the machine.

Examining each of the costs in turn:

a) The two main components of the fixed costs of ownership are depreciation and the interest on the capital invested in a machine. The experience of the second-hand market in tractors and farm machinery is that prices are influenced by the age of the machine in that prices fall quickly at the beginning and more slowly towards the end of its working life, by inflation and by the reputation of a particular range of machinery for reliability. A reasonable approximation of depreciation is given by the Declining Balance Method where the annual depreciation is a constant fraction of the book value at the end of the preceding year. A depreciation rate of 0.25 will be assumed in the following calculations.

The design life for tractors is assumed to be 10,000 hours work and for other farm machinery 2000 hours. Most tractors and farm machinery do not reach their design life either because the design is made obsolete by technical developments or the equipment comes to be regarded as uneconomic to maintain. However, during the working life of a machine it is unrealistic to assume that the price of that type of machine remains constant. The assumption of even modest inflation in machinery prices gives a better representation of replacement values.

In calculating interest on the capital invested in the machine it is customary to choose a constant rate of interest over the life of the machine and to calculate interest charges on the average investment in the machine during each year of its life. A rate of 12% has been assumed in the calculations.

b) Variable costs are directly related to the period during which the machine is in work. They are made up of fuel costs, repairs and maintenance. Fuel consumption is related to

engine size, engine load and the efficiency of the engine. In the case of tractors a common assumption is an average engine loading of 0.7 full load over the year.

Repair and maintenance costs are the most difficult to apportion for tractors and farm machinery and for this reason are discussed separately.

c) Labour costs have been a very influential factor in machinery replacement practice. In its early stages, mechanisation is encouraged by the need to cope with labour peaks of planting and at harvest and to reduce the demand for casual labour in agricultural production. In more developed systems of mechanisation, the drive towards larger equipment and economies of scale is partly the result of a trade-off between additional investment in machinery and a reduction in labour costs.

d) Performance costs: We are aware that there are differences in performance between machinery of different age, different size and from different manufacturers but there is no easy, generally acceptable way to quantify these differences and take account of them in order to weigh the economic advantage of a new machine against an existing one. The problem is made more difficult in agriculture where the factor of „timeliness" is associated with operations such as planting, spraying and harvesting; in each of which there is a narrow window of opportunity for carrying out the operation and if it is not completed in that period there is a financial penalty through loss of yield or quality at harvest.

Furthermore, a general purpose machine, such as a tractor, will, during the working year, be involved in some operations with a high „timeliness" element and in others where the urgency is less great. In replacement studies it is customary to compare the annual costs of one machine with those of another. However, while annual costs give a general picture to the farmer of owning a machine, it does not allow him to focus on the relative merits of a new model in regard to critical operations on which the financial success of his whole enterprise could depend and where the performance of one machine relative to another is a factor affecting the outcome.

One way of dealing with the question of machine performance is to draw up an assignment matrix in which the relative performance of different machines is given a performance rating on a range of operations. The relative productivity index is to allow for the fact that the productivity of machines of essentially similar type but different age and specification, varies from one job to another because of technological development.

| Machine | Operation | | | |
	1	2	3	4
A	0.6	0.8	1.0	0.9
B	0.7	1.0	1.0	1.0
C	1.0	1.0	1.0	1.0

Rows are used to define each machine of a given type A B C. Columns are used to define field operations or even broad categories such as draught, pto, transport, materials handling. Cell values indicate the productivity of a particular machine relative to another working on the same assignment. A value of 1 should appear at least once in each column, if the comparison is to be valid.

In present circumstances the farmer or his adviser will have to estimate the cell values corresponding to the different tractors and operations, which is no more than putting a value to a judgement that they now make subconsciously.

Actual machine cost for A on operation 1 them becomes:

$$\frac{\text{fixed costs} + \text{variable costs} + \text{labour costs}}{0.6}$$

or the performance costs $= (\frac{1}{0.6} - 1)$ (fixed costs + variable costs + labour costs)

An alternative way of taking performance costs into consideration is to consider the different machines that are available in relation to the actual operations to be performed, but to add the timeliness costs imposed on the crop as a result of a reduction in machine performance, to the cost of operating the machine. For example, if sowing takes three weeks with machine X but only two weeks with machine Y, the additional performance costs debited to machine X are the timeliness penalty for the area of crop sown in week three.

REPAIR AND MAINTENANCE

Repairs and maintenance costs are the most difficult to estimate for tractors and farm machinery, partly because standards of maintenance vary widely, which in turn have an influence on repairs and partly because failur. s calling for repair happen randomly. Studies on repair costs of tractors and agricultural machinery have come to similar conclusions in regard to repair and maintenance costs viz:
- that repair costs are a small part of the total annual costs of owning farm machinery, being about 10-15% of the total costs;
- that repair costs increase with the age of a machine and are an important factor in influencing the optimal time for replacing a machine;
- that over the design life of a machine the owner can expect to spend at least as much on repairs as he spent in purchasing the machine;
- that Total Accumulated Repair and maintenance costs of a machine (TAR) can be represented by a smoothed curve of the type TAR = list price of similar machine x factor x $(USE)^n$; For tractors, when USE is measured in units of 1000 hours, the factor is 0.01 and n is 2;
- that the inflation element in the cost of spare parts can be taken into account by relating prices to the current list price of a similar machine.

The crucial influence of maintenance and repair costs in actual decisions on machinery replacement makes it important to draw a distinction between „maintenance" and „repair" in machinery operation. „Maintenance" or „preventive maintenance" is a process that can be scheduled and whose objective is to keep the equipment operating near to its peak efficiency, to extend equipment life and to avoid premature failures. It is concerned with inspection, testing, adjustment, filtration and lubrication on a scheduled basis. Good preventive maintenance helps to prolong equipment life, prevent untimely failures and uncover problems in sufficient time to conduct proper overhauls and rebuilds. Preventive maintenance then is an approximately constant annual cost for servicing the machine throughout its working life.

Repairs are major expenses, which may be necessary as a result of an unpredictable failure of a component in service or of the gradual deterioration of some wearing parts with use, e.g. clutches, tires, gearbox, hydraulics. In order to restore the machine to a dependable condition some major components need to be replaced in a partial rebuilding or the entire unit needs to be completely overhauled.

Unpredictable failures in new machinery are usually covered by the manufacturer's warranty which shields the owner from bearing the cost. The smoothed curve use to represent repair and maintenance data in the literature neither distinguishes between the relatively uniform costs of preventive maintenance and the „lumpy" costs of repairs nor can it recognise the stochastic nature of repairs between different makes or even machines of the same series.

Replacement

The cost equation is the basis of the replacement model and may be used in two different ways:
(i)   Where it is proposed to replace an existing machine by another which is identical with it. This is a statement of the replacement problem in its simplest form where the new machine exactly restores the investment to its original state. The solution is a periodic replacement policy whose objective is to maximise the total net benefits of the investment for its owner. Questions of obsolescence may be ignored and the labour costs are constant so the problem is one of finding and period of ownership with minimises (fixed + variable costs). As the example shows, the result in very dependent on the way repair costs are taken into account.
(ii) Where the defending machine(s) is challenged by improved models with a better technical performance and/or a new combination of equipment which could lead to both better technical performance and lower labour costs, e.g. a bigger combine or the possibility of replacing 3 medium sized tractors by 2 large ones.
In this case the full costs of both the defender and the challengers must be calculated over the assumed working lives of them all and the decision made on a comparison of the costs of both. If the results of the economic analysis are to replace the defender with one of challengers, there are two separate practical financial considerations influencing the decisions which are outside the analysis - the effects of the replacement on the cash-flow of the enterprise and accounting for any differences between the actual salvage value of the defender in the market place and its written down book value. The tax effects on capital gains and losses obviously affect the decisions.

The calculation of the replacement decision can be treated as a problem in dynamic programming or by an economic minimisation type procedure which converts the total replacement cost into an annual cost. This is accomplished by dividing the total expenditure by a 'uniform series present worth factor' for the assumed conditions of rate of interest and service life. The resulting value represents the equivalent equal amount cost for a service life of N years. The example shown in Tabs II-IV is calculated using the 'uniform series present worth factor' and is calculation of the equivalent uniform annual cost of a 75 kW tractor costing £16 000 which works 1000 hours per annum and has a potential life of 10 years. An interest rate of 12% per annum and a declining balance depreciation factor of 0.25 is assumed as well as the following conditions about inflation and repair and maintenance:
(i)   Assume zero inflation and smoothed R & M costs as in Tab. I(a)
(ii)   Assume 6% inflation and smoothed R & M costs as in Tab. I(b)
(iii) Assume 6% inflation and lumpy R & M costs as in Tab. I(c)
The results of the calculations are given in Tabs II-IV.

I. Repairs and maintenance costs (£)

Year of service	1	2	3	4	5	6	7	8	9	10
Zero inflation (a) smoothed R & M costs	160	480	800	1120	1440	1 760	2080	2400	2720	3040
6% inflation (b) smoothed R & M costs	160	578	940	1431	2001	2 658	3413	4276	5260	6375
6% inflation (c) lumpy R & M costs	200	200	3200	200	200	11 200	200	200	200	200

II. Equivalent uniform annual cost, neglecting inflation and using smoothed R & M costs

Year of service	Start of year	End of year	Depre-ciation	Interest	Repairs	Total cost for year	Present worth factor	P	ΣP	Capital recovery factor	Equiv. uniform annual cost
	£	£	£	£	£	£		£	£		£
1	16 000	12 000	4000	1680	160	5840	0.8929	5215	5 215	1.12	5841
2	1 2000	9 000	3000	1260	480	4740	0.7972	3779	8 994	0.5917	5322
3	9 000	6 750	2250	945	800	3995	0.7118	2844	11 838	0.4163	4928
4	6 750	5 062	1688	709	1120	3517	0.6355	2235	14 073	0.3292	4633
5	5 062	3 796	1266	531	1440	3237	0.5674	1837	15 910	0.2774	4413
6	3 796	2847	949	399	1760	3108	0.5066	1575	17 485	0.2432	4252
7	2 847	2 135	712	299	2080	3091	0.4523	1398	18 883	0.2191	4137
8	3 135	1 601	534	224	2400	3158	0.4039	1276	20 159	0.2013	4054
9	1 601	1 201	400	168	2720	3288	0.3606	1186	21 345	0.1877	4005
10	1 201	901	300	126	3040	3466	0.3220	1116	22 461	0.1770	3976

The results of the simple replacement problem posed in the example show how strong are the influences of the assumptions. Using constant prices and smoothed R & M costs, the annual cost of ownership decreases the longer the tractor is retained and the implications of the calculations are that the best policy is to keep the tractor until it is completely worn out in the tenth year (Tab. II). When inflation is taken into account, it boosts the cost of repairs giving a minimum cost of ownership at a seven year life (Tab. III). Using inflation and lumpy repair costs, there is a strong case to replace the tractor at the end of the fifth year just before a major overhaul is required (Tab. IV). If it is decided that the technical specification of the tractor is still adequate and to carry out the overhaul, then it is economical to retain the tractor for the remainder of its useful life.

MATCHING THE MACHINE WITH THE TASK

Matching field machinery with the work that is required to be completed within a window of opportunity is one of the central problems found in farm mechanisation. It is a trade-off between investment in machinery and loss of potential yield. A large and

III. Equivalent uniform annual cost using 6 percent inflation and smoothed R & M costs

Year of service	Written down value during year			Depreciation interest		Repairs	Total cost for year	Present worth factor	P	ΣP	Capital recovery factor	Equiv. uniform annual cost
	start	end		0.25x	0.12							
	actual	adj. for infl.		B	$\frac{A+C}{2}$							
	£A	£B	£C	£	£	£	£		£	£		£
1	16 000	16 960	12 720	4240	1723	160	6123	0.8929	5467	5 467	1.12	6123
2	12 720	13 483	10 112	3371	1370	578	5319	0.7972	4240	9 707	0.5917	5744
3	10 112	10 719	8 039	2680	1089	940	4709	0.7118	3352	13 059	0.4163	5436
4	8 039	8 522	6 391	2131	866	1431	4428	0.6355	2814	15 873	0.3292	5225
5	6 391	6 775	5 081	1694	688	2001	4383	0.5474	2487	18 360	0.2774	5093
6	5 081	5 386	4 039	1347	547	2658	4552	0.5066	2306	20 666	0.2432	5026
7	4 039	4 282	3 211	1071	435	3415	4921	0.4523	2226	22 892	0.2191	5016
8	3 211	3 404	2 553	851	346	4276	5473	0.4039	2211	25 103	0.2013	5053
9	2 553	2 706	2 030	677	275	5260	6212	0.3606	2240	27 343	0.1877	5132
10	3 030	2 151	1 614	538	219	6375	7132	0.3220	2297	29 640	0.1770	5246

IV. Equivalent uniform annual cost using 6 percent inflation and lumpy R & M costs

Year of service	Written down value during year			Depreciation interest		Repairs	Total cost for year	Present worth factor	P	ΣP	Capital recovery factor	Equiv. uniform annual cost
	start	end		0.25x	0.12							
	actual	adj. for infl.		B	$\frac{A+C}{2}$							
	£A	£B	£C	£	£	£	£		£	£		£
1	16 000	16 960	12 720	4240	1723	200	6 123	0.8929	5503	5 503	1.12	6163
2	12 720	13 483	10 112	3371	3370	200	4 941	0.7972	3939	9 442	0.5917	5587
3	10 112	10 719	8 039	2680	1089	3200	6 969	0.7118	4961	14 403	0.4163	5995
4	8 039	8 522	6 391	2131	866	200	3 197	0.6355	2032	16 435	0.3292	5410
5	6 391	6 775	5 081	1694	688	200	2 582	0.5674	1465	17 900	0.2774	4965
6	5 081	5 386	4 039	1347	547	11 200	13 094	0.5066	6633	24 533	0.2432	5966
7	4 039	4 282	3 211	1071	435	200	1 706	0.4523	722	25 305	0.2191	5544
8	3 211	3 404	2 553	851	346	200	1 397	0.4039	564	25 869	0.2013	5208
9	2 553	2 706	2 030	677	275	200	1 153	0.3606	415	26 385	0.1877	4934
10	2 030	2 151	1 614	538	219	200	957	0.3220	308	26 593	0.1770	4707

expensive machine increases the probability of meeting the timeliness requirements of the crop while a smaller cheaper machine, with a lower rate of work, carries the penalty of higher crop losses.

The problem of matching machine performance with a field task can be expressed in the simple equation:

$$\Delta T \eta \, \dot{W} \geq A$$

where: ΔT - duration of the window of opportunity during which the field task must be completed in order to achieve an acceptable quality of crop yield (weeks);

$\dot{W}$ - theoretical capacity of the machine expressed as width x forward speed (ha/week);

η - field efficiency, which is normally defined as actual capacity/theoretical capacity; field capacity should be treated as a much more complicated factor; it should take into account weather, field conditions, time of year and labour availability; in fact all the major factors that influence the availability of a machine in the field in the long run, averaged on a weekly basis;

A - area of land to be worked (ha).

The farmer's goals are time-based; he sees the problem as completing an operation within a set time period. Having selected a machinery combination to satisfy the time constraints, he needs a method of calculating the cost of carrying out those field operations:

(i)   with different combinations of machinery,
(ii)   comparing the costs of alternatives, including the option of a contractor.

DISCUSSION

(i)   Machinery systems should be seen as part of the total farm planning process and machinery purchase as an exercise in investment planning for the whole production system.

(ii)   While a physical model may be used to represent the production process, a business model is a better representation of the farmer's interests. An operational model is required in order to exercise better dynamic control over the production enterprise as a whole.

(iii) Selection and replacement of agricultural machinery is dependent on comparative costings of different machines, which requires information on the performance and repair costs of machines.

(iv)   Matching a machine to a field operation means linking area to be worked with machine performance through a comprehensive definition of field efficiency.

TRENDS IN QUALITY AND DEPENDABILITY PROGRAMS: EDUCATION, TRAINING AND IMPLEMENTATION

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This paper studies contemporary developments in Quality Management Systems and Dependability Assurance Programs as recommended in recently published international standards of ISO and IEC, and implemented as an integral part of their business strategies by foremost enterprises all over the world. The common elements of such systems (programs) are identified and analyzed from the point of view of their incorporation into modern education and training programs for different levels of managerial and technical staff and for rank and file employees in different branches of the economy. The necessary modifications of curricula at teaching institutions within and outwith the educational system are pointed out with special reference to the eligibility of the CSFR to join the Common Market.

quality management system; international standards; dependability; assurance programs; education programs

Examination of the experiences of successful business enterprises abroad during the past two decades shows that top management of these companies is implementing a consistent quality policy as an integral part of its strategic business plan. Such a policy, aimed at the maximum satisfaction of the needs and expectations of specific consumer markets at minimum costs, leads to a better competitive position, improved productivity, increased market share and long-term profits, improved prospects of future development not only of the company and its employees, but also of the whole national economy of the country concerned.

The achievement of such goals is not a simple task, automatically occurring as a result of the operation of the market economy. On the contrary, successful companies (and countries) must operate a complex system of managerial, business, financial, economic, technical, organizational and sociological activities, currently designated by the name of Quality Management Systems (QMS) (alias ,,Total Quality Control-TQC" or ,,Total Quality Management-TQM"). In the engineering industry, efforts in this area have been directed in particular at improving the group of time-related quality features, covered by the term ,,dependability" (including reliability, durability, maintainability, availability and others) which influence customer satisfaction and the effectiveness of complex engineering products in use (Ž a l u d o v á , 1984; S t r a n d b e r g , 1986). Also safety and environmental integrity are assuming an increasingly important role in the assessment of socially acceptable quality and the associated risks of its absence.

The basic principles of QMS, TQC, TQM, formulated over the years by such world experts as Juran, Deming, Feigenbaum, Crosby, Ishikawa and others have now been

incorporated into several national and international standards. In particular, the set of standards ISO 8402 and ISO 9000-9004 provides guidance for implementing unified procedures for Quality Control and Quality Assurance across national boundaries (ISO, 1986) and forms the basis of the QMS certification scheme for the countries linked to the European Common Market.

In the field of engineering equipment and complex technical systems, special groups with reliability responsibility have often arisen within departments of Design and Development, independent of the QC function. In this connection the interdisciplinary science of reliability engineering and management has evolved, providing special methods for reliability specification, modelling and testing and for utilizing information systems to improve and assure product dependability with the aid of Reliability and Maintainability Programs (RAMP). On the international level Technical Committee 56 of the International Electrotechnical Commission (IEC) has issued a series of standards unifying methods for reliabiality and maintainability analysis, specification, demonstration and assurance with validity in all technical fields covered by IEC and ISO. The currently circulating draft document IEC Publ. 300 on Dependability Management programs has now been revised in order to bring it into good harmony with the ISO 9000 series (DIS/IEC).

COMPARISON OF ISO AND IEC PROVISIONS ON QMS AND DEPENDABILITY PROGRAMS

The main elements of QMS and Dependability Programs (RAMP) according to ISO 9004 and IEC 300-1 are listed in Tabs. I and II, respectively. The ISO 9004 standard gives guidance to manufacturers who wish to introduce or improve their quality system in a cost effective way in the form of seventeen recommended elements, presented in sections 4 to 20 of the standard. The elements are grouped in Tab. I into two sets, under the headings of Quality Management, Control and Assurance Activities and Quality-Related Technical Activities. Publication IEC 300-1 lists in sections 4, 5 and 6 twenty-one elements, again arranged in Tab. II into two large groups of predominantly Management-Related and Technical-Related Activities. Comparison shows that the Dependability Program is considered to be a part of the overall Quality System, with special attention given to the time-related features of the product.

The main principles of Dependability Programs (RAMPs) as practiced in the Czechoslovak Engineering Industry are contained in Tabs. III to VI, originally presented in modified form in (H r a b á k , Ž a l u d o v á , 1975).

DIFFERENCE OF APPROACH OF TQC/TQM AND ISO/IEC STANDARDS

In assessing the experiences with introducing modern quality-oriented management systems in recent years, a distinction may be noted between the TQC/TQM approach and the standards-based approach. The TQC/TQM approach as it has evolved during the past few years now includes the overall transformation of attitudes and methods of management and motivation of people in order to achieve customer's satisfaction, prosperity of the enterprise and outstanding competitive results by planned changes and continuous improvement.

Standards, on the other hand, are a useful and necessary instrument in unifying acknowledged minimum requirements, esp. in certain regulatory areas like safety, food, pharmaceutical and environmental protection. They are not the ultimate criterium for

I. Contents of ISO 9004 quality management and quality systems elements

Quality management, control and assurance activities		Quality - related technical activities	
4.	Management responsibility (policy, strategy, goals)		
5.	Quality system principles (Q-spiral, Q-system, structure, organization, responsibilities, methods, documentation, manual, plans, audit)		
6.	Economics-quality-related cost considerations (Q-system effectiveness, feasibility of changes for improvement)		
		7.	Quality in marketing
		8.	Quality in design (specification)
		9.	Quality in procurement
		10.	Quality in production
		11.	Control of production
12.	Product verification (incoming, process and final inspection and test)		
13.	Control of measuring and test equipment		
14.	Nonconformity		
15.	Corrective action (cause analysis, prevention)		
16a.	Handling and post-production operations (information system)		
		16b.	Handling and postproduction operations (packaging, installation)
17.	Quality documentation and records		
18.	Staff (training, motivation, initiative)		
19.	Product safety and liability		
20.	Use of statistical methods		

quality assessment, which must always remain the satisfaction of the customer's needs and requirements. In the quality systems field, there is no doubt about the significant importance of implementing the ISO/IEC recommendations in industrial and business practice. They enable a visible, documented, controlled system of activities and procedures to be developed and applied systematically with feedback, corrective action, analysis of shortcomings and remedial actions aimed at the prevention of their reoccurrence. Theoretically, a precondition of success is the full active participation of management and all employees, with the ultimate goal of meeting the requirements of customers at minimum costs.

In no sense, however, does the certification of a quality management system according to ISO/IEC criteria ensure automatically business success on world markets. Recent experience with introducing QMS in Czechoslovakia shows that the ISO 9000 series requires supplementing, especially in the following areas (Ž a l u d o v á , 1991):
- recognizing the need for changed organizational structure, especially for cross-sectional, interdepartmental quality councils, committees and problem-solving teams;
- participative involvement of all employees;
- accenting the customer-supplier model throughout the entire organization;

	Dependability management activities		Dependability-related technical activities
4.	Management responsibilities		
4.1	Policy		
4.2	Organization		
4.3	Quality system		
4.4	Market research and product planning		
4.5	Management review		
4.6	Dependability program reviews		
5.	Product and project independent program elements		
5.1	Dependability program implementation		
5.2	Methods		
5.3	Data banks		
5.4	Dependability records		
6.	Product or project specific program elements		
6.1	Planning and management		
		6.2	Contract review
		6.3	Dependability requirements
		6.4	Engineering
		6.5	External provided products
		6.6	Analyses, prediction and design review
		6.7	Verification, validation and test
6.8	Life-cycle cost program		
		6.9	Operation and maintenance support planning
6.10	Improvements and modifications		
6.11	Experiences feedback		

- emphasis on the principle of continuous improvement through problem-solving and implementation of the results;
- recommended problem-solving procedure using simple and advanced statistical and other techniques in order to
  1) bring about desirable changes in a controlled manner;
  2) prevent undesirable changes through feedback control;
- recommended methods of planning for quality and feed forward or off-line QC such as Quality Function Deployment, Benchmarking, Value Analysis, Cost-benefit Analysis, Design of Experiments, Failure Mode and Effect Analysis, Fault Tree Analysis and others;
- recommended training programs;
- changed attitudes of people.

Without some of these elements there is a danger that the introduction of the Quality System according to ISO 9004 could lapse into a static, controlled system without the

III. Main management tasks of a RAM program (RAMP)

1.	Setting overall objectives and quantitative goals
2.	Economic analysis of feasibility of goals and effectiveness of RAMP
3.	Elaboration of RAMP plan (specification of tasks, responsibilities, organization, time-schedules, means, methods, personnel, budgets)
4.	Issuing directives for plan implementation
5.	Coordination of all efforts through RAM team
6.	Regular review of task fulfilment, analysis of results from information system, ensuring corrective action
7.	Ensuring education and training
8.	Ensuring moral and material incentives
9.	Cooperation with and supervision of suppliers RAMP
10.	Cooperation with and supervision of RAMP at user, repair or other organization

IV. Main technical tasks of RAMP during preproduction phase

1.	Incorporation of quantitative RAM targets into specifications for equipment and components based on
	- analysis of function and structure of equipment, identification of weak items
	- evaluation of previously achieved RAM measures using information system, incl. definition of main failure modes, their localization, limiting states and criteria of failure
	- preliminary estimation of equipment RAM measures
	- analysis of operating and loading conditions
	- FMEA and FTA
	- analysis of maintenance problems
	- analyses of useful life problems, warranties and spare parts
	- preparation of test methods, incl. accelerated testing
	- analysis and preparation of test and measuring equipment
	- performance and evaluation of development tests
	- analysis of factors of material, design and technology
	- repeated prediction of RAM measures (with eventual redundancy) for various product modifications
	- selection of optimal modification
	- preparation of design and manufacturing specifications
2.	Production and test of functional model and prototype
3.	Performance of design reviews
4.	Implementation of approved changes for RAM improvement
5.	Demonstration of RAM measures, approval of specifications for commencement of trial production

dynamism necessary for technological and social progress. Experiences in CSFR show that the majority of rank and file employees are keen to cooperate on the improvement projects and that the major barriers to change come from the side of middle management. Some of the above shortcomings are being eliminated by the preparation of supplements to the ISO 9000 series, e.g. ISO 9004-4 Guidelines for Quality Improvement.

V. Main technical tasks of RAMP during production phase

1.	Acceptance inspection of incoming material and components
2.	Process capability analysis
3.	Trial series testing and analysis of results
4.	Analysis of failure causes for trial series, corrective action, changes in design and technological documentation
5.	Demonstration test for commencement of series production
6.	Actual series production
7.	Introduction and implementation of statistical process control
8.	Sample reliability testing of final products, comparison with results of aftersales information system, failure cause analysis, corrective action
9.	Quality and quality system audits
10.	Inspection of packaging, conditions of storage and transport
11.	Training of production personnel

VI. Main technical tasks of RAMP during post-production phase

1.	Installation at user
2.	Instruction of operating, maintenance and repair personnel
3.	Collection of data on failures and costs during trial and normal operation
4.	Technical and economic analysis of field failures, corrective action
5.	Utilization of data and RAM measures by manufacturer and user
6.	Implementation of preventive maintenance and diagnostic schedules
7.	Audit of operating procedures
8.	Review of spare parts plans and consumption
9.	Cooperation with repair or other service organizations

IMPACT OF QMS AND DEPENDABILITY PROGRAMS IN CSFR

During the period of 1949-1959 very favourable results were achieved in the Czechoslovak industry by the introduction of methods of statistical quality control and analysis. Since the 1960's professional expertise in the quality sciences was concentrated in the Czechoslovak Scientific and Technical Society, but conditions for application of QMS in industry were unfavourable. Despite this, the Government Decree 178/77 contained the main elements of a TQC system, was partially introduced in practice, but without the necessary audits and feedback to sustain it in the face of unfavourable planning criteria in the economy and emphasis on quantity.

Since 1970 systematic work was carried out with government funding in the field of improving the dependability of components and technical systems and the introduction of Dependability Programs (RAMP) in a number of industrial branches (Ž a l u d o v á, 1987a; Ž a l u d, Ž a l u d o v á, 1988). In a few cases, e.g. power plant equipment very positive results were achieved in improving the reliability and availability of key equipment and thus reducing the forced outage by an average of fifteen percent.

Since the changed political and economic situation at the end of 1989, there is a growing awareness on the part of industry of the need to devote increased attention to the improvement of the quality of products and services. Several well-known West European

are international firms such as RW TÜV, Lloyd's Register Quality Assurance, Bureau Veritas, Det Norske Veritas and others and offering their services in the field of certification of products and quality systems according to EN standards. Preparations are being made for CSFR to have an Accreditation System of its own. An increasing number of joint ventures with foreign partners is requiring, as a condition for partnership, new relationships with suppliers, based on audited supplier quality systems. The difficulties of the transition process of the economy are meantime, however, preventing the full development of the quality effort in practice.

As part of this effort, especially in the engineering industry, it is now clear that Dependability Programs should be part of the TQC program, with RAM Program Teams functioning on special projects (Ž a l u d o v á , 1987b). Recent seminars show that a large basic group of techniques is relatively well-known by a moderate number of R and D engineers, designers, technologists, sales, servicing and quality system personnel. These techniques include:

a) collection and analysis of data on failures and costs during and after warranty (information systems), including failure classification, Pareto analysis, choice of mathematical model of time to failure, testing of hypotheses on goodness of fit, on outliers, on significance of difference from competitor's product, etc.;

b) estimation of dependability measures for both parametric and non-parametric models;

c) specification of requirements (targets, goals) on dependability measures for new or innovated products;

d) verification (demonstration) of compliance with requirements using single, multiple or sequential test plans, with or without censoring.

Most of these techniques are covered in the literature and by international standards of IEC. A further number of special analytical, computational and test methods is under development and less widely applied. These include:

e) probabilistic design and stress/strength models for both static and dynamic conditions;

f) analysis of damage processes and physically based life models for the most common failure mechanisms, (fatigue, wear, corrosion, etc.) or their combination;

g) random process analysis to characterize operating and loading spectra with application in probabilistic design and reliability testing under simulated random operating conditions;

h) system /component structure analysis with allocation and prediction of RAM targets;

i) fault mode, effect and criticality analysis (FMECA) and fault tree analysis (FTA);

j) reliability growth modeling;

k) planned experiments, correlation and regression analysis relating reliability measures to design, technological and operating factors;

l) theory and application of accelerated reliability testing;

m) application of Bayesian procedures;

n) maintainability analysis, optimal maintenance strategies, including technical diagnostics and condition monitoring;

o) planning spare parts requirements;

p) total life cycle costing and its application to optimize design parameters and dependability measures;

q) design reviews;

r) storability analysis;

s) problems of human reliability;

t) dependability and effectiveness models for multi-state systems;

u) use of expert systems in the identification of cause of failure.

Quality courses

A wide training program in quality assurance for all company employees (with differentiation in scope and depth for various groups) is now considered an essential element in any QMS.

Considering the provision of education and training for quality as a social service to be provided by various types of organizations for different types of „customers" , we find it useful to distinguish the following categories of suppliers and customers.

Supplier organization		Customer	
1.	Educational system	A.	Top management
	- secondary schools	B.	Executive and middle management, engineers
	- universities	C.	Supervisors, foremen, line inspectors and operators
2.	Professional, consulting and other organization	D.	Specialists (Q. managers, Q. engineers, Q. auditors)
3.	Companies, plants (in-house)	E.	Special seminars

As with any service organization the customer and his/her needs must be identified and specified. Various types of courses have evolved on all levels in different countries, the most extensive and systematic in Japan. Recent attempts to unify the requirements for different categories of customers (especially for quality and dependability specialists) have led to the recent publication by the European Organization for Quality (EOQ) and the European Foundation for Quality Management (EFQM) of a draft document containing minimum requirements for the three specialist categories of QM, QE and QA (EOQ, 1991). The structure and main topics for these courses are shown in Tabs VII and VIII.

Unfortunately, traditional university and technical college training of scientists and engineers has been singularly lacking in adequate, integrated teaching of the quality and dependability disciplines.
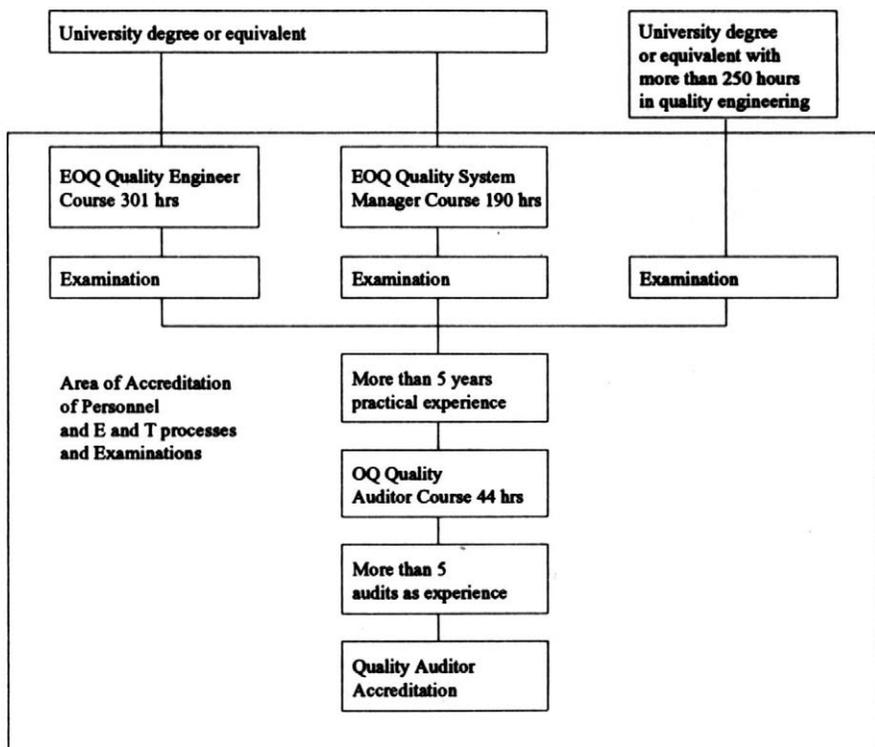
Dependability courses

Many departments at university-type institutions have developed independent courses in reliability, maintainability or safety. Few of them are complex in the sense of dependability and fewer still are presented as part of a TQC/TQM course. In the CSFR one of the few teaching establishments offering a university degree with specialization in dependability sciences is the University of Agriculture, Prague, Faculty of Agricultural Engineering.

At this faculty, engineers are trained to ensure the operation of machines and equipment used not only in agriculture, but also in the associated processing industries. The curriculum of study includes specific requirements in the quality and dependability sciences. The graduate engineer must be trained to take responsibility for the operation of certain machines and equipment with inherent quality and dependability characteristics on the one hand, and on the other hand, to ensure, through maintenance, condition monitoring, repair and servicing operations, that specified performance and dependability measures are achieved in use. In this way our graduates are directly involved in the quality and effectiveness of the enterprises where they work. They must therefore be acquainted with the problems of assuring the quality of design and the quality of conformance of products

VII. Second draft proposal
EOQ QUALITY ENGINEER, EOQ QUALITY SYSTEM MANAGER AND EOQ QUALITY AUDITOR
Level indication and training programme

```
┌──────────────────────────────────────────────┐        ┌──────────────────────┐
│ University degree or equivalent              │        │ University degree     │
└──────────────────────────────────────────────┘        │ or equivalent with    │
                                                          │ more than 250 hours   │
                                                          │ in quality engineering│
                                                          └──────────────────────┘

┌─────────────────────┐   ┌─────────────────────┐
│ EOQ Quality Engineer│   │ EOQ Quality System  │
│ Course 301 hrs      │   │ Manager Course 190 hrs│
└─────────────────────┘   └─────────────────────┘

┌─────────────────────┐   ┌─────────────────────┐   ┌─────────────────────┐
│ Examination         │   │ Examination         │   │ Examination         │
└─────────────────────┘   └─────────────────────┘   └─────────────────────┘

  Area of Accreditation     ┌─────────────────────┐
  of Personnel              │ More than 5 years   │
  and E and T processes     │ practical experience│
  and Examinations          └─────────────────────┘

                            ┌─────────────────────┐
                            │ OQ Quality          │
                            │ Auditor Course 44 hrs│
                            └─────────────────────┘

                            ┌─────────────────────┐
                            │ More than 5         │
                            │ audits as experience│
                            └─────────────────────┘

                            ┌─────────────────────┐
                            │ Quality Auditor     │
                            │ Accreditation       │
                            └─────────────────────┘
```

as well as with problems of product dependability under specific conditions of use during the planned useful life of the product.

The study curriculum also contains the appropriate training in information collection and processing for the evaluation of achieved quality and dependability measures and their utilization as feedback between user and manufacture. Such information also assists in the formulation of future quality and dependability requirements when contracting for technical equipment, taking into account the effect that these requirements will have on the quality performance and competitive position of the user's enterprise.

During the training of our engineers, the ecological aspects of quality are assuming increasing importance. These relate especially to the whole technological process of manufacturing machines and equipment and to the process of their utilization as further means of production. A necessary tool in this connection is the concept of an integral quality index (ratio of the useful effect of an equipment possessing given quality and dependability parameters and the total life-cycle costs). Such an index enables the determination of optimal design and operational parameters, including the setting of optimal intervals for preventive maintenance.

VIII. Proposed topics for EOQ quality engineer and EOQ quality manager courses - June 1991

01	Introduction, concepts and terminology
02	Organization-general
03	Quality management
04	Organization, development and planning of quality systems
05	Management and control
06	Quality improvement programs
07	Economic aspects of quality
08	Quality assurance around the quality spiral
08.1	Marketing and market research
08.2	Quality control and assurance in development and design
08.3	Purchasing/contracting-out
08.4	Production and assembly
08.5	Handling, storage, packing and delivery
08.6	Sales/services
09	Statistical methods
10	Inspection, testing, metrology
11	Information technology
12	Social aspects
13	Legal aspects
14	Education and training in quality
15	Reporting
16	Consultancy (internal)
17	Experiences with implementation

Total number of hours: QM 190, QE 301 (incl. homework QM 490, QE 801)

The Chair of Machine Dependability offers undergraduate and postgraduate teaching in the above fields as well as special courses in Quality Management and Dependability Assurance.

An interesting development in this direction is the launching in 1987 of the European Master's Course in Safety and Reliability initiated by the University of Bradford, UK (C o l l a n i , 1991). The course has 24 intensive, one-week modules which are offered by twelve cooperating European partners (universities and institutes in UK, the Netherlands, Belgium, Germany, Hungary, Portugal, Austria, Norway) - Tab. IX. The Course is supported by a grant from the EC Tempus scheme. Meantime only Hungary has joined from the eastern European Countries. In view of the fact that this course is still confined to the Reliability and Safety area and not to the wider dependability and quality area it would seem desirable to prepare several further modules for inclusion in the scheme, giving adequate attention to maintainability, availability, complex system effectiveness and overal TQC/TQM aspects.

CONCLUSION

In conclusion we wish to emphasize the following important aspects of current trends.
- the need to quantify all features of global quality of products, services, and the environment (including reliability, maintainability and safety) and their influencing factors using probabilistic and statistical models;

IX. Modules of European master's course in safety and reliability - see [12]

	Titles of course modules	Organizations
1	Statistics for reliability part 1	University Bradford
2	Statistics for reliability part 2	University Bradford
3	Reliability assessment - theory and practice	UKAEA
4	Applied fault tree analysis	UKAEA
5	Human reliability analysis	UKAEA
6	Human factors in reliability	University of Delft
7	Software reliability	University of Delft
8	Systems reliability calculations	Cranfield Institute of Technology
9	Reliability management	Cranfield Institute of Technology
10	Disaster management	University Bradford
11	Emergency and crisis management	University Bradford
12	Hazards and risk in the process industry	University Bradford
13	Safety and environmental legislation in the E. C.	University Bradford
14	Bayesian methods in reliability	University of Eindhoven
15	Advanced systems reliability modelling	University of Madrid
16	Reliability assessment of power systems	U. M. I. S. T.
17	Pattern recognition in accelerated reliability testing	Technical University Budapest
18	Product liability	University Bradford
19	Structural reliability	Technical University Lisabon
20	Fire safety management	University Bradford
21	Major hazards	UKAEA
22	HAZOPS	UKAEA
23	Risk analysis	TNO
24	Probability models for reliability, maintenance and safety calculations	University of Eindhoven

- the systems approach to the assurance of global quality using the principles of SPC;
- the universality of the Shewhart, Deming, Ishikawa cycle PDCA (Plan, Do, Check, Act) and the Juran Trilogy „Plan, Control, Improve";
- the concept of continuous improvement using the proved problem-solving techniques;
- the principle of interdisciplinary team work, recognition and self-realization as the basis of motivation in the work place;
- the need for common-sense economic considerations (if possible with quantified risk) as the basis of all decision making; the unnecessary losses due to erroneous work and unsatisfactory quality are in the region of ten to twenty percent of turnover;
- a prosperous economy needs prosperous business and manufacturing organizations which in turn must make quality, effectiveness and satisfied customers and employees their top priority.

References

COLLANI, E.: A new dimension in statistical education. In: Economic Quality Control, 6, 4, 1991, Inst. Angew. Math. u. Stat., Wurzburg, 1991.
HRABÁK, J. - ŽALUDOVÁ, A. H.: Achievement of qualitative reliability targets in new products. In: Proc. EOQC Conf. Venice, 1975.
STRANDBERG, K.: Dependability of telecommunications and information technology systems. Ericsson/IEC TC 56, 1986.
ŽALUD, F. H. - ŽALUDOVÁ, A. H.: European experiences with implementing a reliability strategy in the engineering industry. In: 8. Latin. Amer. Conf. IMCC Mexico, 1988.
ŽALUDOVÁ, A. H.: Systemizing reliability and related concepts. In: Proc. EOQC Conf. Brighton, 1984.
ŽALUDOVÁ, A. H.: Integrating the quality and reliability effort and methodologies. In: Proc. Conf. IASTED, Paris, 1987a.
ŽALUDOVÁ, A. H.: Implementing reliability strategy in the engineering industry. V. Symp. Zuverlässigkeit. Magdeburg, 1987b.
ŽALUDOVÁ, A. H.: Technological progress and quality improvement. In: Treviso Technologia Meeting. July, 1991.
ISO 8402 Quality - Vocabulary 1986.
Series of ISO Quality Management and Quality Assurance Standards 1986:
ISO 9000 Guidelines for Selection and Use. EN 29000.
ISO 9001 Quality Systems - Model for QA in Design. Development, Production, Installation and Servicing. EN 29001.
ISO 9002 Quality Systems - Model for QA in Production and Installation. EN 29002.
ISO 9003 Quality Systems - Model for QA in Final Inspection and Test. EN 29003.
ISO 9004 Quality Management and Quality System Elements - Guidelines. EN 29004.

ŽALUDOVÁ, A. H. - LEGÁT, V. (Česká společnost pro jakost, Praha; Vysoká škola zemědělská, Praha):
Tendence v zavádění programů výchovy a vzdělávání k jakosti a spolehlivosti. Zeměd. Techn., *38*, 1992 (5): 303-314.

Práce pojednává o současných aspektech problematiky systémů řízení jakosti a programů zabezpečování spolehlivosti v oblasti výroby a provozu strojírenských výrobků. Práce vychází z mezinárodních norem ISO řady 9000, které jsou vyzkoušeny u předních světových výrobců strojů a zařízení a také i u jejich zákazníků (uživatelů).

Dále je porovnána norma ISO 9004 a IEC 300-1, tj. vztah mezi systémem řízení jakosti a programy spolehlivosti. Tabelární formou jsou uvedeny zásady programů spolehlivosti realizované v ČSFR.

Pro zlepšení dosud aplikovaných systémů řízení jakosti je důležité zavádění norem ISO řady 9000. Proto jsou zmíněny hlavní oblasti, které nelze opomenout při zavádění těchto norem do praxe, zejména zainteresování vrcholového a středního článku řízení v našich podnicích.

V další části je naznačen vývoj systémů řízení jakosti v ČSFR od roku 1949 do současnosti včetně působnosti zahraničních firem v současné době v oblasti certifikace výrobků a systémů řízení jakosti v různých podnicích. Jsou uvedeny základní postupy a metody, jejichž aplikace je nezbytná k dosažení vysoké jakosti výrobků a efektivnosti výroby.

Z věcných problémů řízení a zajišťování jakosti a spolehlivosti jsou odvozeny požadavky na systém výchovy a vzdělávání odborníků pro dané oblasti činnosti. Tabelární formou jsou prezentovány požadavky na vzdělání inženýrů pro jakost, manažerů pro systémy jakosti a auditorů jakosti. Jsou uvedeny hlavní vzdělávací bloky a moduly evropských kursů pro oblast bezpečnosti a spolehlivosti výrobků včetně obsahu výchovy a vzdělávání k jakosti a spolehlivosti na technické fakultě Vysoké školy zemědělské v Praze.

Celkově lze shrnout, že článek poskytuje soubor požadavků na přípravu vysokoškolsky vzdělaných odborníků pro oblast zajišťování a řízení jakosti a spolehlivosti strojů a zařízení jak ve výrobních podnicích, tak i v provozu.

systém řízení jakosti; mezinárodní normy; nástroje zabezpečování jakosti; výukové programy

A MANAGEMENT INFORMATION SYSTEM FOR AGRICULTURAL MACHINERY MANAGEMENT

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The Management Information System (MIS) focuses on farm machinery organization, budgeting and control. It is intended to serve as a complete management package giving full costings of individual machines and operations. Schedule maintenance according to work schedules, give notice to re-order components according to local conditions and assist in replacement decision. The system integrates physical and financial management to provide a complete information system at both operational and strategic levels.

management information system; agricultural machinery

The control of farm machinery costs if gaining in importance as it comprise up to 40% of farm fixed costs. This high percentage reflects the importance of recording and controlling machinery operating costs. Record keeping is important in that it is needed to determine the cost of production, in monitoring machine performance and influencing decisions on when to replace a machine. Replacement decision also need to take account of the actual machine expenses each year and pattern of costs through the machine life. Management depends on information for decision making and in today's situation it is vital in ensuring business survival.

There are few farmers who keep sufficient data on their operating costs for adequate management control. There appears to be the need for an integrated system that can record the day-to-day operating cost data as the machine is used, record the type and amount of use, fuel and oil consumption, repair and maintenance together with the calculations of the fixed cost of the machine such as depreciation and interest on capital invested. These need to be recorded and kept up to date to give the true picture of machine ownership costs. This information should be automatically analyzed and updated and reports should be generated to give the manager full information to enable him to schedule machine maintenance, servicing, overhauling and assist in making replacement decisions. This can determine whether the machine is operating profitably. Using a work schedule proposed for the machine according to weather conditions and crop data, a maintenance schedule can be developed for each machine in the fleet. This will enable advance budgeting and ordering for spare parts needed before the beginning of the operating season. This creates the need for and efficient management information system to keep records, update and maintain data, calculate costs and develop reports on each machine and operation.

Conventionally machinery costs are defined as being either of a fixed or variable nature. The components of these costs are, fixed costs: depreciation, interest on capital, tax, insurance and housing; variable costs: repair and maintenance, fuel and oil and labour.

Fixed costs are those which you incur regardless of the type and amount of use that a machine receives. This is, however, not quite the case in reality, fixed cost will vary through the machine life and also be dependent on the machine replacement period. Depreciation for example will vary on a year to year basis, where the value of a new machine will fall faster than an older one. In effect if a machine is replaced after only two to three years higher fixed costs will be incurred. A further factor which varies is the actual resale value of the machinery related to hours of use and condition. Standard methods for calculating depreciation costs do not normally consider the condition of the machine. From market information in the late nineteen seventies and eighties it has been possible to give the actual rate of depreciation for machines in average condition. These
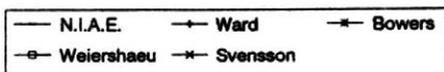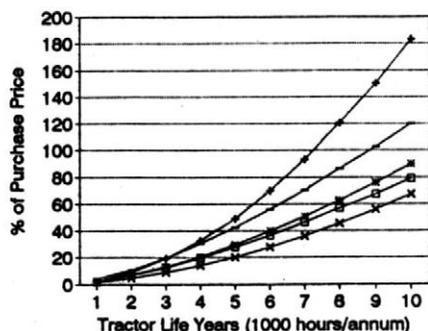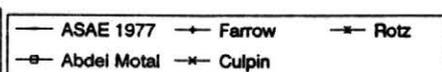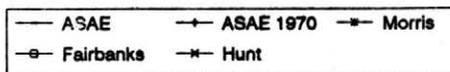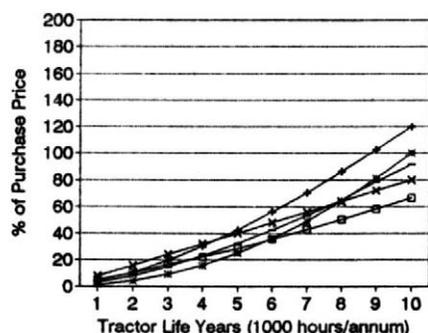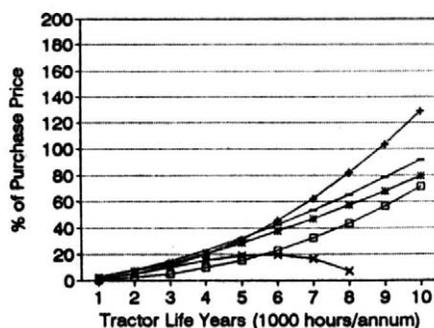
1. Tractor repair cost models cumulative R & M as a percent of purchase price

are expressed alongside the declining balance method which is often used for depreciation calculation (Fig. 1). One problem is to allow for inflation, in general the higher the rate of inflation the shorter the replacement cycle should be. Where low inflation exists it is more cost effective to hold onto a machine for its full working life. The MIS system will allow the user to specify the rate of depreciation using the declining balance method.

A further item to consider is interest on capital invested. This is always included because even if the machinery was purchased from existing resources, the potential income in the form of interest payments has been lost. It is normal practice to consider the amount as the average amount owing over the life of the machine. This is calculated by dividing the purchase average amount owing over the life of the machine. This is calculated by dividing the purchase price plus the scrap or trade in value by two and multiplying it by the interest rate. Again the system will allow the user to input the rate which reflects their own situation. More complex amortization tables can be used to calculate payment, most loans for machinery purchase have an agreed rate of payment set at the beginning of the contract, although fluctuations in bank base lending rate will affect the payments made as the basis for the agreement is likely to be in the form of $X\%$ percent over base rate.

Tax can be put in as a fixed sum which will vary according to the country, insurance costs are expressed as a percentage of machine value. Housing costs have not been considered as a directly attributed cost in this system.

Variable costs can be defined as the costs that vary with the machine utilization and consist of repair and maintenance, fuel and oil consumption, and labour cost.

Repair and maintenance costs are one of the most important costs of operating farm machinery. Repair and maintenance is essential for restoring machine to working condition and guarantee a higher standard of machine reliability.

The cost of repair and maintenance was found to be very difficult to predict and variable from one machine to the other. A large number of researchers both in the USA and Europe working on modelling of farm machinery repair and maintenance costs were faced by this fact and they attributed it to the following reasons:

a) inherent machine qualities are different between makes and even within one make;
b) standards of routine maintenance;
c) machine loading and type of operation undertaken;
d) operator skills;
e) soil type and weather conditions;
f) storage and housing facilities.

These factors lead to a great variability on repair and maintenance costs of machines and led to the fact that all the models developed by researchers cannot predict exactly individual machine repair and maintenance costs but they can be used as a 'rule of thumb'. A further factor which has an important effect are the actual financial conditions in individual countries relating to cost and availability of spare parts.

Fig. 2 shows a number of models developed by researchers to predict repair and maintenance costs of machines in the USA and Europe. It reflects the variability in the models predicting repair and maintenance cost of a 2WD tractors. The figures also showed one of the models breakdown with time (H u n t , 1983) however the tractor age in the sample vary from ten to four years.

The ASAE (1980) stated that repair and maintenance costs are highly variable and unpredictable as to time of occurrence. Surveys of repair and maintenance costs related
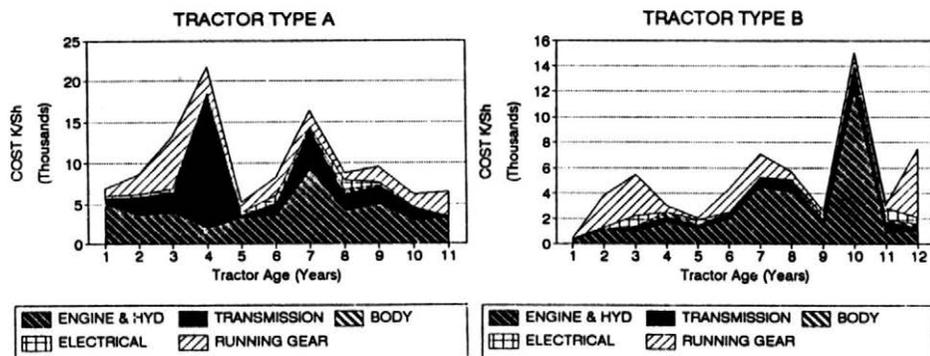
2. Repair and maintenance costs

to accumulated use show consistent trends though the standard deviation equals to the mean is a typical variation in this data. It is also important to note that some of the models were developed in the sixties when tractors were of a more basic design with no accessories such as air conditioned cabs and sophisticated electronics which add to the value of the tractor but have a smaller effect on repair and maintenance cost.

It appears that applying a cumulative repair and maintenance curves to repair and maintenance costs ignore the reality of the situation on the farm. Although the general conclusion of the studies in repair and maintenance is it's uncertainty there are some repair and maintenance costs that can be accurately predicted, some others with cyclic nature like daily checks and greasing, regular engine servicing should occur in definite time interval of working hours, that incurs an oil cost, oil filter cost and fuel filter cost. Other longer term cost cycles also occur as in tyres. Overhauling is also recommended to be within specific time depending on the nature of the work performed by the tractor.

This gives the idea of splitting and analyzing failures and servicing to determine these long and short term cycles and also identify wearing parts due to work so as to reduce uncertainty and give better allocation of costs throughout life of the machine. Other aspects such as field repair and breakdown can be investigated by studying their nature and cause using a full and detailed recording, indicating time of occurrence, cause and operation so as to put a new model form for each component or component group. An example of this can be shown in Fig. 2., where two makes of tractor carrying out similar tasks were investigated, the figures show considerable variation in repair and maintenance costs both in terms of total cost, timing of cost in relation to machine age and distribution of cost between different component groups (P a r k e r , 1988).

Fuel and oil costs can be predicted using the equations developed by ASAE (1980). They stated that fuel efficiency varies with fuel type and load on the engine. They gave the following model for a typical farm tractor diesel engine.

$$Diesel\ Fuel\ Consumption = 2.64\,X + 3.91 - 0.2\,(738\,X + 173)^{0.5} \qquad [1]$$

where: X - the ratio of equivalent pto. power required by an operation to that maximum available from the pto.; typical fuel consumption is given in 1/kW.h.

ASAE(1980) defined oil consumption as the volume per hour of engine crankcase oil replaced as the manufacturer's recommended change interval. They gave the following equation for tractors:

$$Oil\ Consumption = 0.00059\ P + 0.02169 \qquad [2]$$

where: P - the rated engine power in KW, oil consumption is in l/h.

Work scheduling

As the trend in most agricultural areas is to increase farm size with a move to a larger and highly mechanized crop production systems, the adequacy of farm operations depends greatly on weather conditions and machinery availability. According to weather conditions available days for each operation can be predicted and according to the area under each crop and timing for each operation the maximum hours expected to be worked by each tractor throughout the year can be determined. The system only uses the machinery available on the farm, no optimisation of the machinery fleet is attempted. Individual tractors have jobs specified for them and hours of use are then calculated.

Determination of a work schedule for each tractor can then lead to the maintenance schedule for the predictable items like servicing, complete overhauling, tyre change and also help to predict some field breakdowns of wearing parts, such as wheel bearings, plough shares, etc.

This will lead to advanced ordering of parts needed and for budgeting for repair and maintenance. The system can be programmed to give a warning of when reordering needs to take place according to local conditions such as lead time for delivery of spare parts. The system will provide a complete history of machinery use and costs. Hence it can give an indication of machine performance and repair cost behaviour which when linked to fixed cost calculation providing the information necessary for replacement decision making.

System development

A management information system (MIS) is being developed and tested for this process. The system makes use of the database programme (Paradox 3.5) to keep recording of data, manipulate it and make calculations and give reports at different points within the system.

The system keeps records of machinery initial data, machinery use, machinery fixed and operating costs, working days and crop information (Fig. 3) illustrates the data input structure. The system is capable of updating and editing data at any time.

The system output gives reports on the cost of machinery use including repair and maintenance costs, operational cost for both individual machines and the whole fleet, for an individual operation or the whole system.

Fig. 4 gives a simplified menu structure of the reporting options available. Example reports generated by the system on tractor cost and use are shown in Tab. I and II. Tab. I gives an annual report containing information regarding the tractor running costs for the whole fleet. Tractor repair and maintenance costs together with labour costs associated with on farm machinery repair and fuel costs are taken into account to give the total running costs for each machine in that year. Tab. II gives a breakdown of individual tractor repair and maintenance costs where the costs are grouped to provide
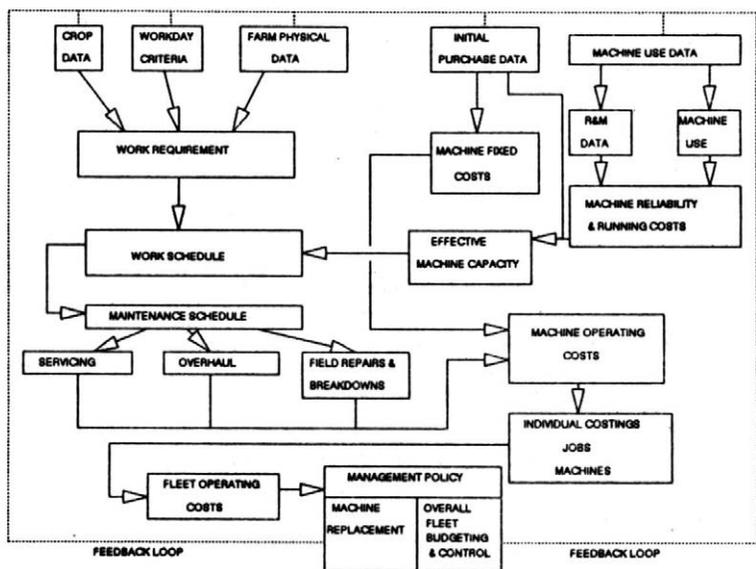
3. Data input structure for management information system

4. Report menu structure
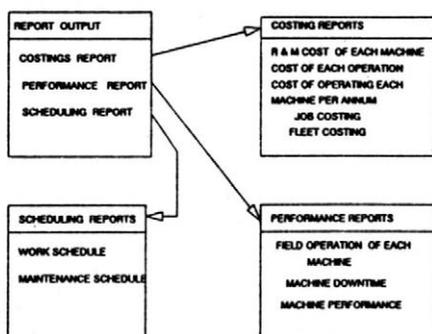
a clearer picture of problem areas. This provides the manager with more comprehensive information on tractor performance and cost, which parts and which tractors are giving most trouble in order to help pinpoint problems. The nature of repairs being carried out is also important when making machinery replacement decisions.

CONCLUSIONS

It is clear that using cumulative repair and maintenance models fail to give the farmer adequate information regarding machinery operating costs. All models fail to take account of loading and operating conditions. In addition they give no indication regarding the type

I. Summary report of tractor running costs in Tsh

ID #	1989 use hrs	R&M cost 1989	Fuel cost 1989	Labour cost 1989	Yearly running cost	hourly running cost
Tractor Make:County						
TZ001	807	370,097.00	858,500	71,984.50	1,300,582.	1,611.6
TZ002	1349	632,866.00	1,430,000	35,758.50	2,098,625.	1,555.7
TZ003	871	716,277.00	886,900	83,617.00	1,686,794.	1,936.6
TZ004	1415	781,495.00	1,199,900	67,299.50	2,048,695.	1,447.8
TZ005	1324	207,284.00	29,400	14,068.00	250,752.	189.4
TZ006	0	1,173,262.00	1,253,000	62,017.50	2,488,280.	0.0
TZ007	2108	858,174.00	739,300	34,053.75	1,631,528.	774.0
TZ008	1020	1,631,294.00	1,201,900	219,232.00	3,052,426.	2,992.6
TZ009	1320	1,629,301.00	1,446,100	117,549.85	3,192,951.	2,418.9
TZ010	481	675,280.00	1,021,200	93,631.15	1,790,111.	3,721.6
TZ011	46	1,233,051.00	830,200	74,370.10	2,137,621.	46,470.0
Tractor Make:Ford						
TZ012	503	1,714.00	1,770,700	35,092.50	1,807,507.	3,593.5
TZ013	0	0.00	248,400	31,308.00	279,708.	0.0
TZ014	893	181,960.00	765,600	23,582.00	971,142.	1,087.5
TZ015	0	190,483.00	234,700	43,898.00	469,081.	0.0
TZ016	259	1,336,258.00	556,400	60,255.00	1,952,913.	7,540.2
TZ017	282	678,093.00	235,100	46,415.00	959,608.	3,402.9
TZ018	0	702,176.00	774,200	71,580.50	1,547,957.	0.0
TZ019	0	898,540.00	699,200	106,978.00	1,704,718.	0.0
TZ020	107	375,832.00	733,500	76,974.00	1,186,306.	11,087.0
TZ021	381	315,709.00	1,069,100	47,111.00	1,431,920.	3,758.3
TZ022	255	601,214.00	635,100	50,774.00	1,287,088.	5,047.4
TZ023	35	231,477.00	558,400	35,560.00	825,437.	23,583.9
TZ024	0		1,199,900	0.00		
TZ025	0	1,057,351.00	701,500	57,785.50	1,816,637.	0.0
TZ026	100	398,382.00	661,500	65,071.50	1,124,954.	11,249.5
TZ027	1296	46,813.00	986,000	20,894.50	1,053,708.	813.0
TZ028	· 0	36,923.00	0	39,261.50	76,185.	0.0
TZ029	0	529,919.00	635,300	38,439.00	1,203,658.	0.0
TZ030	743	106,786.00	658,500	64,279.00	829,565.	1,116.5
TZ031	1301	500,013.00	841,700	40,853.25	1,382,566.	1,062.7
TZ032	306	113,608.00	849,200	34,820.00	997,628.	3,260.2
TZ033	420	82,470.00	481,800	26,325.00	590,595.	1,406.2
TZ034	254	17,962.00	910,900	4,811.50	933,674.	3,675.9
TZ035	1155	227,643.00	757,800	18,293.50	1,003,737.	869.0
TZ036	61	16,488.00	778,500	25,347.75	820,336.	13,448.1

II. Annual report of tractor repair costs (10. 06. 92)

Repair code number	TRACTOR TZ002 R & M COST DESCRIPTION YEAR 1989			Yearly cost for R & M group
	part replaced	quantity	price	
1	diaphgram	1	7,956.00	74,268.00
	elbow	1	4,929.00	
	fuel filter	1	2,566.00	
	fuel filter	6	15,396.00	
	hydraulic filter	2	8,660.00	
	oil filter	5	12,830.00	
	oil seal	4	6,852.00	
	pipe clamp	2	8,334.00	
	stud bolts	1	1,580.00	
	top gasket kit	1	5,165.00	
2	crown pinion	1	11,249.00	11,249.00
	front differential seal	1		
3	drawbar bolt	4	215,752.00	215,752.00
5	tube	3	23,865.00	48,169.00
	tyre	4	24,304.00	
6	bolts & nuts	6	4,572.00	64,450.00
	covers	2	54,214.00	
	linch pin	1	4,552.00	
	lock rings	1	1,112.00	
7	brushes	2	3,226.00	94,710.00
	flat washer	2	12,776.00	
	spring washer	14	78,708.00	
8	bearing assembly	1	7,798.00	24,268.00
	bearing roller	1	3,294.00	
	bearings	4	13,176.00	
	total yearly cost			532,866.00

Repair costs; 1 - engine, 2 - transmission & PTO, 3 - hydraulic system, 4 - steering, 5 - tyres, 6 - boom, 7 - electrical, 8 - bearings

of repairs carried out. A Management Information System is under development which will examine the problem in a more sophisticated way. The system will give the farmer regular feed back including annual reports on individual machines, calculate machinery maintenance schedules from work schedules and basic servicing information. By providing more information the system will give the farmer greater control over his machinery repair budget. It will also help him in making replacement decisions in order to maximise the economic performance of individual machines and ultimately the entire machinery fleet.

Initial of the system has already highlighted problems with a current manual system under examination. Tab. I indicates that tractors are using considerable amount of fuel yet doing no work. It was suspected by the manager that the fuel was being stolen and although the previous manual system was able to detect this, it was possible to get the information quickly enough to act on it. The system also indicates the need for proper identification of parts going into the machine. An extra category for bearings has had to be created in this example, again due to the inadequacies of the historical data obtained through the manual system.

References

ABDELMOTALEB, I. A.: Repair and maintenance cost analysis of tractors and combines. [Ph. D. Dissertation (unpubl.).] 1989. - Iowa State University, USA.
ASAE Yearbook. ASAE D230.3. Agricultural Machinery Management Data. ASAE, St. Joseph, MI, USA, 1980.
BOWERS, W. - HUNT, D. R.: Application of mathematical formulas to repair cost data. Trans. ASAE, *13*, 1970, No. 6, pp. 806-809.
CULPIN, C.: Profitable farm mechanization (third edition). Granada Publ., St. Albans, 1975.
FAIRBANKS, G. E. - LARSON, G. H. - CHUNG, D. C.: Cost of Using Farm Machinery. Trans. ASAE, *14*, 1971, No. 11, pp. 98-101.
FARROW, S. - SHEPHERD, J. F. - WAELTI, H.: A regional test of machinery repair cost equations. ASAE Paper No. 80-1017, ASAE, 2950 Niles Road, St. Joseph MI, 49085, 1981.
HUNT, D. R.: Farm power and machinery management. Iowa, USA, The Iowa State University Press 1983.
MORRIS, J.: Tractor Repair Costs. Fm Mgmt, *6*, 1988, No. 10.
PARKER, A. C.: Management of fleet of agricultural machines. [Final Year Dissertation Bsc.] Hons in Agricultural Mechanization Management (unpubl.), 1988. - University of Newcastle Upon Tyne.
ROTZ, C. A.: A standard model for repair costs of agricultural machinery. Appl. Engin. Agric., *3*, 1987, No. 1.
SVENSON, J. E. T.: Maintenance cost for farm machinery. CIGR, *6*, 1989, No. 4, pp. 2669-2671.
WARD, S. M. - MCNULTY, P. B. - CUNNEY, M. B.: Repair cost of 2 and 4 wheel drive tractors. Trans. ASAE, 1985, pp. 1074-1076.
WEIERSHAEUSER, I.: Repair cost for farm machinery in cost calculations. CIGR, *6*, 1989, No. 4, pp. 806-809.

Článek obsahuje návrh informačního systému pro efektivní řízení provozu strojů v zemědělství na příkladu traktorů. Informační systém je založen na sledování vstupních údajů o výrobním procesu v rostlinné výrobě, odkud jsou stanoveny požadavky na pracovní operace a plány pracovního nasazení a údržby strojů. Druhá informační linie sleduje tok nákladů od nákupu strojů, přes jejich provoz a využívání včetně nákladů na údržbu a opravy až po vyřazení strojů z provozu. Navržený systém se vyznačuje komplexností a tvoří smyčku zpětné vazby mezi vstupními informacemi a pokyny pro řízení provozu strojů.
Autoři podrobněji popisují strukturu fixních a variabilních nákladů na pořízení a provoz strojů. Zvláštní pozornost věnují analýze nákladů na údržbu a opravy traktorů podle různých literárních pramenů i podle svých poznatků. Jsou uvedeny vztahy pro výpočet měrné spotřeby paliva a oleje běžných traktorových motorů jako podklad pro výpočet příslušných nákladů.
Informační systém může v kterémkoliv okamžiku dát zprávu o nákladech členěných na údržby a opravy, na každou pracovní operaci, na každý stroj za rok, na každou zakázku a na celkový provoz. Dále systém informuje

o pracovních výkonech každého stroje zvlášť a o prostojích. Součástí systému je i tvorba plánů pracovního nasazení a údržby strojů.

Navržený informační systém umožňuje zemědělcům lepší kontrolu nákladů na pořízení a provoz strojů a zajišťuje jejich vyšší hospodárnost a lepší využití. Dále systém umožňuje maximalizovat efektivnost provozu jednotlivých strojů objektivním plánováním a řízením provozu, údržby, oprav a obnov strojů jako celků.

informační systém; fixní a variabilní náklady; plány pracovního nasazení a údržby strojů; hospodárnost provozu strojů

IMPROVEMENTS IN THE ACCURACY OF CONTROL OF TRACTOR MOUNTED HOES

P. A. Cowell

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Public concern about the environmental and health impact of excessive herbicide use, as well as cost, have created renewed interest in mechanical methods of weed control. The paper examines the problem of improving the accuracy of control of tractor mounted hoes. Two methods are reviewed; the design of passive systems using a modified hitch design and the use of active systems using crop sensors in combination with an electro-hydraulic control system.

weeder; automatic steering; environment

In recent years there has been an increased concern about the use of herbicides in agriculture, particularly residual herbicides on account of the environmental damage they may cause.

The control of weeds is a major factor determining the success or failure of agricultural crops. Traditionally, mechanical methods of control have been used whereby the crop is grown in rows, and inter-row weeding is carried out using animal or tractor-drawn hoes.

The problem with inter-row weeding is that unless the hoe is accurately steered considerable damage can be inflicted on the crop. The situation is made worse the closer the hoe is set to the crop, and the faster the speed of operation. Steerage hoes have been widely used whereby a second operator sits on the weeding machine and guides the tool. But this is a slow and fatiguing operation. The much simpler alternative of overall crop spraying has therefore been widely adopted.

Apart from the potential environmental damage inflicted by chemical sprays, the costs of treating a crop are not inconsiderable. A recent study by P u l l e n (1966) indicates that the cost of chemical weed control in a typical crop of sugar beet in the U.K. amount to £100 to 150 per hectare. It is clear from these figures that there is considerable economic scope for the use of an accurately controlled mechanical hoe that either eliminates the need for sprays altogether or, which is more likely, reduces the spray requirement to a narrow band over the crop itself. Depending on the level of sophistication in sensing the location of individual plants, targeted spraying of individual weeds may even become a possibility.

The problem of accurately positioning a mechanical hoe in relation to the crop can be divided into firstly, knowing where the row is and secondly, controlling the hoe so as to inflict maximum damage to the weeds and minimum damage to the crop.

If crops are grown in rows then the position of the row must be accurately known. If the crop is grown on performed ridges, then the furrow base provides a good measure of the row, even in the case of quite heavy weed infestation, and a mechanical row sensor such as a furrow wheel is an adequate to guide and control the machine.

However, if the crop is planted in rows on the flat, as is the case with many horticultural crops and cereals, visual or other means of row location are required. The problem is further compounded by the relative height of the crop and competing weeds. If the crop is low lying and of a similar height to the weed population, a heavy weed infestation will make it increasingly difficult to visually recognise where the row is. Early control of weeds in these circumstances is therefore essential. On the other hand, tall growing crops such as maize and sorghum tent soon to grow above the surrounding weeds and sensing of the row is an easier task.

Visual sensing of the crop row is a normal task for the driver, and enables him to drive the tractor down the row. A potential alternative is machine vision sensing which has the virtue that since the information of the crop location is stored electronically, it can be used for controlling the position of the hoe.

Machine vision sensing offers two principal possibilities- locating the row and locating individual plants. If inter-row weeding is all that is required, row only sensing should be sufficient for control purposes. However, if intra-row weeding is required the individual plants need to be recognised. The latter task is clearly much more formidable than the first. Machine sensing of rows can also be of assistance to the driver particularly if he intends to operate at higher forward speeds or perhaps in subdued lighting conditions.

Controlling of the position of the hoe relative to the crop can be carried out either by passive or active means. Passive control implies a form of open loop control in which the machine follows along a path determined by that taken by the tractor and by the design of the hitch. If the hoe is rigidly attached to the back of the tractor, then any steering adjustment made by the driver results in an immediate response from the implement, a response which is usually unsatisfactory (R e e c e et al., 1966). If the implement is rigidly attached to the front of the tractor the driver has better control of the lateral position of the hoe, but he must concentrate hard to steer accurately.

If the implement is attached to the rear of the tractor on an unrestrained linkage the hoe follows behind the tractor with an attennuated lateral movement. In none of these cases does the implement accurately follow the row of the crop.

Active control implies some form of feedback control in which the hoe is steered in response to an input signal. If the system response is fast enough it may be sufficient to sense the crop position alongside the hoe. This has the disadvantage that high accelerations and a higher power input are required. If the row is sensed ahead of the hoe then the advanced information given to the control system allows more time for the hoe to respond. However, this places a limit on accuracy, particularly where long spatial delays are involved.

The method of steering the implement has an effect on the tractor-hoe system as a whole. One methods is to mount a tool-bar rigidly to the tractor and to index the hoe blades sideways along the tool-bar. Such a form of control requires side forces to be

applied to the hoes which must be reacted by the tractor tires. This in turn affects the tractor and may produce unwanted lateral vibration.

An alternative approach is to use a free linkage and steer the hoe by grounden gaging wheels or a fin. These induce a sideways reaction on the soil and uttle if any side force is exerted on the tractor.

Steering with passive linkage control

The path taken by an implement which is mounted with free lateral movement has been shown to be governed by a second order differential equation with constant coefficients (C o w e l l , M a k a n j u o l a , 1966). In practice the damping ratio tends to be large so for most practical purposes the response approximates to a first order response. Thus if the hitch point is given a step movement χ_i to one side, the sideways movement of the implement χ_o follows an exponential path given by

$$\chi_0 = \chi_i \left(1 - e^{-s/l} \right)$$

The spatial time constant of the system is equal to the hitch length l, so the greater the hitch length the slower the response of the implement (Fig. 1).

1. Lateral response of an implement to a step movement of the hitch point
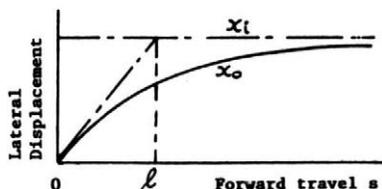
The inherent lag in the response can be eliminated by a judicious selection of the hitch point. If a real hitch point is provided at a point halfway between the rear axle of the tractor and the wheels on the implement (or the soil engaging parts if the implement has no wheels) then the hoe will follow directly in the path of the centre of the rear axle of the tractor (M a k a n j u o l a , C o w e l l , 1970). The arrangement is illustrated in Fig. 2.

2. Showing the condition for exact tracking of an implement behind the tractor rear axle
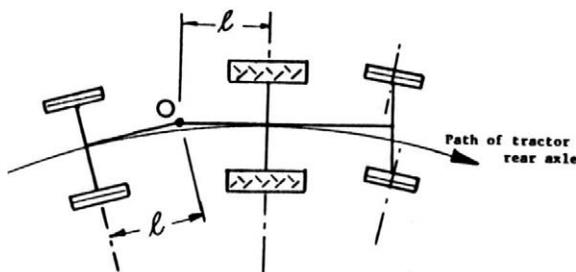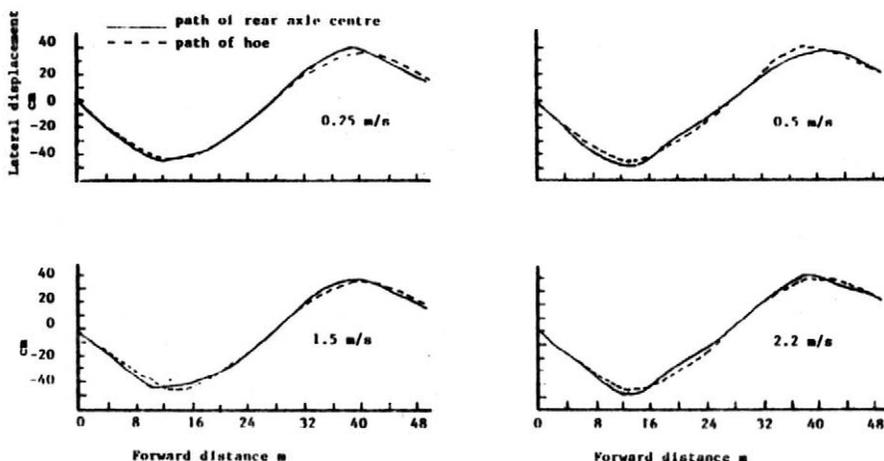
3. Path of hoe in response to movement of tractor rear axle when using centralising hitch

Tests have been carried out on a machine constructed on the basis of this principle (K e r u , 1988) at Silsoe College.

The rear axle of the tractor was driven along a sinusoidal path and the path taken by the hoe in response was measured. The results, shown in Fig. 3 illustrate that the hoe was capable of closely following the prescribed track.

The system requires that the driver positions the rear axle of the tractor accurately with respect to the row, which is a somewhat more difficult task than positioning the front wheels.

An actively controlled steerage hoe

In order to test the effectiveness of a fully automatic system a machine was designed and built at Silsoe College (K w a n g w a r o p a s , 1988). The machine was attached to the back of a tractor on the normal three point linkage and its weight was carried on a pair of steerable wheels. The crop was sensed by a mechanical feeler on a light parallel linkage and the signal from it actuated and electrohydraulic control valve. A hydraulic actuator steered the wheels of the hoe. In addition, mechanical crops sensors ahead of the tractor gave the driver both an audible and a visual warning when he was too close to the crop.

Tests were conducted in maize and sorghum and it was found that the degree of damage resulting from a single pass could be reduced from around 5.2% to 1.2% (Fig. 4). As speed increased from 0.7 m/s to 1.7 m/s there was a marked increase in damage to the crop when operating without controls. When the controls were introduced damage to the crop was maintained at a level at all speeds. The crop in each case was around 35 cm in height and above most of the surrounding weeds, so no problem was experienced in row detection.
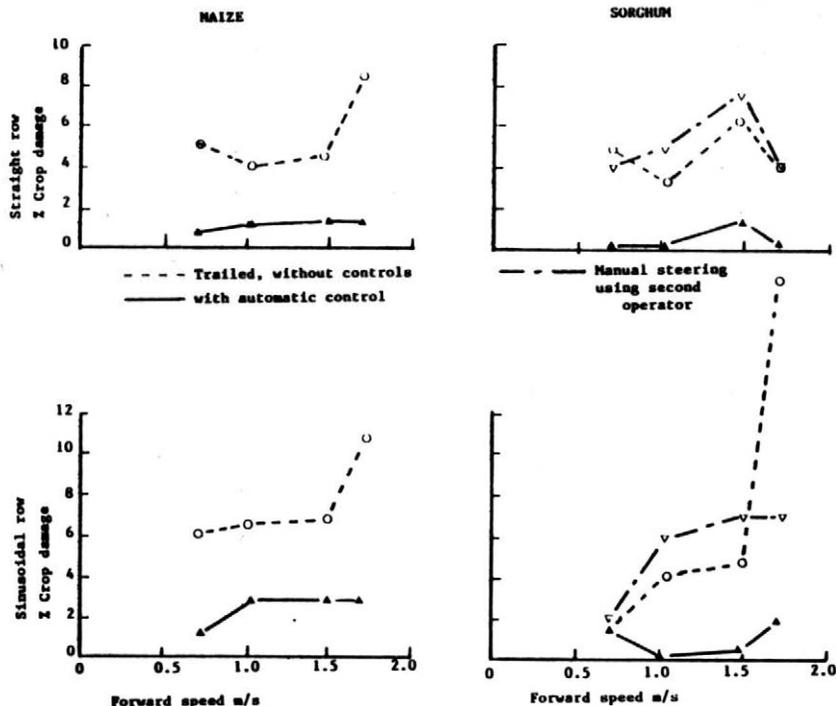
MAIZE   SORGHUM

4. Showing the percentage damage inflicted on maize and sorghum after a single pass of a mechanical hoe

Conclusions

Although passive systems of control can improve the accuracy of following of tractor mounted hoe, success in the field will depend on how accurately the operator drives the tractor.

A fully automatic system is capable of accurately controlling a hoe and minimising damage. However, this is conditional on being able to sense the row accurately. Whilst this is a straight forward matter for tall crops such as maize and sorghum, the challenge remains for sensing crops at an early stage when grown on flat land and in the presence of weeds.

References

COWELL, P. A. - MAKANJUOLA, G. A.: The lateral dynamic behaviour of tractor mounted implements with particular reference to the three point linkage. J. Agric. Eng. Res., *11*, 1966, No. 3.
KERU, T. K.: Design and evaluation of a centralising hitch for storage hoes. M. Sc Thesis, Silsoe College, 1988.
KWANGWAROPAS, M.: An electro-mechanical aid for improving the performance of tractor drives in post establishment row crop operations. Ph. D. Thesis, Silsoe College, 1988.

MAKANJUOLA, G. A. - COWELL, P. A.: Optimisation of the lateral dynamic behaviour of tractor-mounted implements. J. Agric. Eng. Res., *15*, 1970, No. 32.
PULLEN, D. W.: Thesis Research Report. Silsoe College, 1991. (Unpublished).
REECE, A. R. - GUPTA, R. - TAYALS, S. S.: The lateral stability of tractor mounted implements. J. Agric. Eng. Res., *13*, 1966, No. 2.

COWELL, P. A. (Silsoe College, Vysoká škola technologická, Cranfield, Velká Británie): *Zvyšování přesnosti řízení traktorem nesených pleček.* Zeměd. Techn., *38*, 1992 (5): 325-330.

Veřejný zájem o vliv nadměrného používání herbicidů a stejně tak nákladů na životní prostředí a zdraví podnítil obnovení zájmu o mechanické metody boje proti plevelům. Je prověřován problém zvyšování přesnosti řízení traktorem nesených pleček. Jsou posuzovány dvě metody: návrh pasívních systémů, které používají modifikovaný projekt závěsné plečky, a užití aktivních systémů, používajících snímače sklizně v kombinaci s elektrohydraulickým řídicím systémem.

plečka; automatické řízení; životní prostředí

COMING TECHNOLOGIES IN AGRICULTURE

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Compared to industry, creation and acceptance of innovations in agriculture have specific aspects due to structural characteristics. As these innovations are often linked one with another, their analysis need a rather broad systemic approach, taking into account relations between science, technology and socioeconomics. Between 1950 and 1980, new technologies aimed at increasing yield per hectare and production per worker to get a greater independence towards hazardous conditions. The level of inputs increased. Being successful, it has led to excess of products, damage to the environment, social and geographic disparities. Two main families of technology coming now, biotechnology and information technology, represent high potentialities to solve these problems, or, at least, restrict their extension. Most of the coming technologies will need more intellectual tasks than manual for the farmer. More research work has to be done for evaluating their impact on size of farms, structures, agricultural practices, part-time farming, use in common of equipments etc. New technologies will not only concern agriculture but also rural activities (landscape, quality of life of rural people: air, noise, water etc.).

innovation; analysis; systemic approach; biotechnology; information technology

Agriculture has in many countries specificities which make creation and acceptance of innovations different from industry. These specific aspects are linked with structural characteristics : many small (or relatively small) units of production, mostly family run in Western countries. Materials are not inert but living ones. A great diversity of climatic and soil conditions - as also social and economic conditions - prevail.

Innovative systems

Innovations in agriculture are closely related each other. A new plant variety needs more fertilizer or more chemical protection, and the harvesting machine cannot be completely independent from some plant characteristics. So the analysis of these innovations need a broad systematic approach, taking into account the relations existing between science, technology and socio-economic conditions. These interrelated techniques represent, as a whole, a technical system. This system is a compromise or an equilibrium between the science push - a general trend, caused by the development of scientific applications in all societies, with different paces - and the demand pull, which is the moderating - or accelerating - factor coming from the needs expressed by the social demand and its possibility to integrate the science push in the economic system.

Innovations developed in agriculture as in other sectors can be classified, into three categories:
- Innovations on products, like new varieties introduced and adapted by farmers (sunflower, soybean, peas), but it is in the agrofood industry where we can find the greater number of innovations of this type;
- Innovations on processes lead to new ways in cultivating techniques or breeding of cattle. Some of them introduce new inputs : fossile energy, chemicals, seeds and breeds, new materials (plastics);
- Innovations in organization, like optimization of agricultural practices, specialization and concentration of productions, or new partition between farmers and agro-industry, play also a significant role in agriculture.

In most of Western countries, innovation is issued from private societies, and public research institutions. The role of these latter is increasing, but, at the same time, tends to be at a more fundamental level. A part played by equipment manufacturers and more generally intermediary goods suppliers is very important. P. Bye (1989) states that technology in agriculture is more and more depending on general scientific and technical knowledge on one side and on the other side from mechanical and chemical enterprises playing an essential role of transfer from researchers to final users.

What have been the general trends in the technical systems in agriculture, and what are the coming ones? A broad survey is given in Tab. I, from 1950. Between 1950 and 1990, new technologies aimed at increasing yield per hectare, and production per worker. Together, a greater independence towards hazardous natural conditions (climate in particular) was recorded. Development of irrigation, greenhouses or out-of-season production, and less non productive periods in animal breeding are examples of the artificialisation of the productions. This intensification has led to an excess of production, damages to the environment and social and geographic disparities.
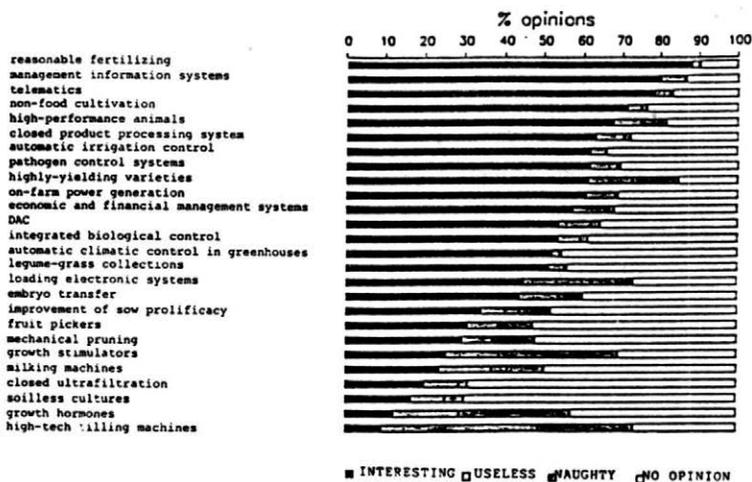
The dissemination of an innovation results in a classical „S" curve. A concrete example is given in Fig. 1 showing the number of vineyard harvesting machines sold in France from 1971 to 1989. A very interesting inquiry has been undertaken by two INRA economists (Institut National de la Recherche Agronomique), S. Bonny and P. Dauce (1990), on the opinions expressed by one thousand French farmers on technical innovations. On the top of Fig. 2, the most satisfactory opinions are put on: a reasonable fertilizing, microcomputers for farm management, telematics, non-food cultivation, animals with better productivity, and conditioning and processing on the farm. On the bottom part of the drawing technological innovations are far less successful! Robotization receives less than 40 % of interest, and the ploughing robot is a bestseller as dangerous or naughty

I. General trends

	Technical system in agriculture 1950 - 1980	New t. s. since 1980	Coming t. s.
Scientific basis	mechanical and chemical processes	biological and information technologies	artificial intelligence and life, biotechnologies
Objectives	mass production with few regulation	diversity quality and regularity of production	global management of rural areas (landscape, environment, optimization of production systems from industrial methods)
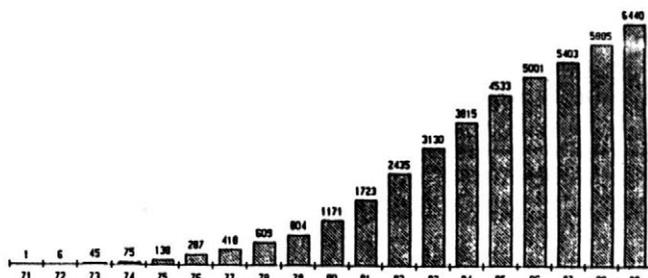
1. Self-propelled grape harvesters sold in France in 1971 to 1989 (ITV source)


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                              % opinions
                    0  10  20  30  40  50  60  70  80  90  100
reasonable fertilizing
management information systems
telematics
non-food cultivation
high-performance animals
closed product processing system
automatic irrigation control
pathogen control systems
highly-yielding varieties
on-farm power generation
economic and financial management systems
DAC
integrated biological control
automatic climatic control in greenhouses
legume-grass collections
loading electronic systems
embryo transfer
improvement of sow prolificacy
fruit pickers
mechanical pruning
growth stimulators
milking machines
closed ultrafiltration
soilless cultures
growth hormones
high-tech tilling machines
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■ INTERESTING □ USELESS ▨ NAUGHTY ▯ NO OPINION

2. Opinion expressed by 1,000 French farmers on technical innovations (B o n n y , D a u c e , 1990)

type of innovation. The question was clearly provocative in a country where the national ploughing competition is a very popular event! But mentalities move rather fast in this matter as soon as people can see and appreciate, in the field, the performance of machines only presented as potentialities.

Biotechnology

But, as we have seen just above, favourable opinions refer principally to biotechnology. Both with information technology they represent possible solutions of some problems listed previously or, at least, restrict their extension. Biotechnology modifies plants and animals from inside. Instead of inert, non-organic materials, chemicals or energy, living beings are used, modified or programmed as actors. Bacteria become new slaves of men, like machines previously. And use of renewable sources in enhanced.

Between all possible applications, we can list the following:
- Living beings modified by genetic transfer. Some varieties are already resistant to certain diseases or pests (insects). Research is done on cold or dryness resistance. Composition may be altered for a richer content in proteins for cereals. Physiology can also be modified to fix nitrogen directly from the air. With some imagination, and to satisfy people who have some excess in cholesterol, biotechnology will certainly develop eggs not containing lipids (at least, or less). Microorganisms may help production in critical phasis, like bacteria against icing. Certain specific pharmaceutical moles were produced and sold (by Plant Genetic System in the USA, for example).
- New tests for diagnosis: These tests are needed for characterization of the quality of a product.
- Biological engineering: *In vitro* cultivation is now well developed. DNA synthesis has been obtained.

But there are some limits. For wheat fixing nitrogen directly, 17 genes were involved, and research has started 10 years ago - without any result. These processes have, by nature, a destabilizing effect. The high sophisticated procedures, rather costly, excludes those who cannot afford it. Ecological movements are anxious about the risks of genetic modifications which cannot always be controlled. This kind of risk is not well evaluated.

Trends in biotechnical conversion of agricultural products, following the studies of Dr. Baganz, of ATB (Potsdam-Bornim), are from now a production of fuels (ethanol, oil, diester) at low price in high quantity, to enzymes, antibiotics, high value moles but in smaller quantities.

Information technology

As to play a significant role in the coming years, it may be defined as the technology (software, hardware) needed to handle information. The European Community Club of Advanced Engineering for Agriculture (ECCAEA) during its last technical review held in Braunschweig has listed, four main types useful to farm managers:
1. Information systems for recording and manipulating data and presenting up-to-date information in a way that is directly useful;
2. Automation and control systems, that can reduce stress to farm workers or animals, improve the health and safety of workers, and improve efficiency by controlling or monitoring machines, buildings or equipment automatically (in real-time mode);
3. Model-based decision support systems, computer systems which can suggest and explain possible decisions and predict the consequences of decisions (impact) under various circumstances;
4. Data transfer and communication systems that allow the exchange of information either internally on the farm between different operational units or sensors, or between the farm and external organisations or databases.

Let's give some illustrations on automation and control systems. Image processing is widely spreading for various applications, using Fourier and Spatial domain analysis of image texture:
- a vision guided mower for the upkeep of natural environment (Derras, Berducat, Bouton);
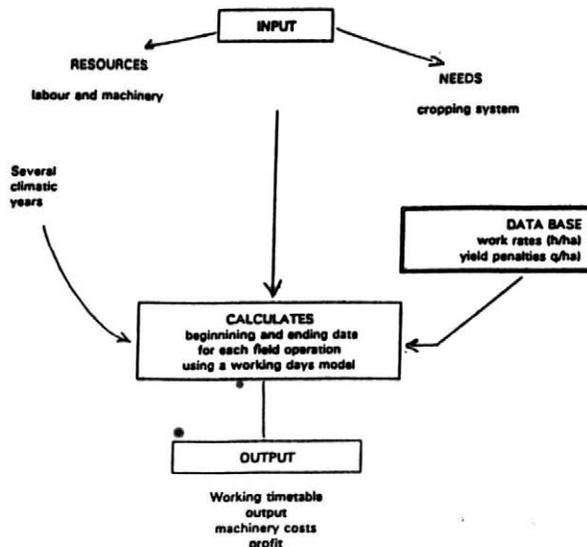
- grading lots of turkey carcasses on suspension chain by machine vision (Marty-Mahe, Marchal, Louveau).

In food processing, there are neural networks still used for simulating chemical batch reactors (Bourgine), and expert systems for the optimization of the wine alcoholic fermentation (Grenier). Back-propagation neural networks are suitable to solve the problems of quality sorting for different agricultural products, when no other statistical mean can be used, like:
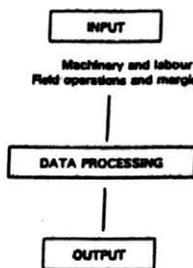- simulation of human judgement on pot plant quality, as artificial expert for quality evaluation (Brons, Rabatel, Sevila);
- grading of carrots (Wasserman), Florida grapefruit (Miller), pine seeding (Rigney and Kanzler), muskmelons, weed seeds, pork ham (Zhuang, Jia, Schinchol).

Many other types of sensors exist like a soil water sensing systems for automated irrigation developed in the USA where a microprocessor based control system monitors continuously the motion of irrigation machines (presented in the Conference Automated Agriculture for the 21st Century, ASAE - Chicago 1991).

For decision support systems, diagnosis on the working status of the tractor can be supervised and given more quickly thanks to an expert system (SCORPIO, which gives 70 % of good answers in 10 seconds). Agricultural chemical evaluation and management system (AGCHEMS) using a chemical transport model, a weather simulation model and a geographical information system has been presented in AG ENG 92 by Haan and Nofziger, from Oklahoma State University (USA). In economy, SIMEQ and GEDE give a good support to farm management (Figs 3, 4). But a lot exists already in many countries. Tab. II summarizes some potential applications of information technology.
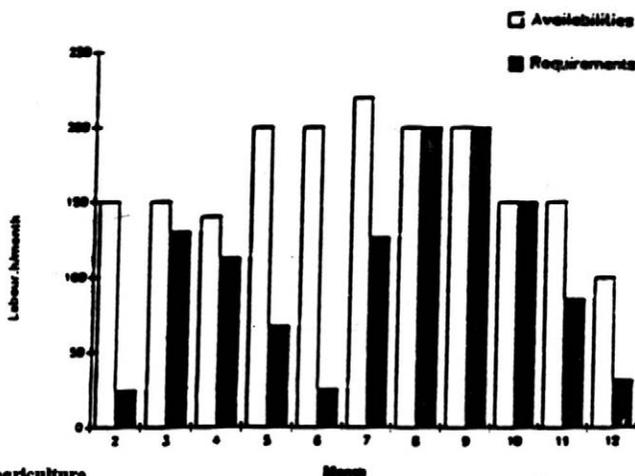

3. The process of SIMEQ

INPUT

Machinery and labour resources.
Field operations and margin for each crop.

|
DATA PROCESSING
|
OUTPUT

1 an optimal crop layout and ...

2... the existing restrictive resources

Sunflower (12%)
Peas (15%)
Oil seed rape (23%)
Wheat (50%)

4. GEDE, a computerized
farm model

☐ Availabilities
■ Requirements

Impact on agriculture

Apparently, up to the recent modifications of the common agricultural policy (CAP) in Europe, productivity - more than production - is still in the mood. It is true that the basic micro-economic justification, i.e. reduction of costs of production per unit, remains unchanged. ECCAEA has also shown how engineering research could bring some help in reducing input costs in a cereal crop (Tab. III). So, artificialization continues, and, like in industry, men are, more and more replaced by machines. But there are some limitations: pollutions, penetrating mainly from nitrates into the water table; excess of charges for the individual farmers who own their equipments, with more and more bankrupt; an excess of the migration of people from rural areas, mainly farmers, to the cities cause desertification in certain regions because the level of population is too low to maintain social equipments (shops, schools, post-office, etc.).

On pollution, certain countries like Holland or Germany have published severe regulations. As Uwe Riest from DLG presented it during the Symposium of the Club of Bologna in 1987, rules of environment-related farming were published in Germany, in 1985. Recommendations - and setting up of new investigations - focused on:

II. Potential application of I. T.

- computer to help farm management
    * cattle breeding
    * choice of cultivations
    * diagnosis on illness of animals ... or farm economy
- telematic
    * information on
        ● market prices
        ● weather
        ● advise from tech. centers
    * relations between farmers
- on-board computers and electronics (machines - buildings)
    * tractor/tools supervision
    * site specific fertilizing
    * growth of trees/irrigation (pepista)
    * quality of air in buildings
- robots
    * milking (time constraint)
    * fruit picking (cost/lack of manpower)
    * green house (health)
    * forest felling (drudgery of work)
    * ploughing (night work)

III. Enegineering research and estimated potential input cost reductions for cereals

Operation or materials	Estimated cost (4) ECU/ha (includes labour)	Potential saving in cost of operation %	Reduced cost ECU/ha
Cultivations	120	50 (1)	60
Drilling and fertilizer applications	60	25 (1)	45
Fertilizers	140	-	140
Seed	70	-	70
Spraying	50	10 (2)	45
Sprays	130	25 (2)	95
Harvesting and handling	170	50 (1)	85
Drying	110	5 (3)	105
Total cost	850		645

Total estimated reduction in input costs 25 %
(1) From Pellizzi G. et al.
(2) From AFRC Engineering Project Review, Miller P. C. H.
(3) Estimate Bruce D. M., AFRC Engineering.
(4) Calculated from data in Nix J., Farm Management Pocket Book (1988)

- treatment of manure (drying, aeration, fermentation, separation of ingredients)
- application of manure with special implements (right manner, time and amount), far from biotops and open water surfaces.

A storage capacity adapted to winter months and treatment to reduce odour emission and agressive compounds was required for slurry. Application in accordance with plant growing (specially those with roots close to the surface), in small rates, eventually at sub-surface level, could reduce use of mineral fertilizers.

Odours - especially from intensive pig and poultry production - near urban or touristic areas have to be drastically reduced. Once again, testing and research for new machines are needed, present machinery available for organic fertilizing is not precise enough. This sector is rather obsolete if compared to the modern sprayers used for pesticide. It is expected, in the coming information age, that prophylactic applications of agricultural chemicals will cease, at the benefit of actual location and real-time application of pesticides, with more and more integrated pest control systems (biological etc.).

Will there still be sprayers in 2010? The company Rhône-Poulenc announces that a new concept of fungicide for wheat by wrapping the seed protects the plant from stem and leaves diseases. The estimated turnover is 200 millions US$/year. The group will sell directly treated seeds, no chemicals, resulting in a major impact on environnement. Also in the Symposium of Bologna, Dr. R. E. Phillips (Pennsylvania State University) states that for the next few years, there will be a resurgence in demand for machinery designed for the smaller scale farming. Presently over 60 % of the net farm family income in the USA is from off-farm sources.

Farmers, to reduce their risk will be handling multiple small enterprises instead of a single larger one. Part-time farming will require more equipment reliability. Many of the control functions on machinery will have to be computer controlled. As farmer will not have time to learn how to use it, the computer will have to collect by itself the information needed for decisions, using preset artificial intelligence to list operations to be done to minimize risk and maximize farm profits.

New orientations

Agricultural Engineering Research has some good prospects in front of it. More and more, engineering becomes a joint venture between countries both for common research projects, and for funding the research. As far as farming systems are concerned, the major trend is a better adaptation of inputs to the exact needs of plants and animals. Sensors and softwares to help decision making will equip both tractors, machines (Fig. 5) and equipments inside building (e.g. overall conception for pig management systems Fig. 6).

Now research and policy makers insist more on sustainable agriculture and extensification of production (i.e. trying not to obtain the maximum potential yield of a field, but
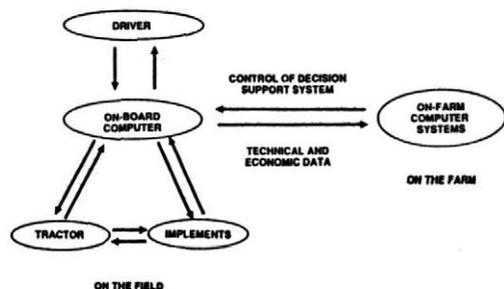
5. Sensors and softwares to help decision making will equip both tractors, machines

a determined value - 80 or 85 % for example). The main objective is to reduce pollution and restrain the degree of artificialisation that producers have developed over centuries. A new engineering could have as an objective to speed up the come-back to more nature. Can we call it „ecological engineering"? (Fig. 7).

This is also a new job for rural areas, where specialists will also take more care about landscape. In certain countries, a positive reconstruction of hedges around fields has been
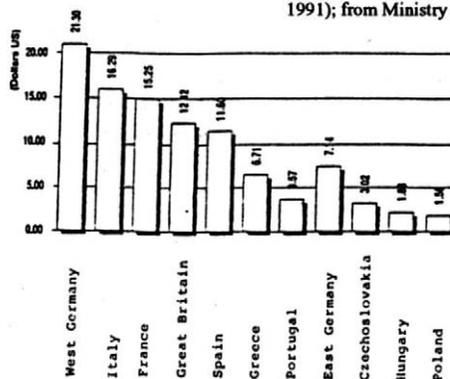
6. An overall conception for pig management systems
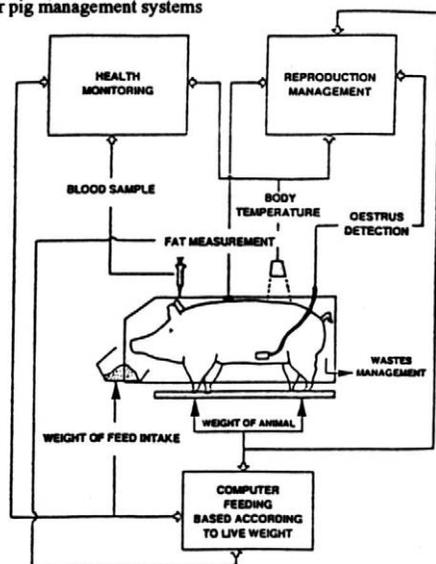
7. Ecological engineering
(D u n g l a s, B l a n - d i n, 1991)
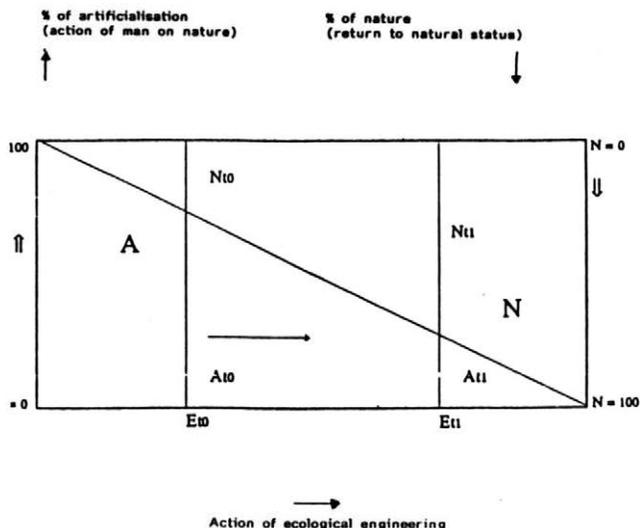
Action of ecological engineering
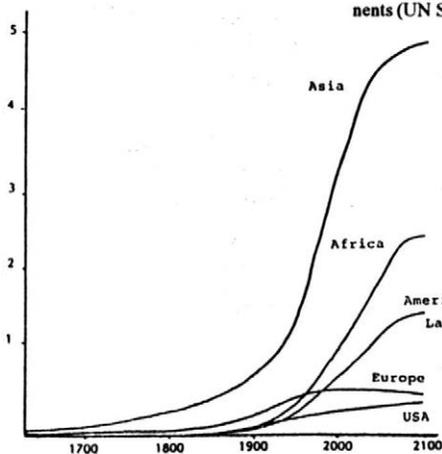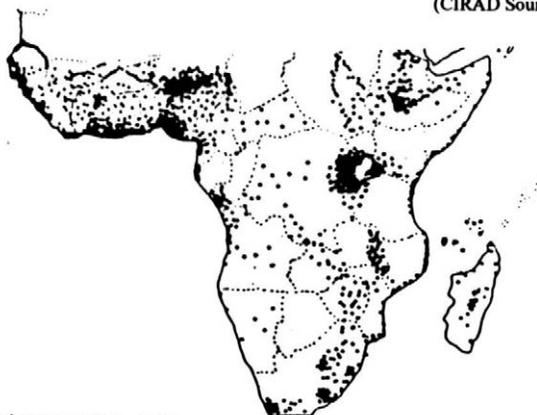
started to recover all benefits for game, limitation of floods in river basins, less monotonous landscape, etc. These new tendencies will spread in the European Community where one European out of 3 is living in a rural zone, representing 85 % of the EC territory, and where only one European out of 12 is a farmer.

If new common agricultural policy (CAP) consists in reduction of food production, two new areas are necessarily opened to support farmers : new crop varieties of high quality to satisfy changes in consumer needs towards new tastes, flavours and luxury meals (this part could represent 15 % of the total food market), and, on the second hand, crops for nonfood use.

For non-food products, a necessary reduction of costs for the production, and a regular quantity and quality will be needed for industrial users. Among the possible scenarios, robotisation and automatisation are one, another could be employement of temporary workers coming from countries having a very low level of salary (Fig. 8).

Thinking about food production, one cannot ignore the dramatic problem of less developed countries, where a quick demographic inflation (Fig. 9) make the food problems more acute. This is emphasized by the concentration of people in urban areas (Fig. 10) which introduces changes in the processing of products, to better adapt them to urban needs. This is a world challenge, and a particular role should be played by production equipment, rather than by the delivery of excess of cereals produced in Europe or USA, not always corresponding to the consumer's habits of local people, and only needed in urgency situations.

In all countries around the world, agricultural producers have to take a greater participation into the processing of their own production (high quality, locally labelled food) and into the maintenance of the rural area they are living in. New professional needs, and special training of engineers, technicians and farmers are also changes likely to occur, not only in agriculture, but also in the rural society, in the next years.

Recent advances in research about artificial life show that already, for certain risky or drudgery works and, at a longer term, for routine tasks, artificial operators will act instead of human beings.

Fortunately, they will not need the same type of food. But, by the way, what are men going to do? Like many other sectors, intellectual tasks - decisional in particular - will replace manual ones. It seems to be perfectly in line with the general evolution of mankind.

References

BONNY, S. - DAUCE, P.: Cahiers d'économie et sociologie rurales. Les nouvelles technologies en agriculture - une approche technique et économique, INRA, ENSAA, 1989, No. 13.
Automat. Agric. 21st Century. Proc. Symp. Chicago, Illinois, Amer. Soc. Agric. Engr., 16-17 December 1991.
Europ. Club Advanc. Engng Agric. Minut. 3rd Techn. Rev. Inform. Technol. Braunschweig (Germany).
Int. Conf. Agric. Engng, Uppsala, Sweed. Inst. Agric. Engng, 1-4 June 1992.
Simp. Int. sulle Mechaniz. Agric., Ricerca a divulgazione per l'innovazione nel sistema agroindustriale del 2000, XVIII EIMA Bologna, Novembre 1987.

Ve srovnání s průmyslem má vznik a zavedení inovací v zemědělství svá specifika, která mají své kořeny ve struktuře zemědělství. Ačkoliv inovace bývají často spojovány mezi sebou navzájem, jejich analýza potřebuje spíše široký systémový přístup, který zvažuje vztahy mezi vědou, technologiemi a socioekonomií. V období 1950 až 1980 měly nové technologie za cíl růst hektarových výnosů a produktivity práce bez ohledu na velká rizika s tím spojená. Dosažené úspěchy přinesly přebytek produktů, poškození přírody a sociální a geografické rozdíly. Nyní přicházejí dvě hlavní skupiny nových technologií: biotechnologie a informační technologie, obě mají velké možnosti řešit uvedené problémy nebo je přinejmenším stabilizovat. Velká většina vstupujících technologií a techniky bude potřebovat mnohem inteligentnější prostředky, než jakými jsou jednoduché návody pro zemědělce. Musí proběhnout mnoho výzkumů pro zhodnocení dopadů těchto technologií na velikost farem, jejich strukturu, zemědělské zvyklosti a postupy, společné využívání zařízení apod. Nové technologie se dotýkají nejen zemědělství, ale také venkovských aktivit, jako jsou krajina, kvalita života vesnického obyvatelstva: vzduch, voda, hluk apod.

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Manuscript layout shall correspond to the State Standard ČSN 88 0220 (quarto, 30 lines per page, 60 strokes per line, double-spaced typescript). Tables, figures and photos shall be enclosed separately, not on paste-board. A figure or graph number shall be written on the reverse, along with the author's name. Texts to figures and graphs shall be indicated on a separate sheet. Tables shall be given Roman numerals. The text must contain references to all these annexes.

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The author's names are given without academic degrees, first names are given as abbreviations.

Summary - a brief one

The summary is an information selection of the contents and conclusions of the paper, it is not a mere description of the paper. It must present all substantial information contained in the paper, but its role is not to replace this paper. It shall not exceed 170 words. It shall be written in full sentences, not in form of keynotes. It is published in the language the paper is written in, it should comprise base numerical data including statistical data.

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This summary is a basis of English translation, it should contain comments on the results of the study, references to tables and figures, or to the most important literary citations. Its extent shall be two to three typescript pages. It may be submitted in English, if it is submitted in Czech or Slovak, an annexed English vocabulary of technical and agricultural terms will be appreciated.

Key words, index terms

They follow after the brief and longer summary on the next but one line (both summaries shall have the same keywords). A key word (index term) is a noun which is necessary for subject classification of the paper. The order of key words is from common to concrete concepts. The first word is written in small letter, semicolons shall be used between these words. Their number depends on the subject-matter of the paper, it should not be smaller than three and higher than 12 words.

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This section has to present the main reasons why the study was conducted, and the circumstances of the studied problems should be described in a very brief form. Extensive historical reviews should be avoided. It does not have a title. If the paper does not include the section Review of Literature, literary citations referring to the treated problem should be given in this introductory section.

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References

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