Digitale Landwirtschaft – Technische Entwicklungen

Achim Walter, Institute of Agricultural Sciences, Departement of Environmental Systems Science, ETH Zürich, Switzerland
When will farmers be replaced by robots?

Never!

…but they are increasingly complementing each other…
Agriculture, culture & society

- Ca. 10’000 a ago: Domestication of plants & animals
- Only since then: Sessile lifestyle, differentiated societies, high population densities, cities...
- Agriculture is the foundation of our culture & societies

Reading recommendation: ‘Guns, Germs and Steel’ (Jared Diamond)
Agriculture and technology

- During 5’000 a: Domestication of useful species
- During 9’900 a: Moderate development of technology
- The past 100 a: Explosive development of technology, breeding (biological features of species) and human population density
Agriculture and breeding

- During 5’000 a: Domestication of useful species
- During 9’900 a: Moderate development of technology
- The past 100 a: Explosive development of technology, breeding (biological features of species) and human population density

Increase carrying capacity of earth by a factor $> 1000$
Today: 'Industrial Agriculture' in lots of regions

Solutions?
1.) Decrease / consolidate livestock production
2.) Less intense, more diverse crop cultivation (Org. Ag. etc.)
3.) Smart use and development of technology
   a) Biotechnology (e.g. CRISPR/Cas9)
   b) Digitalization / Sensing / Robotics (topic today)
To my opinion, all of these approaches are required!
Currently: We experience the onset of the next step in technology development

- To a large extent: Precision Agriculture
- Smart farming; big data; artif. intelligence
- Less pesticides, fertilizer & other input
- Sufficient yield @ higher efficiency
- Development of new technologies
- Digitalization of agriculture
- Wise use of this technology
- Less ecological side effects
- Economic & social progress

**Precision Agriculture** (scheme from Gebbers & Adamchuk, 2010): Use input exactly when & where necessary
Digitalization of agriculture / Smart Farming: Which approaches do we see today

- The world of global Agribusiness – e.g. Monsanto
- The world of European research – e.g. Internet of Food & Farm
- My personal observations in recent years, e.g. from
  - ICRA 2018, Brisbane, World Leading Conference in Robotics & Automation
  - ICPA 2018, Montreal, World Leading Conference in Precision Agriculture
  - Other meetings, discussion panels, contacts in Switzerland & abroad
- Current state of the art in some crop sensing technologies
- Would it make sense to discuss a vision / ‘Leitbild’ for future ag.?
- Conclusions
My Interpretation: The big AgBiz companies do not want to miss the introduction of disruptive technologies (similar to Kodak – photography; Nokia – smartphones): Heavy investment in artificial intelligence, deep learning, big data
Big Data picked up by AgTech: This is all about money

Big AgBiz companies acquire possibilities to get hold of environmental data, farm data, modelling solutions. Aim: Increase efficiency, decrease product prices. Mergers necessary to save costs.
Example: Proceeding of Monsanto as ‘first mover’ in this area

Monsanto (Climate Corp): first mover advantage

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Precision Planting (sensors, data transmission) - 210 Mi US $</td>
</tr>
<tr>
<td>2013</td>
<td>Climate Corporation (Dig. Agr. Platform) - 1 Bio US $</td>
</tr>
<tr>
<td>2014</td>
<td>Rebranding Climate Basic (Climate View)</td>
</tr>
<tr>
<td>2015</td>
<td>Vitafields (European farm management)</td>
</tr>
<tr>
<td>2016</td>
<td>Various data connectivity agreements</td>
</tr>
<tr>
<td>2017</td>
<td>Hydrobio (Irrigation data analytics)</td>
</tr>
<tr>
<td>2018</td>
<td>Investments in increasing the compatibility (currently 65% all farm equip. in the US)</td>
</tr>
</tbody>
</table>

Interesting: No further development in 2019!

Techn. problems?

Platform Climate FieldView: DIGESTS all relevant data of a farm and of the environment
Vision: Agriculture as fully automated business

Sources: Hitachi und Frost & Sullivan
Japanese approach: Company Optim

- Focus on development of technology
- Vision: Agriculture with as little human intervention as possible
- Label for high-tech grown food: 'Smart veggie'
- Collaborations within Japan; Hokkaido University
Large-scale European research project

- Led by Wageningen
- More than 70 partners
- Joint Experiments on Field Sites

Already established in the Netherlands: Platform ‘Akkerweb’, where farmers receive decision support based on satellite images etc.
Germany: Excellence Cluster Phenorob

http://www.phenorob.de/
Conference on Robotics & Automation - Take-home-messages

• ‘Chief Scientist of Australia’: You guys (scientists involved in ‘deep learning’ & automation) will soon be the next to earn wages around 1 Mio $/a
• The field grows strongly – 3’000 participants; 1’000 MS submissions accepted
• It will take a long time and huge efforts until automated control is established
• Important fields for the future:
  1. Communication between robots&humans (& robot-robot), robot swarms of small machines
  2. Agricultural Sciences / Food Production; humans first as commanders, then partners, later: bystanders – but will require lots of efforts and intermediate steps
  3. Learning of robots, how to learn, deep learning,…
  4. Safety margins, SLAM (synchronous locomotion and mapping during e.g. UAV flights)
  5. Machines that help to erect and modify buildings
  6. Autonomous car driving is rather seen as a hype / something for the relatively far away future, but lots of industry development
  7. Medicine / assisted operations etc. is also a growing field
Specifically on Agricultural Sciences / food production

• Australia is leading in this field
• But also there, commercialization is still a few years away
• Walking robots that can deal with ‘unstructured terrain’ are important;
• Robot Swarms and joint seeing is considered very important
• Cooperation with farmers and authorities; specific solutions dealing with real needs are valued (‘when you ask, what you should do as a robotics guy, these farmers always tell you: it depends...’)
• Bosch / Deepfield: among leaders, have huge datasets
• John Deere / Blue River Technologies (Jim Ostrowski) will probably be the first major commercial player in automated weed removal
• Some manipulations can be done from UAVs already (drone-based pesticide spraying already practiced at large scale in China, Japan, Korea)
Research approaches of my and other groups at ETH
Considerations for orientation of my research in Switzerland

- Small-Scale, diverse agriculture
- No access to oceans, run-off from Agriculture ends up in drinking water
- High pressure to reduce pesticide use
- New ways are needed to control pests & diseases
- Crop breeding needs to take local climate into account (cold temperatures)
- Characterizing plant (and soil) performance from images
- Form consortia with robotics, social sciences, environmental sciences
- Perform On-Farm experiments
Application 1: Precision Agriculture

Example: Yara N-Sensor
EU-Project Flourish – communicating UAV & field robot

UAV detects positions of potential issues with weeds or fertilization in the field & transfers these positions to the cloud.

Info is processed in the cloud and sent to the autonomous ground robot (Bonirob, Bosch / Amazone).

Bonirob gets to these positions, performs detailed analysis and destroys weed or fertilizes the soil.

PI: Siegwart (Zürich); partners: Stachniss (Bonn), Burgard (Freiburg), Pradalier (France), Walter (Zürich), Bosch (Germany),...
Application 2: Improve crop breeding
Crop phenotyping @ ETH: FIP-Spidercam-installation on ca. 1 ha

Field Phenotyping Platform
FIP: rope camera system with various sensors
Analysis of plant height, canopy cover, plant colour, temperature,...
In wheat, soybean, maize,...

Kirchgessner et al. (2017)
Application: Differences between crop cultivars with respect e.g. to temperature – detection of ‘ideal’ genotypes

Which genotype grows optimally during winter months?

RGR: Relative Growth Rate; Source: Grieder et al. (2015)
Differences between hundreds of genotypes (height growth)

GDD: Growing Degree Days; Source: Kronenberg et al. (2017)
Limits of current research: E.g. quantify disease symptoms reliably

Which leaf is healthy, which one shows disease symptoms? (Septoria? Other disease? Normal senescence/aging?)

How can you detect a spot with the same precision in sunny and shady conditions?

Is that spot beyond a certain threshold for disease severity?

Do we need to apply fungicide?

Mahlein et al. (2018)
State of the art:

Commercial applications and research forefront – mostly in sensing and automation
Current state of the art: Reviewed in King 2017

A technological revolution in farming led by advances in robotics and sensing technologies looks set to disrupt modern practice.

By Anthony King

Over the centuries, as farmers have adopted more technology in their pursuit of greater yields, the belief that "bigger is better" has come to dominate farming, rendering small-scale operations impractical. But advances in robotics and sensing technologies are threatening to disrupt today's agribusiness model. "There is the potential for intelligent robots to change the economic model of farming so that it becomes feasible to have a small producer again," says robotics engineer George Karner at Carnegie Mellon University in Pittsburgh, Pennsylvania.

Twenty-first century robotics and sensing technologies have the potential to solve problems as old as farming itself. "I believe, by moving to a robotic agricultural system, we can make crop production significantly more efficient and more sustainable," says Simon Blackmore, an engineer at Harper Adams University in Newport, UK. In greenhouses devoted to fruit and vegetable production, engineers are exploiting automation as a way to reduce costs and boost quality. Devices to monitor vegetable growth, as well as robotic pickers, are currently being tested. For livestock farmers, sensing technologies can help to manage the health and welfare of their animals. And work is underway to improve monitoring and maintenance of soil quality, and to eliminate pests and diseases without resorting to indiscriminate use of agrochemicals.

Although some of these technologies are already available, most are at the research stage in labs and spin-off companies. "Big machinery manufacturers are not putting their money into manufacturing agricultural robots because it goes against their current business models," says Blackmore. Researchers such as Blackmore and Karner are part of a growing body of scientists with plans to revolutionise agricultural practice. If they succeed, they'll change how we produce food forever. "We can use technology to double food production," says Richard Green, agricultural engineer at Harper Adams.
Visions / ideas already existed decades ago...

Fertilization management

- point sensors from tractors – Yara N and other products; spectral indices
- satellite services – e.g. Farmstar in France (16’000 farms)
- images acquired by drones – research projects

https://www.youtube.com/watch?v=P55GqaMDyfo; https://www.youtube.com/watch?v=-kdied2Awug
Field calendar from satellites

- E.g. ‘OneSoil’ (Belarussian Website / Company); online 2019 for free
- Displays type of crop based on Sentinel 2 images (since 2016)
- Resolution down to 10 x 10 m; reliability? Check yourself…

https://onesoil.ai/en/
Pesticide application via spraying drones

https://www.youtube.com/watch?v=P2YPG8PO9JU

DJI MG-1S – ‘Agricultural Wonder Drone’ (in use throughout Asia)
State of the Art: Vineyard weeding robot

Similar principles are also applied in autonomous devices or tractor-mounted rather conventional devices as e.g. by Steketee, Zürn, other suppliers – an image-based algorithm helps detecting the row (and partly the individual plant) and hoeing is done in between.

Ted, the vineyard weeding robot (company Naïo, France)
Application: Hoeing in vegetables

- Similar principle as in vineyard
- Smaller machine
- Mainly for use in horticulture

Robot Oz, Company Naïo: Controlling weeds in row crops
Weed control by lots of companies...

...and approaches

Insert: Steketee (Lemken group)

See developments presented at Agritechnica 2019...
Picking robots (USA, Belgium)

- Image processing to detect fruits
- Controlled picking and deposition of harvested fruit

Apple picker from the US, Strawberry picker: Belgium
State of the Art: Intelligent crop herbicide application

https://www.youtube.com/watch?v=YCa8RntsRE

See & Spray - Blue River Technology's precision weed control (John Deere; not available yet)
Research frontier: Autonomous field control

https://www.youtube.com/watch?v=Li9eWpLGFiU

RIPPA: Demonstrating Autonomous Crop Interaction in Australia
Current development: Communicating small robots

- Small (50 kg), interacting robots
- Perform single seed sowing
- Product Xaver, research project “mobile agricultural robot swarms” in Germany

Xaver, Agricultural robot swarm by company Fendt / AGCO: Autonomous single seed sowing
Interested in even more videos? A few links (2019)

DeepField Robotics – small weeding robot (Germany):
https://www.youtube.com/watch?v=T3Ho7tjZ2e0

Tevel Aerobotics (Israel):
https://www.youtube.com/watch?v=E45hQxGsbXY

The small robot company (England):
https://www.youtube.com/watch?v=poHDW9J3h-A

Overview on several robots (comprised in June 2019):
https://www.youtube.com/watch?v=Tuz__azXz7Q
Concerns with which I’ve often been confronted

- Agriculture will be controlled even more by the big Ag companies
- Small farmers will not be able to buy expensive machinery
- Small farmers will be out of business – especially in developing countries
- Technology will deliver oversimplified solutions to complex situations
- If introduction of robotics is pushed too offensively: Similar ‘locked-in’ situations as with the advent of biotechnology 20 years ago will occur
My personal conclusion?

It is even more important that scientists engage themselves for establishment of really ‘smart’ solutions – together with farmers and in a dialogue with institutions.
Therefore: Smart Farming = Technology + Diversity + Institutions + Networks

**Smart Farming:** Technology is developed along the needs of stakeholders and society (opinion paper Walter, Finger, Huber, Buchmann, 2017, Proc. Natl. Acad. Sci., PNAS)

**TRANSDISCIPLINARY Research** approaches are crucial to introduce new technologies that are accepted by stakeholders and actors
Leitbild Landwirtschaft? Folien aus 2016 überspringen...

E.g. currently started research project Innofarm:
Interaction w. farmers in Switzerland; use of UAVs
- From summer 2018 onwards: UAVs take pictures of fields of participating farmers
- Mobile greenhouse-gas analysis platform in several field sites
- Small weather stations next to core field sites
- Interviews, questionnaires with several dozen farmers, agent-based modeling of the results
- Advisory panel with contribution of federal offices and companies

Humans & agriculture in future?

Agriculture & Employment

28% Global population directly or indirectly employed by agriculture

Risk: Agriculture is seen as a dirty, boring business of others – product prices will need to get lower and lower

Therefore: Additional challenges to be addressed in parallel to automation in agriculture

1. What kind of work do we want?
2. Who will do how much of this work?
3. How to win appreciation of the consumer?
4. How do we rate sustainability?
5. How to increase diversity in agriculture?
6. How to increase communication and knowledge transfer?

What kind of work do we want?

A mix of physical and intellectually challenging work

Who will do how much of this work?

Increase share of young persons working in agriculture – also in part time, internship or volunteer projects

How to win appreciation of the consumer?
The consumer needs to understand the special value of the product – and have a

How do we rate sustainability?
Sustainability has three dimensions: Economy, ecology, social aspects. All of them need to be reconsidered

How to increase diversity in agriculture?
Diversity leads to resilience. And diversity is fun!
Personal thoughts on sequence of some developments
Which steps will gain / diminish in importance for farmers in the long run by cooperation with AI?

+ Assessment of new diseases and operation along given thresholds for diseases
+ Learn / operate new software and hardware (robotics, automation)
+ Find your individual niche & spectrum of services
+ Cooperate more directly with customers
+ Marketing of your own product’s strengths
+ Learn by experiences made in other fields of work; don’t stay restricted to agriculture
+ Teach importance and values of your own work to people with other professions & mindsets
+ Perform well-balanced risk-assessments: Which insurance to buy in; which strategy to choose

– Manual, time-consuming routine work
– Stop at level of acquired knowledge
– Be secure that spectrum of work will stay the same for a long time; be self-confident that you’re doing exactly the right thing
Research advances may not only be derived from ‘technological reasoning’, but must result from a transdisciplinary stakeholder dialogue process

- Agriculture is under pressure globally: Production must increase AND get more sustainable

- There are lots of facets of technological progress that are relevant: Image processing, deep learning, communication technology, block chain, CRISPR/Cas9...

- Which ones do we want to refine first for agriculture in a given regional context?

- Answers will necessarily differ for different settings!

- It is the responsibility of all of us to engage ourselves & promote the aspects of relevance for our field of expertise

- To do this, we must inform ourselves and form necessary partnerships / networks
My overall conclusions

1. Technological developments are only one facet of ag. progress

2. Sustainability needs to increase: This will require efforts in lots of other fields as well

3. Farmers, consumers, ‘normal people’ need to state what they expect of future farming

4. Technology and artificial intelligence have the potential to increase sustainability

5. Farmers & robots (automated techn.) are future companions
Is 5G necessary?

Faster internet (e.g. 5G) is mainly necessary to establish the ‘internet of things’, in which devices communicate with each other.

To my opinion, there are still a lot of other technological steps to be taken in the interest of increased sustainability before 5G becomes the bottleneck.
Thank you for your attention

- My team (picture),
- Collaboration partners (as partly mentioned)
- Funding sources (e.g. European Union, Swiss National Science Foundation, Industry funds)