# Precision Farming

*- From Beginning to Eco-friendly Land Use Systems -*

Prof. i.R. Dr. H. Auernhammer
TUM Emeritus of Excellence

Online-Presentation „Dürnast Smart Farming Seminar “

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# Precision Farming

Several definitions in literature and daily discussions

*In my mind:*

**Precision Farming aims to tailor everything even more precisely to the individual requirements of plant and animal performance, health, wellbeing and the environment**

*Today I'd like to talk about the technology of Precision Farming with:*

- Technical initial points
- Yield measurement
- Planting
- Application Technology
- Transborder Farming

and I'd like to end with the IKB-Dürnast project

# „Technical Initial Point 1“ (Weihenstephan)

**1974 - 1986: SFB 141** *Collaborative Research Project*

***„Production techniques in cattle farming“***

**Beside other topics in dairying four key technologies investigated:**

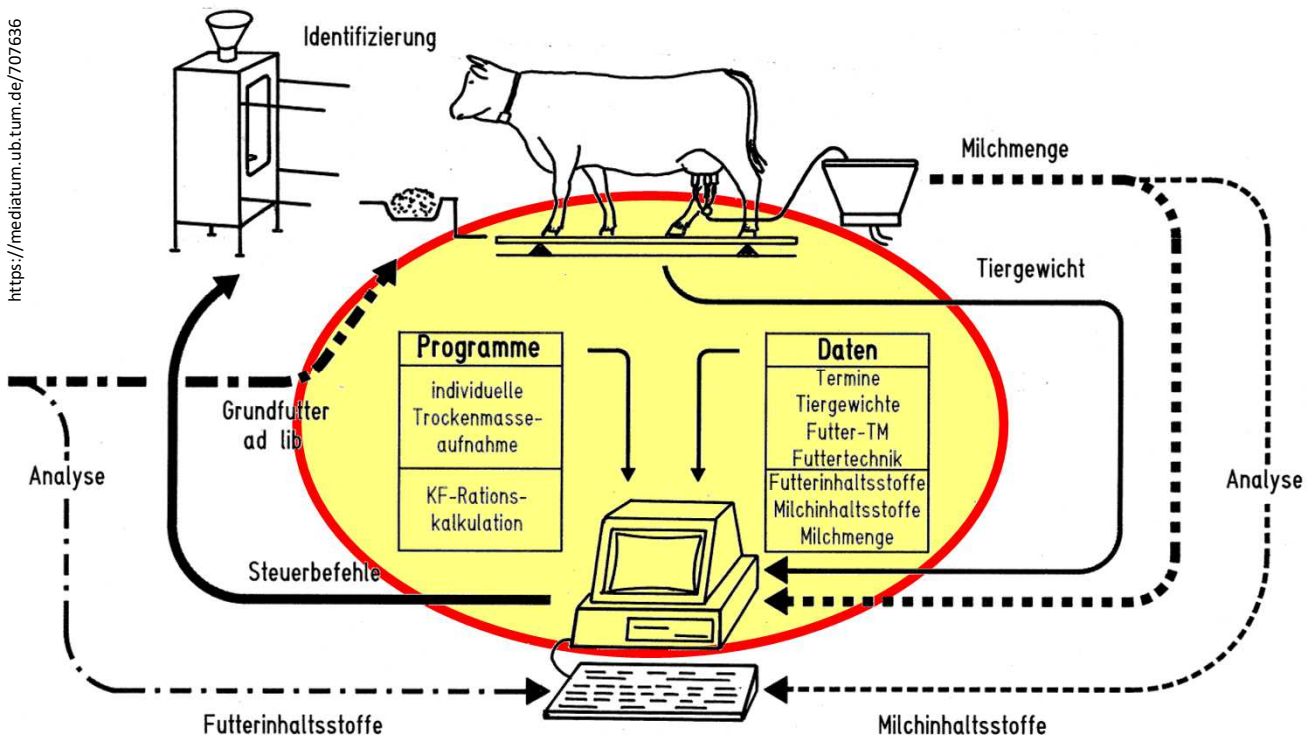
- *RFID animal identification*
- *Concentrate feed dispenser*
- *Individual milk quantity measurement (weight, volume)*
- *Individual animal weight detection (pass-trough scale)*

With this new technologies an energetic **animal-specific control loop** becomes possible, as:

**Animal weight will be stable, when (simplified):**

$$E_{\text{Basic feed (Estimate function)}} + E_{\text{Concentrate feed (1 kg = 2 l Milk)}} - E_{\text{Milk amount (measured)}} = 0$$

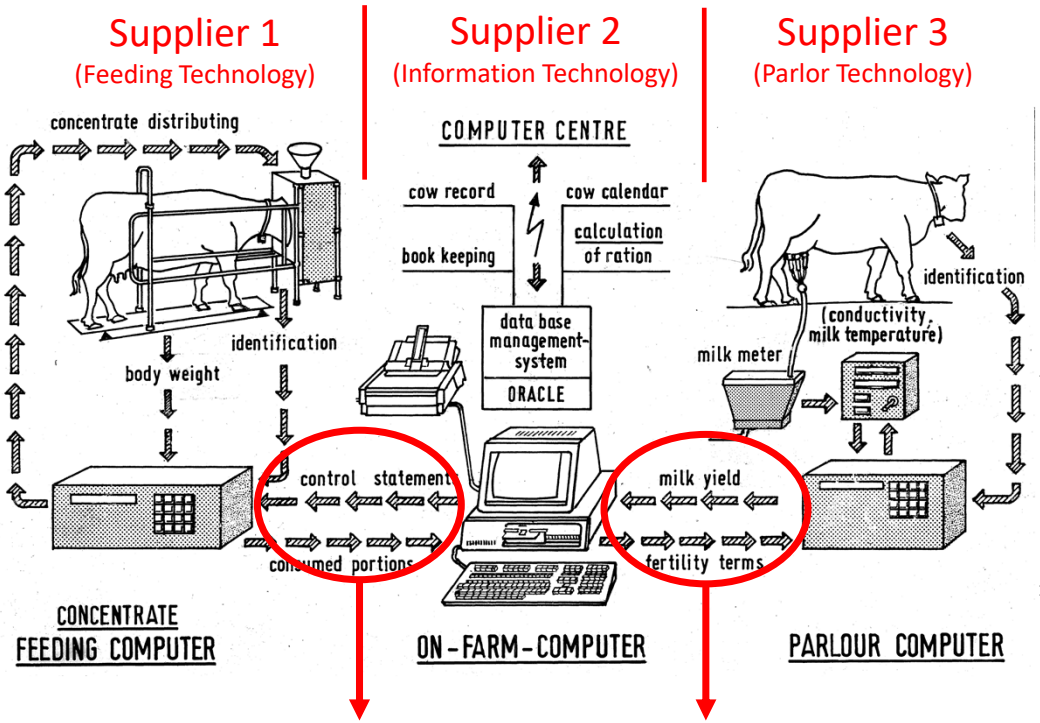
# Dairying becomes „Precision Lifestock Farming“




**2. April 1984:** For the first time a daily report per cow is generated automatically
(MS-DOS, ORACLE, proprietary interfaces)

Source: Auernhammer, H., Wendl, G. (1987): Experiences with data handling in micro computer based herd management systems. In: Proceedings of the third Symposium "Automation in Dairying", Wageningen: IMAG, pp. 331-337

# „Precision Lifestock Farming“ at Farm Level




https://mediatum.ub.tum.de/1439124

!!! Company (supplier) independence only with a standardized communication system !!!

**Standardization attempt:** "Electronic indoor communication" 1984 - 1986 failed, standard still not available today!

Leistungsdaten der Herde mit 47 Kühen an 6. 2.1986

| Kuh-nr. | Milchmenge (kg) g-abends | morgens | Tag | Mittelwert | Abweich | Jahres-kg | Kraftfutterverbrauch (kg) Sorte 1 | | | Sorte2 | | Besam. datum | Kalb-datum | Lakt-tage | Kode |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.1 | 7.5 | 14.6 | 14.9 (6) | -0.3 | 698.9 | ( 2.4) | 2.5 | 240.1 | ( 0.8) | 0.8 | 37.9 | 23. 1.86 | 10.11.85 | 88 | 7 |
| 2 | 3.5 | 3.9 | 7.4 | 7.1 (5) | 0.3 | 812.5 | ( 0.0) | 0.0 | 130.7 | ( 0.0) | 0.0 | 18.5 | 1.10.85 | 17. 8.85 | 173 | 7 |
| 3 | 10.5 | 11.3 | 21.8 | 21.2 (5) | 0.6 | 587.3 | ( 5.0) | 5.0 | 121.4 | ( 0.8) | 0.8 | 18.8 | 0. 0. 0 | 7.12.85 | 61 | 7 |
| 4 | 4.7 | 0.0 | 4.7 | 6.9 (4) | 0.0 | 1062.3 | ( 0.0) | 0.0 | 146.0 | ( 0.0) | 0.0 | 18.5 | 20. 6.85 | 5. 5.85 | 277 | 7 |
| 5 | 7.7 | 9.3 | 17.0 | 15.7 (5) | 1.3 | 634.4 | ( 5.2) | 5.2 | 103.8 | ( 0.8) | 0.8 | 13.0 | 0. 0. 0 | 20. 1.86 | 17 | 0 |
| 6 | 6.5 | 7.1 | 13.6 | 12.3 (5) | 1.3 * | 1722.9 | ( 0.6) | 0.4 * | 399.4 | ( 0.8) | 0.7 * | 48.3 | 11. 9.85 | 27. 7.85 | 194 | 7 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 876.4 | ( 0.0) | 0.0 | 122.6 | ( 0.0) | 0.0 | 20.9 | 26. 5.85 | 1. 3.85 | -31 | 7 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 0.0 | ( 4.0) | 4.0 | 4.0 | ( 0.8) | 0.8 | 0.8 | 0. 0. 0 | 0. 0. 0 | 0 | 0 |
| 9 | 7.1 | 7.3 | 14.4 | 13.2 (4) | 1.2 | 960.6 | ( 2.0) | 2.0 | 44.0 | ( 0.9) | 0.8 | 13.2 | 0. 0. 0 | 9. 1.86 | 29 | 0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 701.0 | ( 0.0) | 0.0 | 0.0 | ( 0.0) | 0.0 | 0.0 | 10. 6.85 | 1. 3.85 | -46 | 7 |
| 11 | 5.3 | 4.3 | 9.6 | 11.6 (4) | -1.9 * | 1489.0 | ( 0.0) | 0.0 | 292.8 | ( 0.2) | 0.1 * | 33.7 | 21.10.85 | 22. 7.85 | 199 | 7 |
| 12 | 8.7 | 11.1 | 19.8 | 19.1 (5) | 0.7 | 760.6 | ( 4.0) | 4.0 | 99.0 | ( 0.8) | 0.8 | 16.5 | 0. 0. 0 | 29.1285 | 39 | 0 |
| 13 | 6.1 | 6.7 | 12.8 | 12.6 (6) | 0.2 | 1417.0 | ( 0.6) | 0.6 | 306.4 | ( 0.8) | 0.8 | 41.9 | 4.10.85 | 30. 7.85 | 191 | 7 |
| 14 | 9.5 | 9.1 | 18.6 | 19.4 (6) | -0.8 | 650.4 | ( 4.0) | 4.0 | 182.3 | ( 0.8) | 0.8 | 27.7 | 3. 2.86 | 25.11.85 | 73 | 7 |
| 15 | 6.3 | 5.5. | 11.8 | 11.3 (5) | 0.5 | 470.3 | ( 4.0) | 4.0 | 66.0 | ( 0.8) | 0.8 | 12.0 | 0. 0. 0 | 9. 1.86 | 29 | 0 |
| 16 | 8.3 | 9.3 | 17.6 | 17.9 (6) | -0.3 | 583.1 | ( 3.0) | 2.5 * | 51.7 | ( 0.8) | 0.7 * | 11.6 | 0. 0. 0 | 22.12.85 | 46 | 0 |
| 17 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 949.8 | ( 0.0) | 0.0 | 167.2 | ( 0.0) | 0.0 | 24.0 | 7. 6.85 | 7. 4.85 | 299 | 7 |
| 18 | 7.3 | 10.3 | 17.6 | 16.8 (6) | 0.8 | 1637.0 | ( 2.2) | 2.2 | 411.9 | ( 0.8) | 0.8 | 46.9 | 19.11.85 | 28. 9.85 | 131 | 7 |
| 19 | 4.3 | 4.7 | 9.0 | 9.7 (6) | -0.7 | 890.5 | ( 0.0) | 0.0 | 185.7 | ( 0.0) | 0.0 | 24.9 | 29.10.85 | 30. 9.85 | 127 | 7 |
| 20 | 5.7 | 6.7 | 12.4 | 11.6 (6) | 0.8 | 1247.8 | ( 1.2) | 1.2 | 320.6 | ( 0.8) | 0.8 | 41.6 | 1.11.85 | 31. 8.85 | 159 | 7 |
| 21 | 4.0 | 4.7 | 9.0 | 8.3 (6) | 0.7 | 1028.9 | ( 0.0) | 0.0 | 131.7 | ( 0.0) | 0.0 | 20.6 | 8. 7.85 | 12. 6.85 | 239 | 7 |
| 22 | 7.3 | 8.1 | 15.4 | 14.9 (6) | 0.5 | 1754.3 | ( 1.2) | 1.1 | 423.0 | ( 0.8) | 0.7 * | 47.1 | 22. 9.85 | 24. 6.85 | 227 | 7 |
| 23 | 5.5 | 7.7 | 13.2 | 13.0 (5) | 0.2 | 1546.2 | ( 0.4) | 0.4 | 337.1 | ( 0.8) | 0.8 | 41.0 | 28. 2.85 | 13. 7.85 | 208 | 7 |
| ... | | | | | | | | | | | | | | | | |
| 40 | 4.5 | 5.5 | 10.0 | 9.8 (6) | 0.2 | 1167.9 | ( 0.6) | 0.6 | 279.6 | ( 0.6) | 0.6 | 38.5 | 8. 1.85 | 22. 9.85 | 137 | 7 |
| 41 | 7.5 | 7.7 | 15.2 | 13.5 (6) | 1.7 * | 1632.1 | ( 0.6) | 0.6 | 365.7 | ( 0.8) | 0.8 | 42.0 | 20. 1.86 | 19. 9.85 | 140 | 7 |
| 42 | 7.1 | 8.3 | 15.4 | 15.3 (2) | 0.1 | 37.9 | ( 5.0) | 5.0 | 63.6 | ( 0.8) | 0.8 | 11.0 | 0. 0. 0 | 22. 1.86 | 15 | 0 |
| 43 | 10.1 | 12.5 | 22.6 | 22.1 (5) | 1.4 | 733.6 | ( 4.9) | 4.0 | 84.4 | ( 0.8) | 0.8 | 12.0 | 0. 0. 0 | 3. 1.86 | 34 | 0 |
| 44 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 1177.8 | ( 0.0) | 0.0 | 222.2 | ( 0.0) | 0.0 | 28.8 | 12. 6.85 | 17. 3.85 | -48 | 7 |
| 45 | 0.0 | 9.9 | 9.9 | 0.0 (0) | 0.0 | 661.0 | ( 5.0) | 5.0 | 91.6 | ( 0.8) | 0.8 | 9.8 | 0. 0. 0 | 28. 1.86 | 9 | 0 |
| 46 | 0.0 | 0.0 | 0.0 | 0.0 (0) | 0.0 | 0.0 | ( 0.0) | 0.0 | 0.0 | ( 0.0) | 0.0 | 0.0 | 0. 0. 0 | 0. 0. 0 | 0 | 0 |
| 47 | 4.9 | 5.3 | 10.2 | 10.6 (6) | -0.4 | 1284.9 | ( 0.0) | 0.0 | 276.4 | ( 0.0) | 0.0 | 31.0 | 3. 9.85 | 2. 7.85 | 199 | 7 |
| Summ | 229.6 | 262.7 | 492.3 | 476.6 | 15.7 | | 73.8 | 73.1 | | 21.8 | 21.4 | | | | | |

Anzahl der gemolkenen Kühe = 38
Milch pro Kuh und Tag = 13.0 kg

bisherige Jahresmilchproduktion = 61522.3 kg d.h. 82.6 % des Kontogentes bereits erfüllt
bisherige Monatsproduktion ab 1. 2. = 2562.7 kg
bisheriger Jahreskraftfutterverbrauch = 127.58 dt (S1) 19.47 dt (S2)
bisheriger Kraftfutterverbrauch ab 1. 2. = 4.27 dt (S1) 1.27 dt (S2)

*) Abweichung um mehr als 10 % vom Mittelwert bzw. Sollwert

Source: Auernhammer, H., Pirkelmann, H., Wendl, G. (Hrsg.): Prozeßsteuerung in der Tierhaltung - Erfahrungen mit der Milchmengenerfassung, Tiergewichtsermittlung und Bereitstellung von Managementdaten. Schriftenreihe der Landtechnik Weihenstephan, Weihenstephan 1985, Nr. 2 (https://mediatum.ub.tum.de/683701)

## Silsoe 1984 - Sabbatical at Silsoe College (Cranfield University, UK)

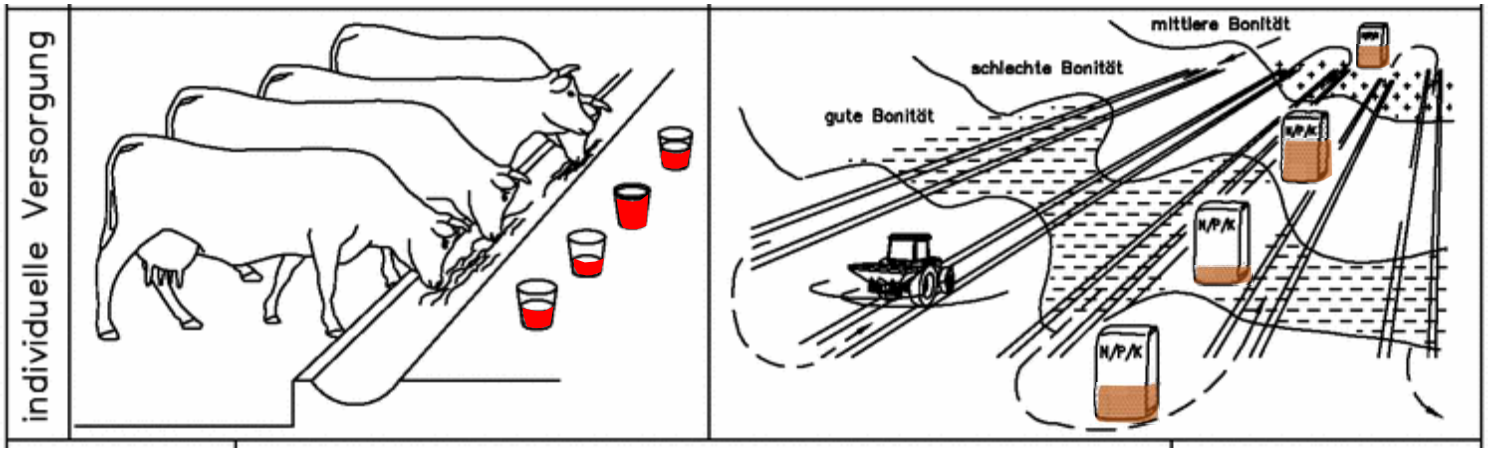
### John TAYLOR demonstrated a Handheld-NIR Device

Many and long lasting discussions:

- Will the sensor replace the eye of the tractor driver during fertilization (greenness)?
- Will this sensor detect the overall plant growth (performance like the milk meter)?
- How can it be included in a „closed loop fertilization control system“ (electronic communication system)?

## → Individual Nutrient Supply 1986

→ **Research strategy from dairying transferred to crop production!**



# Lessons learned

Systematically no difference between animal and crop production systems

| | | | | |
|---|---|---|---|---|
| • Animal | → | Part field / Plant | → | Identification |
| • Milk yield | → | Crop yield | → | Yield meter |
| • Body weight | → | Soil fertility | → | Soil sensing |
| • Concentrate dispenser | → | Fertilizer distributor | → | Distribution control |

**→ No chance of realization without an Electronic Communication System, as:**

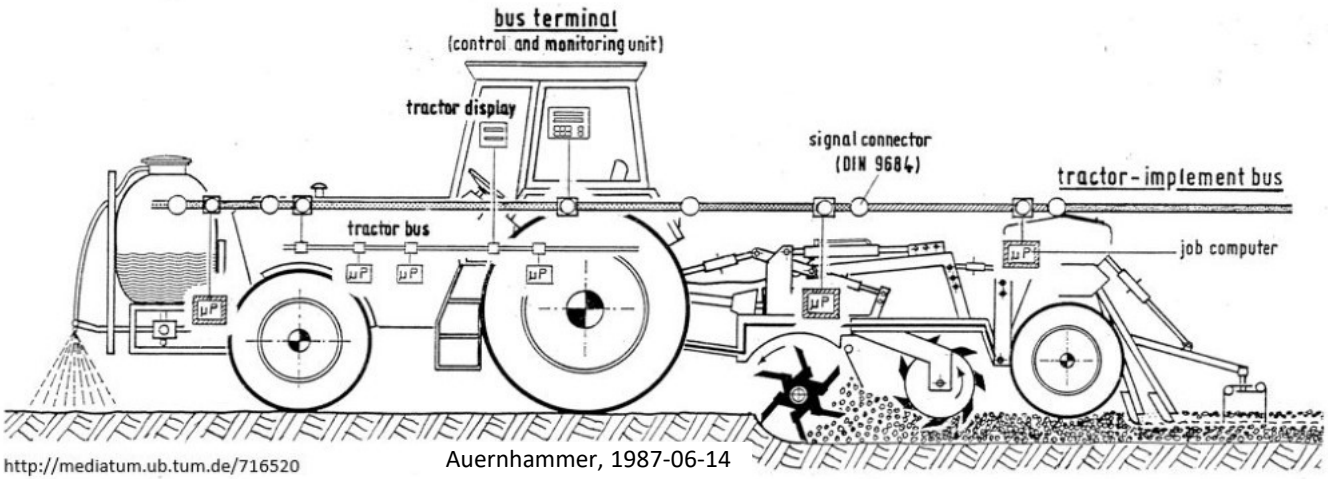
Outside self-propelled machinery no dominant Ag Machinery manufacturer

- Several tractor manufacturer from very small once to big once, all of them with OEM suppliers (engines, gear boxes, axels, three-point-linkage, tyres, … )
- A huge number of implement manufacturer as small and medium-sized family enterprises
- Tractor and implement combination selected by farmers according to regional and farm-specific requirements

# „Technical Initial Point 2“ (Germany and neighbor countries)

## Electronic Tractor Implement Communication

### Tractor – Implement – FMS → LBS (23.6.1987 – 19.1.1998) & ISOBUS (26./27.2.1990 - ?)




http://mediatum.ub.tum.de/716520 Auernhammer, 1987-06-14

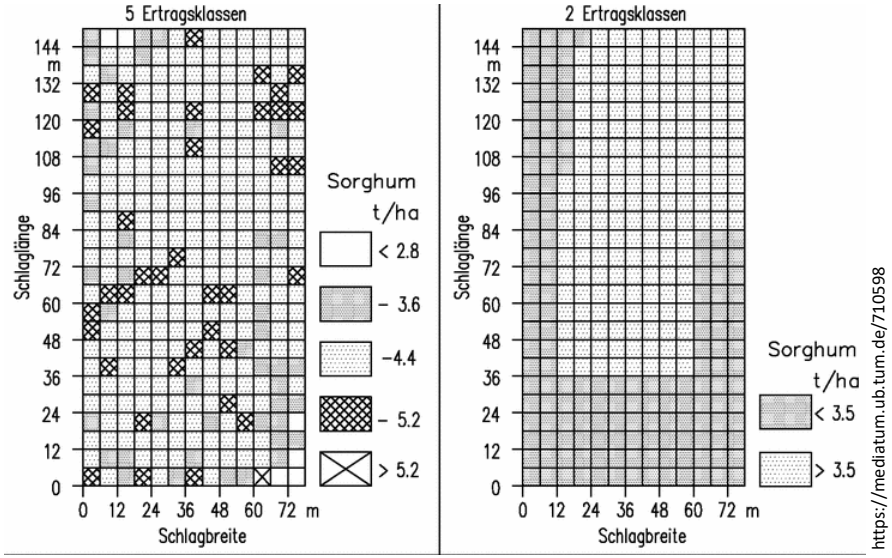
## LBS Standardization procedure within LAV (DIN 9684)

- Largest standardization procedure that time in DIN
- For the first time a standard was defined before implementation und usage
- Implementation to ISO 11783 was initiated and accompanied

Source: Auernhammer, Hermann; Frisch, J. (1993): Mobile Agricultural BUS-System – LBS, https://mediatum.ub.tum.de/?id=1509574

Oksanen, Timo; Auernhammer, Hermann (2021): ISOBUS — The Open Hard-Wired Network Standard for Tractor-Implement Communication, 1987-2020, https://mediatum.ub.tum.de/?id=1595782

# „Technical Initial Point 3“ In-field localization (USA) 1986/1987




https://mediatum.ub.tum.de/710598

**Texas A&M 1986** (Stout, Schueller, Searcy et al.):

**Triangulation + Plot combine → Yield mapping**

*Results:*

- Requires infrastructure (not to be put into practice!)
- Usage of the military system **GPS** (Under development, timing availability open, civilian use possible?, accuracy?, cost?)

→ **Continuation of the tests discontinued!**

**GPS-Receivers in Germany, an unknown technology** (10 Satellites available, for military use only):

- Only supplier in Germany 1987 SEL Alcatel (Stuttgart), Receiver price = 42.000 DM
- Only supplier in Germany 1988 SEL Alcatel (Stuttgart), Receiver price = 18.000 DM
- Only supplier in Germany 1989 SEL Alcatel (Stuttgart), Receiver price = 9.800 DM, system purchased

→ **Stationary accuracy tests 1989 Lehrstuhl Landtechnik Weihenstephan and Gut Wittenfeld**

# „Technical Initial Point 4“ Locale Yield Measurement 1990 (FAM)


**DANIA MD with yield sensor + own GPS** (12 Satellites available, no SA, Golf-War, time of harvest adjusted to GPS availability)

**12.08.1990**
Flachfeld Scheyern
17,1 ha WW

**20.08.1990**
Gut Schlüterhof
7,9 ha WW

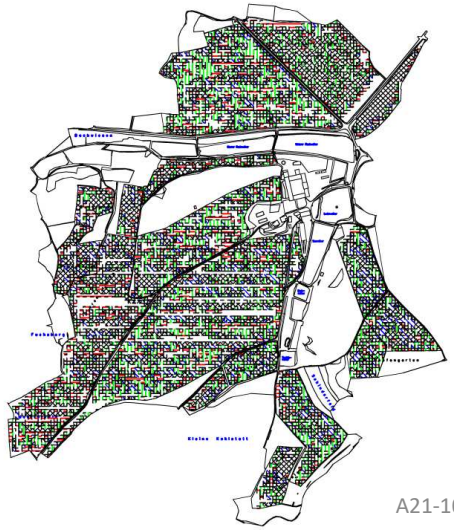
# Local yield measurement from 1991 to 2000 - FAM Scheyern


## World's first large-scale use of local yield determination 1991 & 1992 with series combines and DGPS on > 100 ha

- **Trace maps**
- **Yield maps** abs. in grid format (5, 12, 24 m side length)
- **Yield maps** rel. in grid format (5, 12, 24 m side length)
- **Moisture maps** in later years

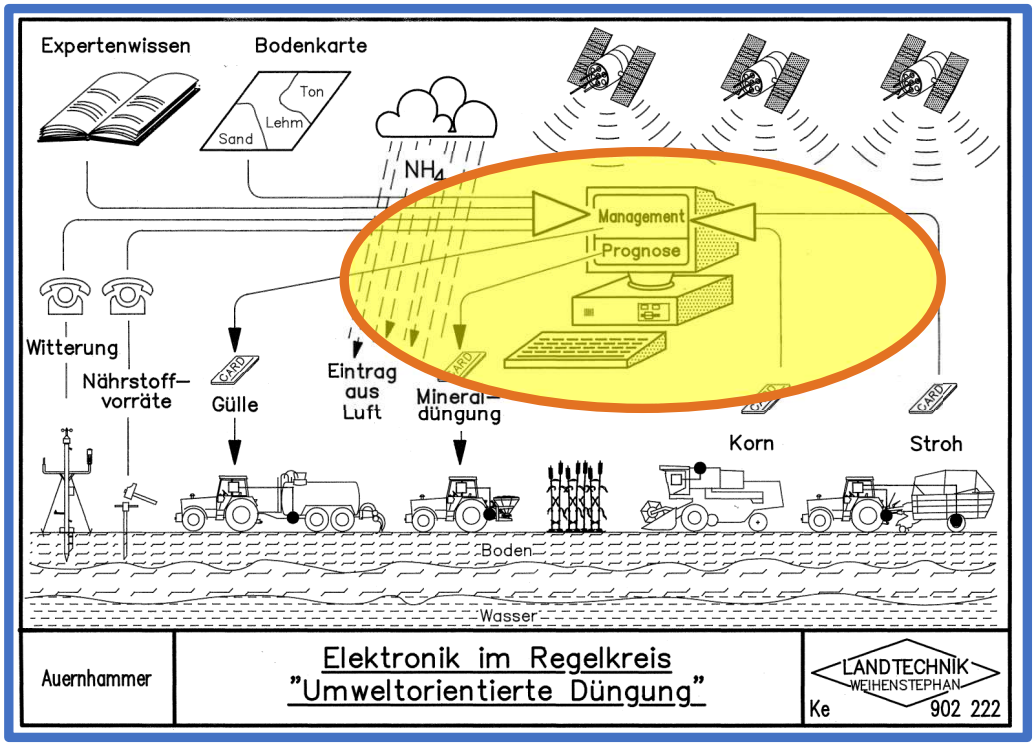
→ A total of 1,371 maps available at: https://mediatum.ub.tum.de/?id=1575449

(Yield data in preparation with standardized format for publication in mediaTUM)



https://mediatum.ub.tum.de/?id=1544121

# Also in arable farming information in the center (identical to animal husbandry)




https://mediatum.ub.tum.de/?id=710617, erstellt am 14.08.1990

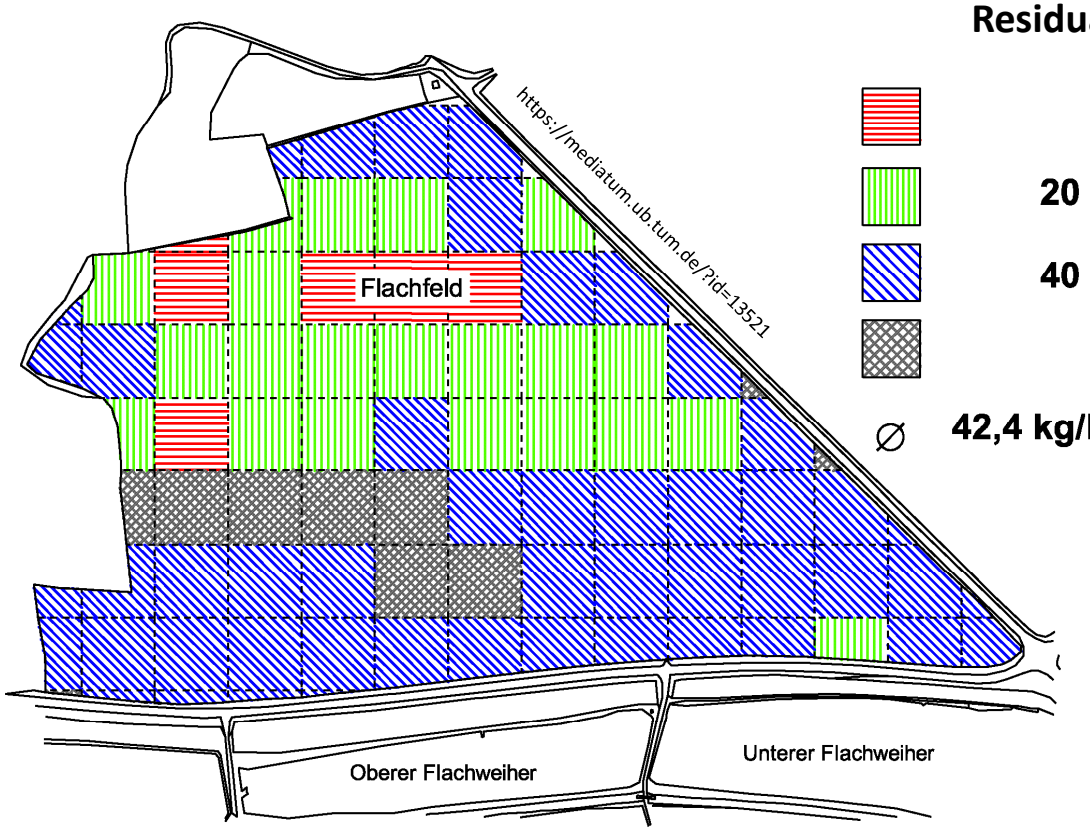
Closed loop control of part-field N-supply possible, with:

## Nitrate pollution environment (simplified):

$$N_{\text{Exact distribution}} + N_{\text{Input air}} + N_{\text{Mineralization}} - N_{\text{Yield}}\ (\text{Straw remains}) = 0$$

# Calculated residual nitrogen „Flachfeld“ 1991

(Winter wheat „ORESTIS“; 16.6 ha; fertilization 160 kg N/ha uniformly)




Nach Maidl, Demmel, Auernhammer

| Residual nitrogen | Area shares |
|---|---|
| < 20 kg/ha | = 7,7 % |
| 20 - 40 kg/ha | = 30,8 % |
| 40 - 60 kg/ha | = 50,8 % |
| > 60 kg/ha | = 10,7 % |
| ∅ 42,4 kg/ha | = 26,5 % N over-fertilization |

| | |
|---|---|
| Maximum/Raster | 71 kg/ha = 44,4 % |
| Raster | 50 x 50 m |
| Werte pro Rast. | 25 (a 100 m²) |
| Werteanzahl | 2302 |
| davon selekt. | 2285 = 99,3 % |

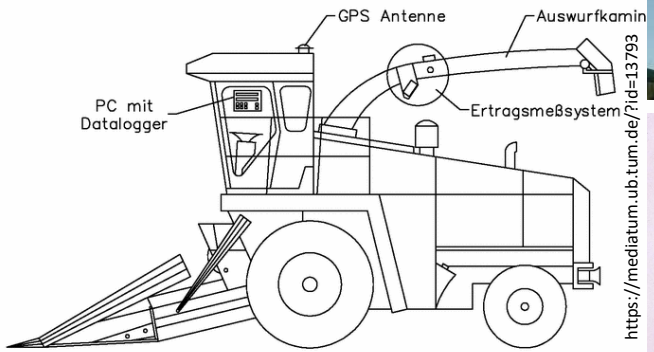
N

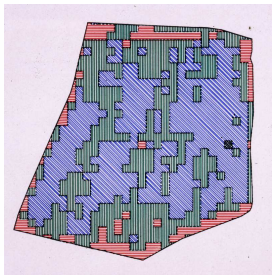
200 m

022 238

# FAM - Local yield determination for the whole crop rotation

## Chopped material 1993

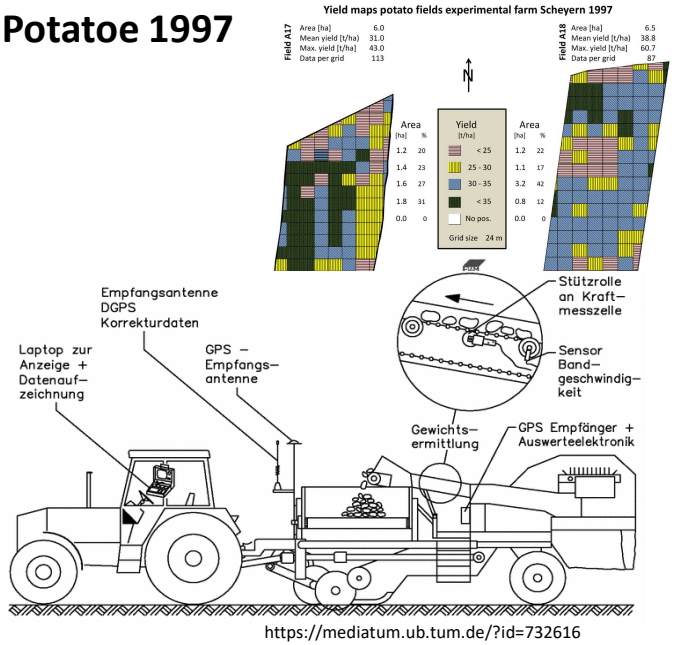


https://mediatum.ub.tum.de/?id=13793

Source: Auernhammer, Hermann; Demmel, Markus; Pirro, P.J.M. (1995): Yield Measurement on Self Propelled Forage Harvester, https://mediatum.ub.tum.de/?id=1509590

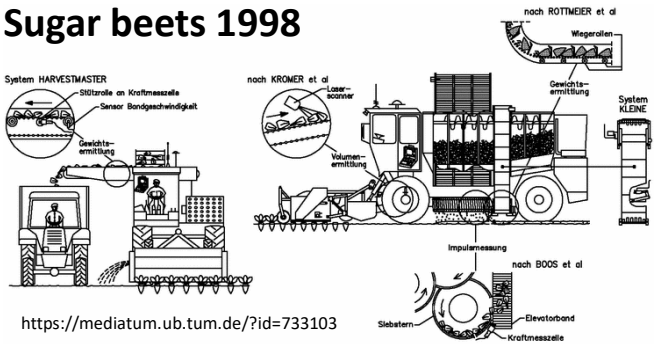
## Potatoe 1997




https://mediatum.ub.tum.de/?id=732616

Source: Demmel, Markus; Auernhammer, Hermann (1999): Local yield measurement in a potato harvester and overall yield pattern in a cereal-potato crop rotation, https://mediatum.ub.tum.de/?id=1509624

## Sugar beets 1998




https://mediatum.ub.tum.de/?id=733103

Source: Demmel, Markus; Auernhammer, Hermann; Rottmeier, Josef (1998): Georeferenced Data Collection and Yield Measurement on a Self Propelled Six Row Sugar Beet Harvester, https://mediatum.ub.tum.de/?id=1380425

**→ Will it ever be possible to determine root crop yields by satellite ?**

# Theoretical considerations on robotics 1995

## Autonomous seeding

https://mediatum.ub.tum.de/?id=1449070

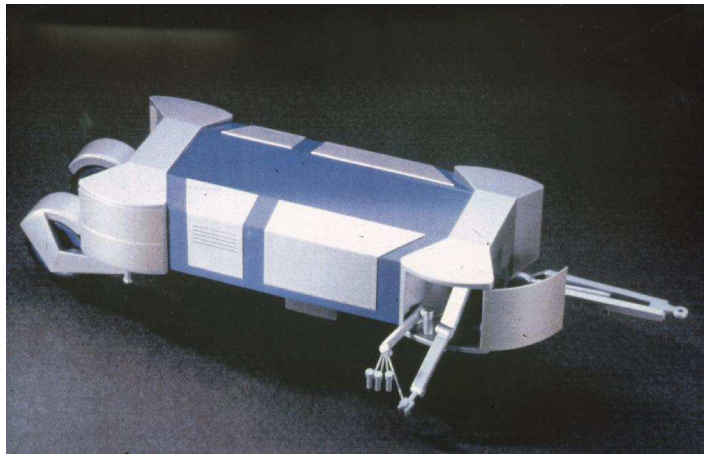
Follows the seedbed preparation unit (goes with it to field and return with it to farm)

Hybrid drive with bio Fuels

Sufficient seed capacity for all-day work

Source: Pilgram, Christian (1995): Selbstfahrende Saatbettkombination, https://mediatum.ub.tum.de/?id=1449070

## Mobile Milking Robot



https://mediatum.ub.tum.de/?id=1449073

For the pasture operation in summer

As a mobile milking parlor in winter for "small dairy farms" with a cubicle stall and automatic concentrate feeder, but without own milking technology.

Source: Schneider, Franz (1995): Mobiler Melkstand, https://mediatum.ub.tum.de/?id=1449073

# Part-field technique and equal spaced planting 1996 - 1998

## LBS and part-field technique 1996


https://mediatum.ub.tum.de/?id=13427

LBS in a standard tractor

GPS-Integration

Manual activation of the part-field section control in in an air spreader

Source: Auernhammer, Hermann; Demmel, Markus; Ostermeier, Ralph; Weigel, R. (1996): Bus Configuration and Bus Load in a Tractor Fertilizer Spreader System (LBS by DIN 9684), https://mediatum.ub.tum.de/?id=1509600

## Equal-spaced planting 1998

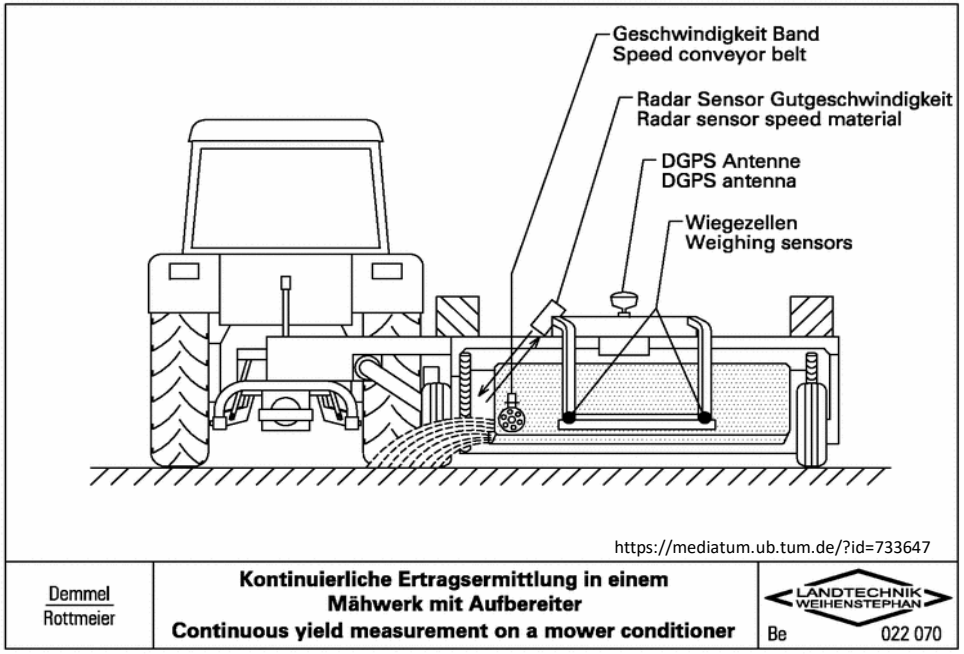
Each plant same stand space

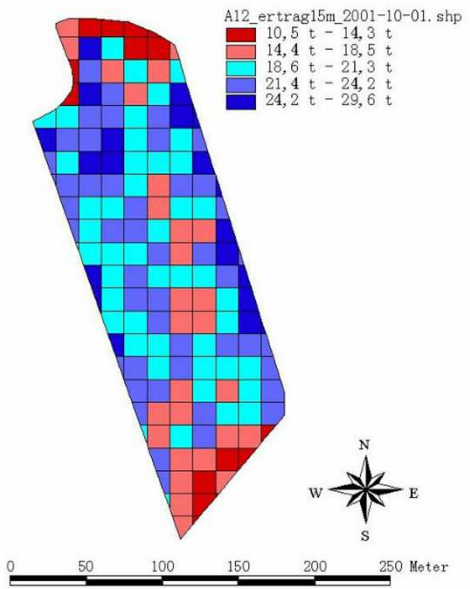
Manually adjusted diagonal connection at start of plant row (nowadays easily realizable via GNNS)

→ In diagonal hoeing, no need for crop chemical protection agents (optimal use of robotics)

Source: Demmel, Markus; Auernhammer, Hermann; Kormann, Georg; Peterreins, Markus (1999): First results of investigations with narrow row equal space planting of corn for silage, https://mediatum.ub.tum.de/?id=1509625

# Grassland yield measure where it occurs 1998




Use of standard sensors (strain gauges, reed contact, radar)

→ *Simplified extension with NIR for moisture and ingredients measurement*

*Relatively easy integration into today available butterfly configurations*

Source: Rothmund, Matthias; Auernhammer, Hermann (2005): Transborder Farming - Virtual Land Consolidation for Improved Farming in Small-Scale Farming Systems, https://mediatum.ub.tum.de/?id=1380429

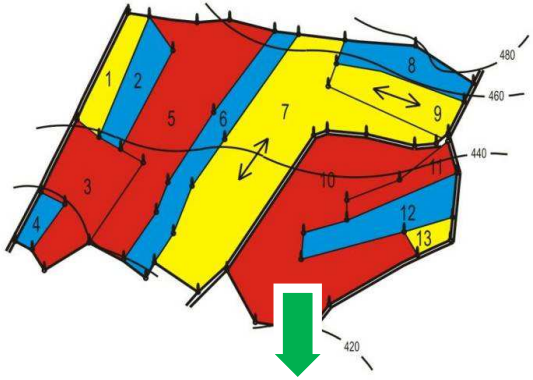
# Transborder Farming (small scale field structures = part field) 1998

## Sub project „Micro Precision Farming“ in the Collaborative Research Project „preagro“

**Existing structure**

Example:

„Hersbrucker Land“

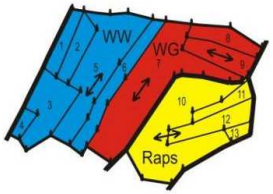



| | WW | WG | Raps |
|---|---|---|---|
| Landwirt | A | 12 | 5 | 1 |
| " | B | 4;6 | 10 | 9 |
| " | C | 8 | 3 | 13 |
| " | D | 2 | 11 | 7 |

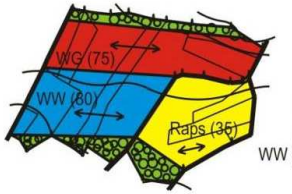
https://mediatum.ub.tum.de/?id=733232

Focused on yield (economy)

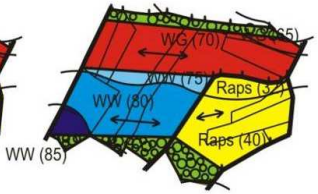
Transformed to environment (ecology)



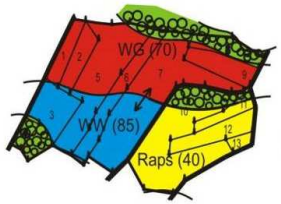

Aligned to property



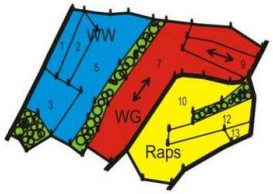

Joined yield target




Part-field realization




Reduction of erosion




Landscape preservation

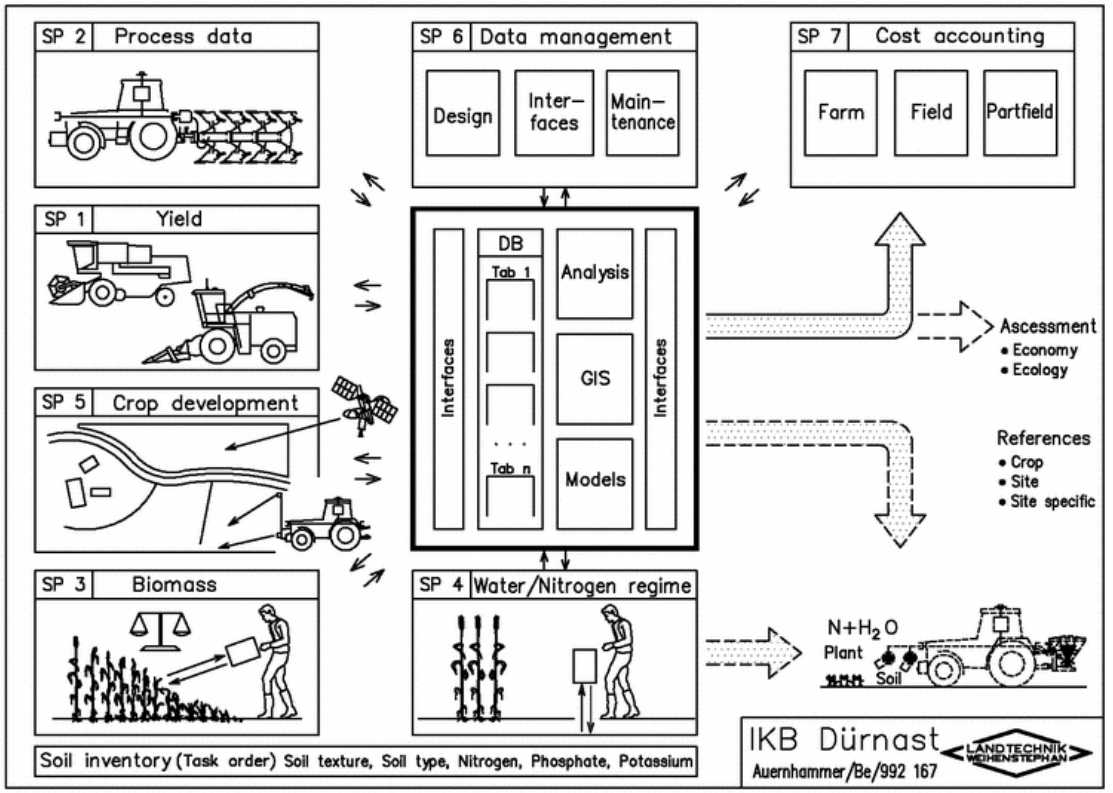
Source: Rothmund, Matthias; Auernhammer, Hermann (2005): Transborder Farming - Virtual Land Consolidation for Improved Farming in Small-Scale Farming Systems, https://mediatum.ub.tum.de/?id=1380429

# IKB-Dürnast "Information System Small-Scale Crop Husbandry" 1999 – 2005

## DFG funded Collaborative Research Project

Chairs of Agricultural Engineering (Application and management), Agronomy, Plant Nutrition, Farm Management and Economy

- Two 3-year funding periods
- Use of latest machine technology
- 8 PhD-Theses
- Worldwide Reputation

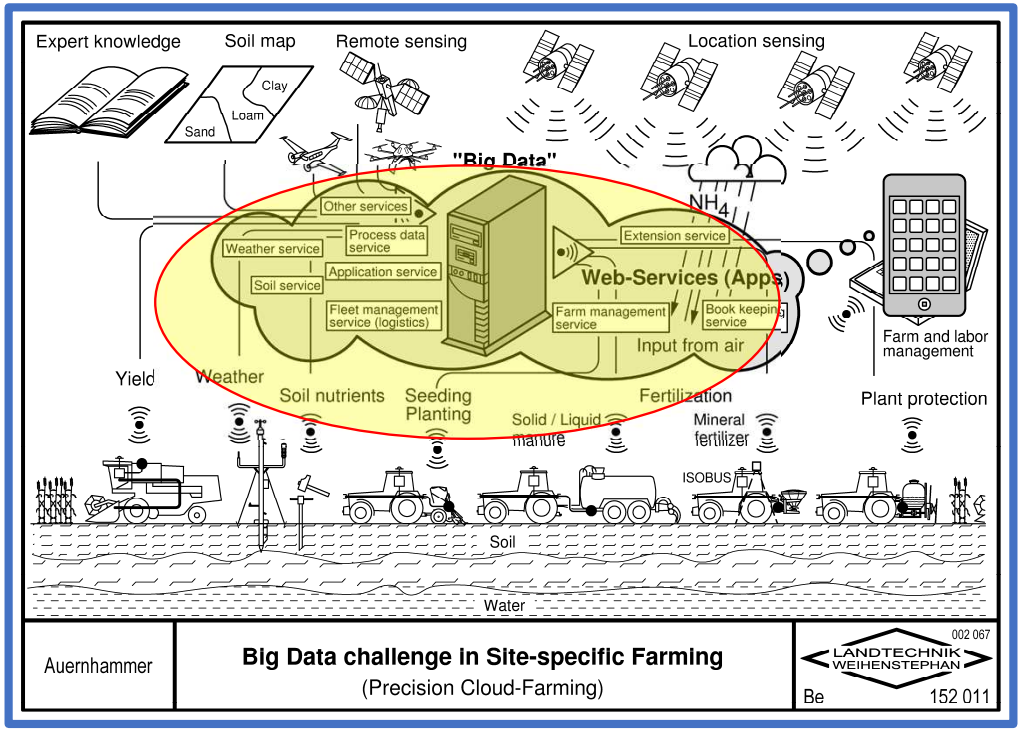



https://mediatum.ub.tum.de/?id=733092

Source: Auernhammer, Hermann; Demmel, Markus; Maidl, Franz X.; Schmidhalter, Urs; Schneider, Thomas; Wagner, Peter (1999): An on-farm communication system for precision farming with nitrogen real-time application, https://mediatum.ub.tum.de/?id=1509622

# Precision Farming „Quo vadis ?“

***Thanks to all of them:*** *Pirkelmann, Wendl, Wendling, Stanzel, Taylor, Gerl, Reinholz, Nienhaus, Robra, Buschmeier, Goense, Toft, Muhr, Demmel, Rottmeier, Wild, Kormann, de Baerdemaeker, Schueller, Terao, Ostermeier, Schneider, Pilgram, Fröhlich, Spangler, Trukenbrod, Perger von, Steinmayr, Maidl, Stout, Searcy, Blackmore, Wagner, Vellidis, Motobayashi, Gemtos, Ehrl, Werner, Rothmund, Spreng, Molin, Noguchi, Steinberger, Noack, Gallmeier, Heckmann …* ***and many more!***




https://mediatum.ub.tum.de/?id=1238738

- Much has changed and been further developed,
- much has been achieved
- and many new challenges are open (the challenge for all of you)!

Source: Auernhammer, H., Demmel, M. (2015): State of the Art and Future Requirements. In: Precision Farming Technology for Crop Farming (Ed.: Zang, Q.), Boca Raton, FL (USA): CRC-Press, pp. 299-346 (ISBN 9781482251074)