Paper No. 98 1034
An ASAE Meeting Presentation

Analytical and Modelling Deduction of Requirements on Tractor Concepts for Cultivation and Application Purposes

by

Demmel M., Auernhammer H.
Institut für Landtechnik, Technische Universität München
85350 Freising-Weihenstephan, Germany

Written for Presentation at the
1998 ASAE Annual International Meeting
Sponsored by ASAE

Disney´s Coronado Springs Resort
Orlando, Florida
July 12-16, 1988

Summary:

Based on changing conditions for tractor utilization the requirements on tractor concepts for cultivation and application purposes are deducted. From the data of a survey on utilization the special use and implement parameters were ascertained. They were the basis for putting together a specification list. In a model examination alternative tractor concepts were defined and assessed, using a multi attribute utility technique, on the fullfiment of requirements. It showed that specialized light load carriers have significant advantages compared to standard and system tractors.

Keywords:

Tractor concepts, tractor utilization, cultivation, application.

ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659 USA
Voice: 616.429.0300 FAX: 616429.3852 E-Mail: <hq@asae.org>

Analytical and modelling deduction of requirements on tractor conceptions for application and cultivation purposes

Demmel, M. Auernhammer, H.
Institut fuer Landtechnik - Technische Universitaet Muenchen
Am Staudengarten 2, D-85350 Freising-Weihenstephan, Germany

1. Introduction

Western European and especially German farm mechanisation is caracterized by very high tractor engine performance per acreage and per agricultural enterprise. The reasons for this are found in the historical development of mechanisation and the structures with small farms with an average acreage of 35 ha (before reunificaion in 1990 18 ha).

But the structures are changing, not only by the reunification, the process started in the 60th and speeded up more and more during the last decade with deregulation in the EC and GAT developments.

Therefore farm mechanisation also has and will change to follow the needs of the changing agriculture. As the tractor is the key machine on the farm he is most involved in such a process.Therefore at many German agricultural institutions a discussion on the needed tractor technology, especially on the necessary tractor conceptions is held from time to time and was renewed at the end of the 80th and the beginning 90th.

In this discussion the major question was if special tractor conceptions will follow universal used standard tractors, which can be produced cheaper, because of their advantages of the exclusive design for a special purpose. The development of tractor conceptions until now has been the following (figure 1)

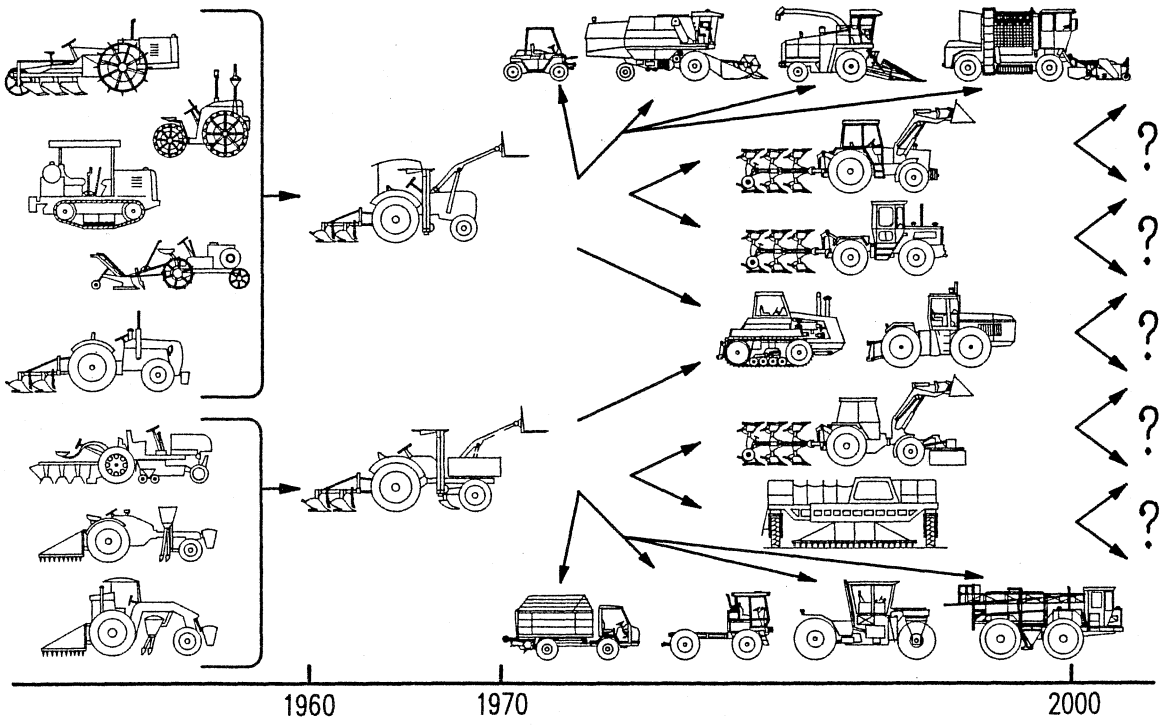


Figure 1: Tractor conceptions in a historic view.

While the first motorized agricultural machines have been specialized systems for tillage or mowing, universal used standard tractors or tool carriers followed in the 60th and 70th. Then a new time of diversification followed with the mechanical front wheel drive and additional trac-tractors on the tractor side and the development of self propelled machines on the other side.

More and more self propelled machines took over the tasks of tractor-implement combinations especially in harvesting. This process is finished for the combine harvester, for the chopper and also for the sugar beet harvester. Also in loading and transport this development is on the way.

On the other hand the development of the universal used tractors showed increasing horsepowers and a specialisation for heavy pull type work. New engine and transmision technology and improvements on draft and slip control and the four wheel drive management are some examples.

Looking on the described developments a question for future tractor construction will be how cultivation and application tasks will be fulfilled in future. The investigation presented in the following therefore has two main topics:

1. Which requirements have cultivation and application tasks on tractors
2. How should optimized tractor conceptions for cultivation and application purposes be designed.

2. Material and Method

A list of requirements is the basic for tractor design. The different factors of influences on tractor conceptions is shown in figure 2:

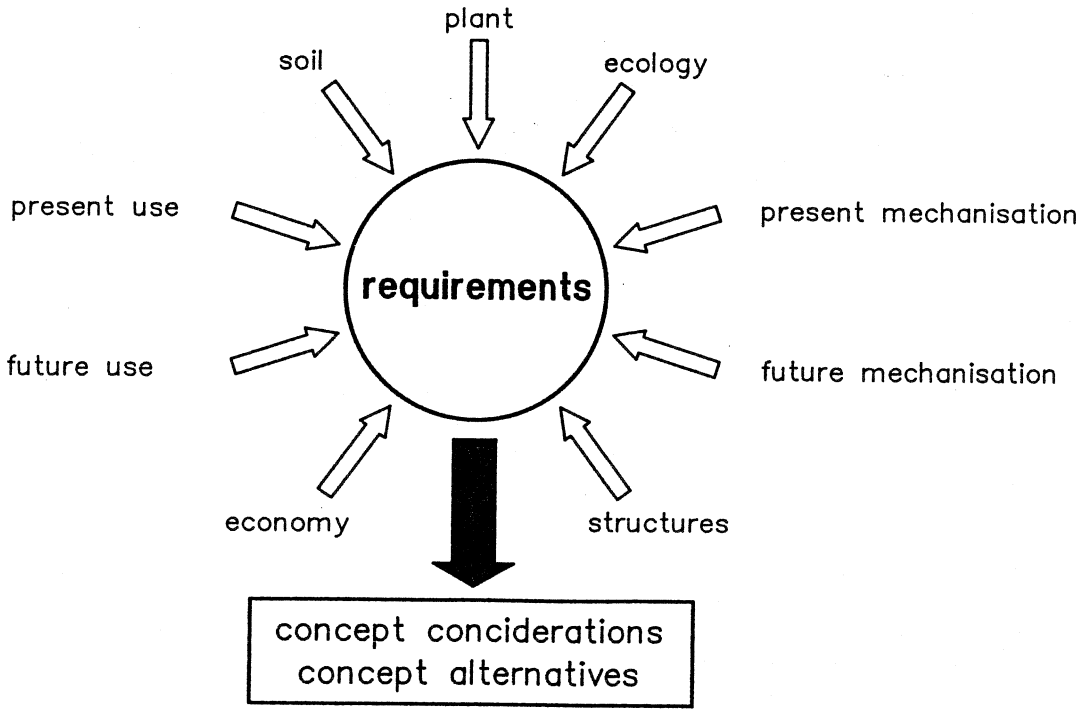


Figure 2: Factors influencing the requirements on tractor conceptions

The influences come from the agricultural structur, from the plants, from the soil, from economy, from ecology and from the present and future production technology as well as from the present and future use of the implements.

Based on publications and on analyses on the official data on the development of the German agriculture the influence of the fast changing strukture with the changes of machinery use could be derived. Very impressive is the fast growing of the farms and and their high specialization which surpasses one's wildest hopes (table1).

Table 1: Development of farms in the agriculture of the Federal Republic of Germany (Germany in boarders of 1989, projections by NEANDER 1986).

	statistics			projection (by NEANDER 1986)	
	1971	1983	1990	1990	2000
basic data:					
agricultural acreage	12.7 Mio ha	12.0 Mio ha	11.8 Mio ha	11.7 Mio ha	11.3 Mio ha
number of farms	1 160 000	768 000	667 000	683 000	558 000
acreage per farm	11.0 ha	15.3 ha	17.7 ha	17 ha	20 ha
acreage per full-job farm	17.4 ha	24.7 ha	28.1 ha	28 ha	34 ha
share of: **priority farm** (50% and more of the margin of the enterprise out of one production segment)	**78.5 %**	**92.0 %**	**94.9 %**	**95 %**	**97 %**
share of: **special farms** (75% and more of the margin of the enterprise out of one production segment)	**29.1 %**	**51.2 %**	**63.5 %**	**60 %**	**67 %**

The requirements of the plants, of the soil, of the future production technology, of future use of machinery and of future mechanisation were also deduced by the analyses of publications.

The present use of tractors and implements and their demands were derived from two surveys hat have been made, the "Großschleppererhebung" in 1980 (474 farms, avg. acreage 100 ha) and the "Pflegeschleppererhebung" in 1989 (577 farms, avg. acreage 91 ha) (table 2).

Table 2: Surveys on the tractor use in Germany.

data type of the survey	"large tractor-survey" Weihenstephan	"tractor-survey" FAL-OLFE	"cultivation tractor-survey" Weihenstephan
year of survey	1980	1980	1989
number of participating farms	478	1978	577
avg. agricultural acreage	100 ha	54 ha	91 ha
total number of tractors in survey	971	5097	1922
avg. number of tractors / farm	2.0	2.6	3.3
avg. engine power / tractor	72 kW	44 kW	60 kW
avg. engine power / 100 ha acreage	148 kW	216 kW	222 kW
avg. tractor hours / year	523 h	350 h	432 h

Based on the list of requirements five alternative tractor models were defined and rated using a multi attribute utlity technique. It is able to value effects of different dimensions as well as only qualitativ judgements. Beside the fact that only alternative planings or solutions can be compared, the weight of the aims of judgement is a basic element. It makes a final comprehensive evaluation possible.

Final calculations based on the main parameters like farm type, farm size, working capacities, soil and climate, should show, what acreage is needed to reach an effective use of the favourite conception, first time now also under the conditions of the eastern countries of Germany

3. Requirements of implements for cultivation and application purposes

The analyses of the data of the machinery use for cultivation and application work showed, that very productive implements are used for this purposes (table 3).

Table 3: Working width, working speed and container/tank capacity of implements for cultivation and application purposes ("Pflegeschleppererhebung" 1989).

implement	number	working width average, (stddev.) m	working speed average, (stddev.) km/h	container/tank volume average, (stddev) kg
drill, air-seeder	179	**3.3** (1.1)	**8.9** (19)	**370** (210)
planter sugar beet	282	**3.7** (0.4)	**5.7** (1.0)	---
planter corn	180	**3.1** (0.5)	**6.6** (1.2)	**250** (120)
planter potatoes	109	**2.1** (0.8)	**5.4** (1.9)	**530** (420)
centrifugal spreader	514	**12.9** (2.7)	**9.5** (2.0)	**830** (320)
drawn spreader	75	**12.0** (4.5)	**9.4** (1.8)	**4610** (1280)
air spreader	92	**13.2** (3.9)	**9.0** (1.8)	**1460** (380)
3pt mounted sprayer	334	**11.8** (2.5)	**7.2** (1.5)	**695** (280)
platform sprayer	279	**14.2** (3.4)	**7.0** (1.2)	**1650** (410)
drawn sprayer	29	**16.5** (4.3)	**6.5** (1.4)	**2390** (610)
cultivator / hoe	317	**3.4** (1.1)	**5.9** (1.7)	**290** (60)

They are caracterized by high average working speeds, large average working width and high capacity containers or tanks which cause high demands on the used tractors. If the implements are three point linked, tractors with high lifting capacities are necessary to handle these machines.

If specialized tractor conceptions like the MBtrac, UNIMOG or FENDT tool carrier were available, in most cases they are used with platform mounted sprayers and spreaders to get high tank or container capacities distributed on both axles.

On the other hand, if three point mounted, this implements require tractors with a high lifting capacity that is normaly combined with high engine power and high tractor weight. Multiple regression calculations show this connection between three point mounted implements and engine power (figure 3).

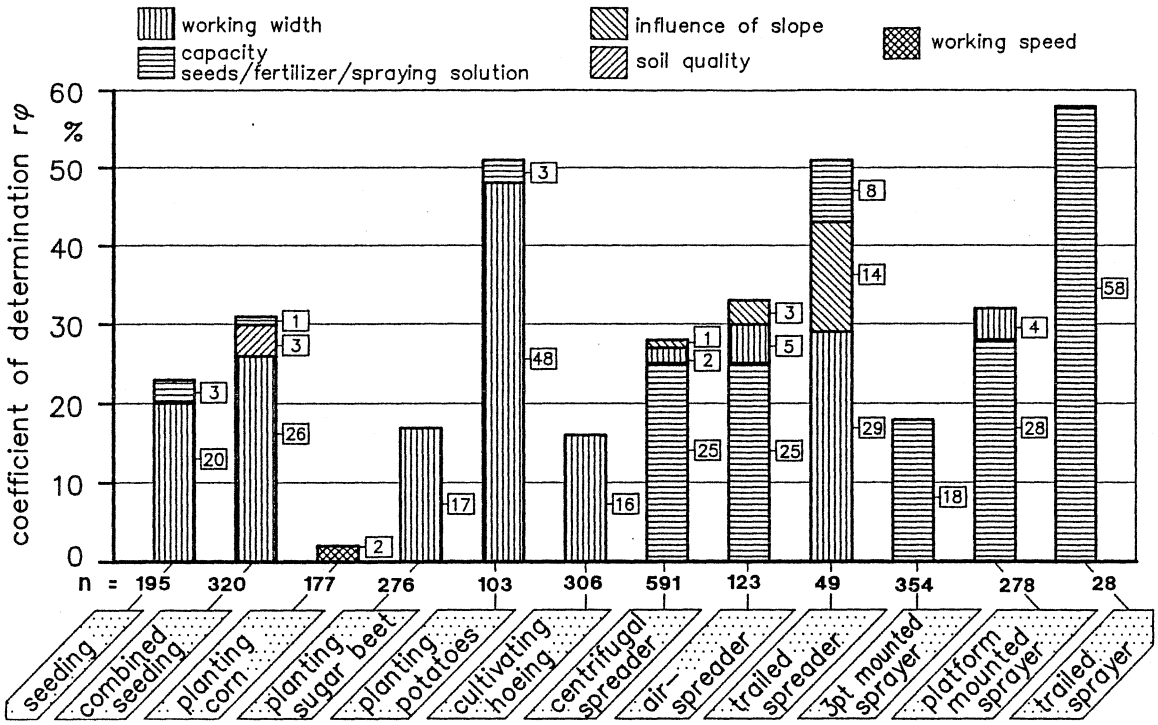


Figure 3: Influences of different parameters on the tractor engine power with implements for planting and cultivation

All the analysed parameters have influences on the main functions of a tractor (figure 4).

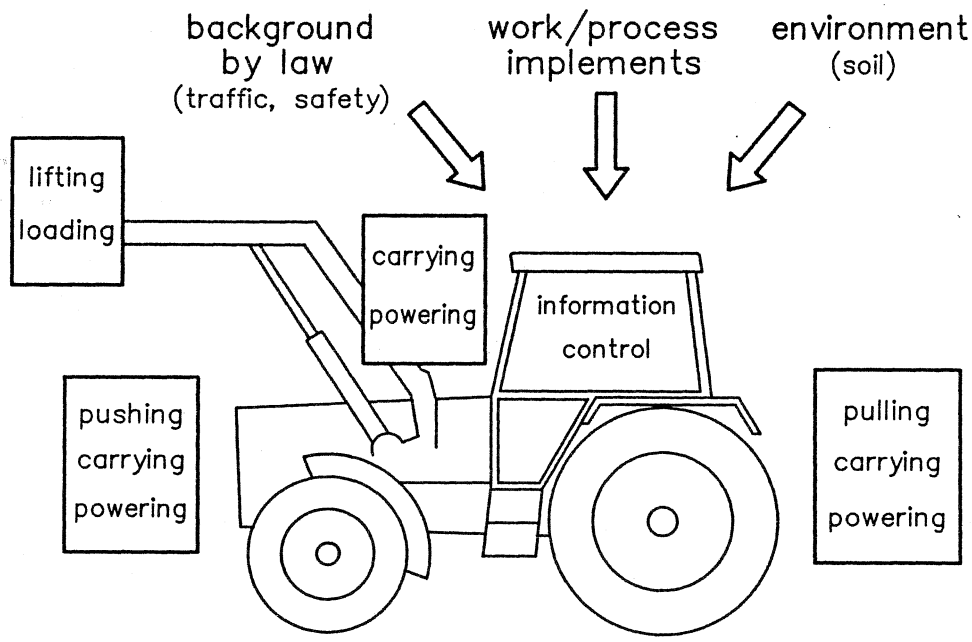


Figure 4: Main functions of an agricultural tractor.

The conditions of the mentioned applications with the different implements lead to the following requirements on the basic functions of a tractor conception for application and cultivation (table 5).

functions	requirements
pulling	driving in the field, heavy pulling not necessary
pushing	light pushing
carrying	carrying is main task
powering	small to medium power demand
lifting / loading	loading (front end loader) not necessary
information / control	man-machine interface tractor-implement interface

Table 4: Requirements on the functions of a tractor conception for application and cultivation.

Based on this list the requirements on the components of tractor conceptions for application and cultivation have been defined.

4. Design and rating of alternative tractor models

Based on the list of requirements five alternative trator models have been defined (figure 5).

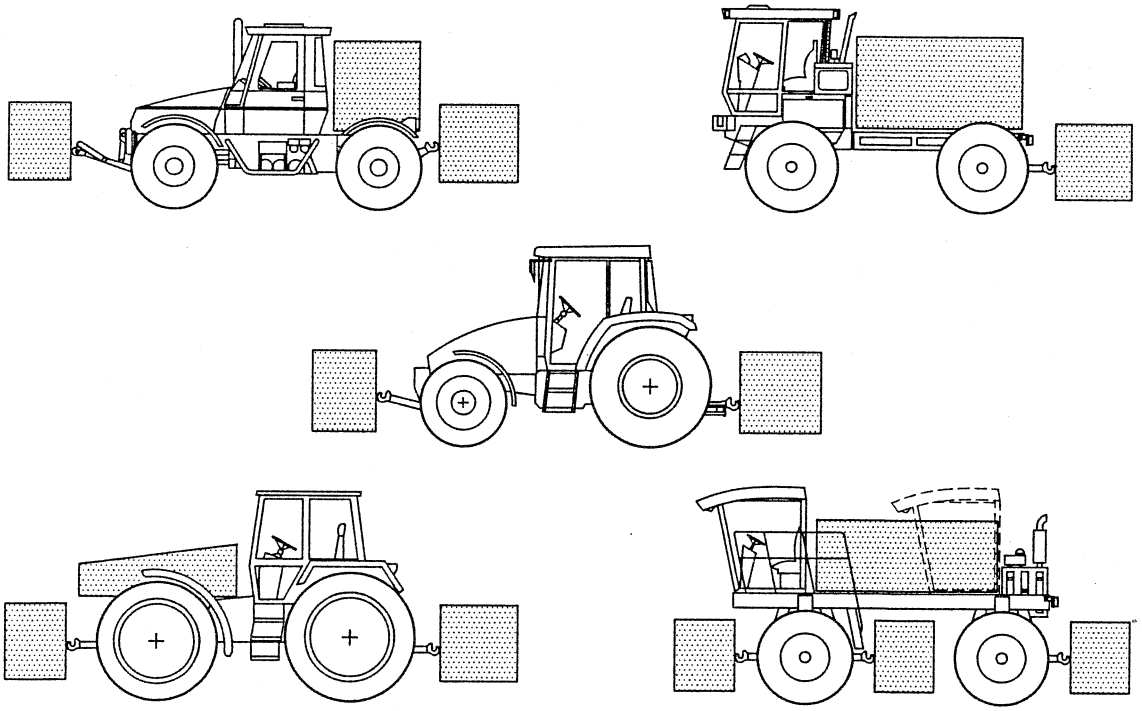


Figure 5: Alternative tractor models.

The first tractor is a standard row crop machine with a frame, mechanical front wheel drive and a mechanical continous variable transmission (CVT). The second corresponds with a "tool carrier" tractor (platform infront the cabine), with high clearance chassis and additional front wheel drive, CVT and continously variable PTO. The third model is a trac-tractor (with a platform behind the cabine) with a frame chassis, for wheel drive, and transmission / PTO like the tool carrier. The last two models are light load carriers to carry tanks or containers.

Their design is based on self propelled sprayers and spreaders like they are built in Great Britain and the USA. Both have hydrostatic transmissions. While load carrier I has only a rear three point linkage, load carrier II has also one in front and between front and rear axle. A turn- and shiftable cabine allows a superb sight on this positions. Hydraulic tread adjustment makes work in crops with different row spacings possible. Table 2 shows the technical data of these five models:

Table 5: Technical data of five tractor models for cultivation and application purposes.

features/ property	standard- tractor	tool- carrier	trac- tractor	load- carrier I	load- carrier II
construction	frame	block	frame	frame	frame
engine rating	90 kW	90 kW	90 kW	90 kW	90 kW
driving	mfwd	mfwd	4wd	4wd	4wd
transmission	cvt mechanical	cvt mechanical	cvt mechanical	cvt hydrostatic	cvt hydrostatic
steering	2w (front	2w (front)	2w / 4w	2w / 4w	2w / 4w
power take off	front/rear	front/rear	front/rear	front/ platform	front/raer/ between axles-/ platform
pto rating	full engine 540/750/1000	full engine cvt mech.	full engine cvt mech.	20 kW cvt hydr.	20 kW cvt hydr.
empty weight	5000 kg	5200 kg	6200 kg	3500 kg	4000 kg
load	3600 kg	2300/3800 kg	2800 kg	4000 kg	4000/6000 kg
tread settings	150/180/200 cm	150/180/200 cm	180/200 cm	180/200/225 cm	225-300 cm
clearence	40 cm	70 cm	40 cm	80 cm	120 cm
speed	40 km/h	40 km/h	40/60/80 km/h	20/40 km/h	20/40 km/h

With a multi attribute utility technique these alternative tractor models were compared. The weight of the factors of valuation, which have been the requirements of functions and components, was defined according to their value for cultivation and application works (table 6 and table 7).

Table 6: Evaluation of the fulfillment of the requirements on functions of tractor conceptions for cultivation and application tasks with multi attribute utility technique.

functions	weight of factors	evaluation of tractor models *				
		standard- tractor	tool- carrier	trac- tractor	load- carrier I	load- carrier II
pulling	10 %	5	5	5	3	3
pushing	5 %	4	4	4	1	3
carrying	50 %	2	3	3	5	5
power take off	15 %	3	4	4	3	3
lifting / loading	0 %	4	4	4	1	1
information	10 %	3	4	3	2	4
control	10 %	1	3	3	4	4
final evaluation	**100 %**	**2.6**	**3.5**	**3.4**	**3.9**	**4.2**

* 5 = very well, 4 = well, 3 = sufficient, 2 = deficient, 1 = not fulfilled

Table 7: Evaluation of the fulfillment of the rquirements on components of tractor conceptions for cultivation and application tasks with multi attribute utility technique

functions	weight of factors	evaluation of tractor models *				
		standard-tractor	tool-carrier	trac-tractor	load-carrier I	load-carrier II
engine	5 %	5	5	5	5	5
drive/transmission	12 %	5	5	5	5	5
undercarriage	16 %	2	3	4	4	5
pto	10 %	2	3	4	4	4
hydraulics	5 %	4	4	4	4	4
implement carrying	20 %	2	4	3	3	5
electrics /electronics	8 %	3	4	4	4	4
cabin	6 %	4	4	4	4	5
measure /weight	18 %	2	2	5	5	4
final evaluation	**100 %**	**2.8**	**3.6**	**3.6**	**4.2**	**4.6**

* 5 = very well, 4 = well, 3 = sufficient, 2 = deficient, 1 = not fulfilled.

The final evaluation showed, that the light load carriers have the highest qualification for this purposes.

5. Calculations of the needed acreage for a optimized use of a light load carrier

The final calculations showed, that the light load carriers with application or/and cultivation implements have to work large acreage to reach utilizations of 500, 750 or 1000 h/a (table 8).

Table 8: Necessary acreage for the use of a load carrier tractor conception for cultivation and application tasks.

cases of use	necessary acreage for annual use of		
	500 h/a ha	750 h/a ha	1000 h/a ha
application mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF)	460 / 830	690 / 1 240	920 / 1 640
application mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF) + planting (25 % AF)	410 / 670	620 / 1 000	820 / 1 330
application mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF) + planting (25 % AF) + cultivating / hoeing (2x 25 % AF)	340 / 600	510 / 900	680 / 1 200
application mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF) + slurry to grain (50 % AF)	390 / 670	590 / 1 010	790 / 1 350
application mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF) + planting (25 % AF) + slurry grain (50 % AF) + corn (25 % AF)	310 / 510	470 / 770	620 / 1 030
qpplication mineral fertilizer (2x) + pesticides (3x) + seeding (75 % AF) + planting (25 % AF) + slurry grain (50 % AF) + corn (25 % AF) + cultivating / hoeing (25 % AF)	290 / 470	430 / 710	580 / 950

Depending on the conditions of the use (smaller acreage = bad conditions in a machinery ring or of a contractor with a lot of driving on the road / higher acreage = good conditions on large farms with nearby fields) and the different types and combinations of tasks acreages between 290 ha and 1640 ha are necessary to reach the mentioned machine hours per year.

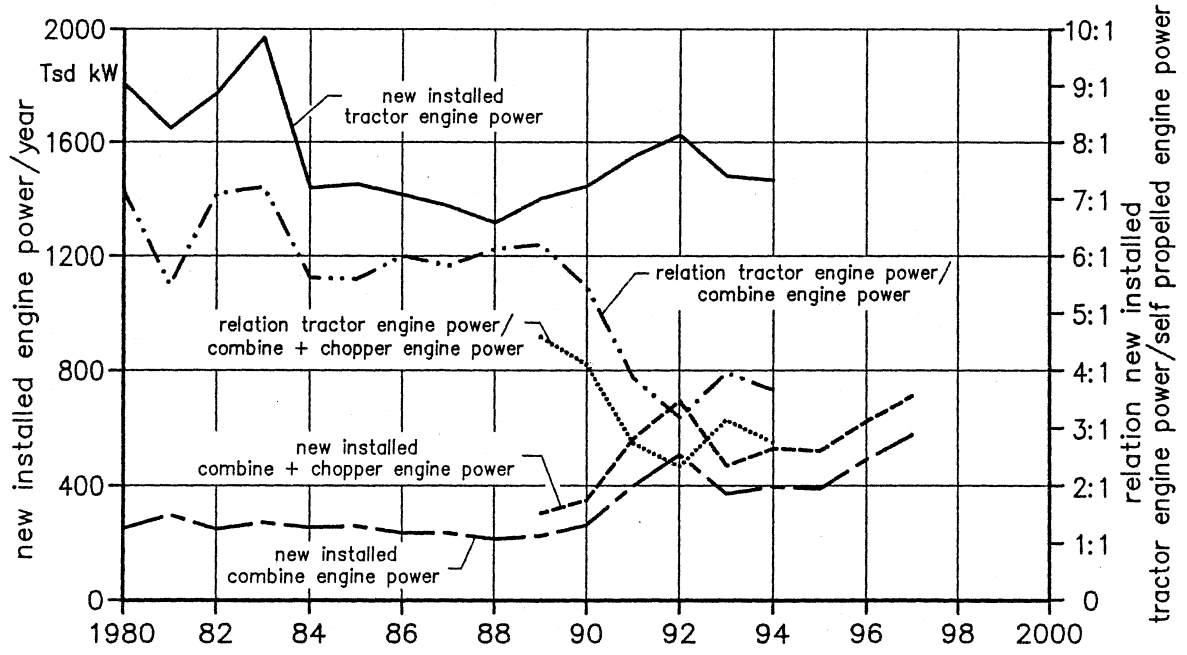
6. Conclusions

The detailed analysis of tractor and implement use for cultivation and application purpose on 577 farms have showed, that the used equipment is very productive and specialized and puts high demands on tractors.

The rating of the alternative tractor models by a multi attribute utility technique also showed, that specialized conceptions like light load carriers fulfill these high demands better than the universal usable systems.

To get a sufficient use of the capacity of the self propelled machines for cultivation and application purposes large farms or comparable methods of organisation like it is found with contractors or machinery rings is necessary.

Such structures require specialized productive and therefore self propelled machines. For harvesting self propelled equipment is the accepted and prefered technology today. Therefore a lot of tractor - implement combinations lost a significant part of their work (figure 6).



source: Stat. Jahrbuch über Ernährung, Landwirtschaft und Forsten, LAV, Mitteilungen des Kraftfahrtbundesamtes

Figure 6: New installed engine power of tractors and self propelled combine harvesters and forage choppers

During the last 20 years the every year newly installed engine power of tractors decreased more than the engine power of self propelled combines and choppers. Therefore the ratio between both decreased from 7:1 to about 3:1.

There is no reason why this development won't become reality also for other self propelled machines. Unfortunatelly the development of the numbers and engine power of self propelled sugar beet harvesters, loaders, fork-lifts, telescopic handlers, spreaders, sprayers and trucks are not registered, eighter by the authoroties nor by the Landmaschinen Vereinigung LAV (German pendant to EMI).

From the results of the presented investigation it seems clear that in futur in German agriculture a increasing number of self propelled equipment will be used also for cultivation and application purposes. The question that cannot be answered is if the conceptions used will be "multi purpose light load carriers" or highly specialized single purpose sprayers, spreaders etc. May be that there will be a combination of "multi purpose light load carriers" used as "single purpose machines" never changing the implements in their life.

7. References

Demmel, M.(1997): Analytische und modellhafte Ableitung der Anforderungen an Schlepperkonzepte für Pflege- und Verteilarbeiten. Forschungsbericht Agrartechnik 309. Dissertation, Institut fuer Landtechnik der TUM, Freising - Weihenstaphan.

Demmel, M. und H. Auernhammer (1997): Spezialisten oder Alleskoenner. Anforderungen an Traktorkonzepte fuer Pflege- und Verteilarbeiten. Landtechnik 52, Heft 5, Seite 237-239.