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VISION

Do more with less, better and in time!
Sustainable Value Creation in Agriculture by Implementing Digital Technologies

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Symbol for Technological Intervention for Innovative Agriculture

Global Symbol for Internet

Symbol for Digital Agriculture

Today, at the beginning of the 3rd Millennium, agriculture is confronted with a wide range of complex challenges. The task is to meet the growing demand for food, feed, fiber, fuel, industrial products and products based on 'functional' plants and improved agricultural production systems. Future-oriented, knowledge-based, added-value agriculture will have to become a reality. This will mean reduced use and redisposition of resources – in other words, *'Do more with fewer resources and with better results – and do it in time!'* (*Kern, 2014*).

Within this context, the possibilities offered by the implementation of digital technologies in agriculture will improve the prospects of being able to use our limited natural resources to the best. The appropriate use and timely development of these new technologies will enable better agricultural production systems. By pressing the ***IGREEN ®evolution*** forward in agriculture through implementation of digital systems such as smartphones, apps, global positioning systems (GPSs), sensors, robotics, drones, unmanned autonomous vehicles (ULVs), and others, the changing world will be able to address "**Factor** F^n" ("**FFFF FFFF FFFF FFFF**"): **F**uture **F**arming, **F**ood, **F**eed, **F**itness, **F**uel, **F**iber, **F**lowers, **F**reshwater, **F**ishery, **F**orestry, **F**lora, **F**auna, **F**un, **F**ortune, **F**reedom", which are milestones on a roadmap for tackling the challenges of the 21st Century.

Today, several hundred commercial communication satellites are circling around the globe, and many more will soon be following them. As a result, both public information and expert knowledge are being increasingly digitized and made available via the internet in real time.

Meanwhile, agricultural production systems with access to general data, public geo data, knowledge sources and services, are increasingly providing software interfaces, apps and digital systems which provide effective support for farmers on site and in the field.

Implementation of the ***IGREEN ®evolution*** will make digital farming or precision agriculture possible and add sustainable value to agricultural production systems worldwide – for smallholders as well as large-scale farmers. It will be possible to understand the needs of fields, crops, crop management systems, and the management of resources (seeds, water, nutrients, energy, costs) in a more efficient, effective and real-time way.

1. **Smartphones** are or will be available everywhere in the world. In 2012, approximately 6.7 billion paid **apps** were downloaded via mobile devices. By 2016, download figures for paid mobile apps are projected to reach 13.5 billion. A forecast shows 14.8 billion for the year 2017. If global unpaid app downloads are included, the total will meanwhile be more than 100 billion (*Statista, 2015*).
Side by side with this, the development and implementation of apps (electronic applications) in agriculture shows exponential growth rates as well. Several thousand agriculture apps are available – and this is only the beginning. The enormous numbers of downloads are having a significant impact on agriculture, while mobile app stores are overflowing with a great variety of applications specific to agriculture. To choose the right agriculture apps is not easy for farmers.
Nevertheless, an excellent overview of actual and relevant agriculture apps (livestock production, animal health and production, farm management, crop production) was published by Purdue University in 2014. Special apps have been introduced by the John Deere company (*2014*), offering guidance systems, field and crop management programs, together with information and logistic systems. Monsanto offers a “Climate Basic App”, covering weather, soil and crop data on the field level in order to improve production decisions. Bayer CropScience in Germany provides apps for the determination of 232 pests and 218 diseases in different crops, with recommendations for relevant control measures. BASF has implemented a “Weed ID App” in UK to identify 140 weed species as well as a “Cereal Disease ID App” to offer quick and easy mobile access to information on 36 cereal diseases, including information about symptoms, life cycle, host, importance and control options. DuPont Crop Protection has introduced a new “Tank Mix App” for iTouch and iPhone users. This free app helps to calculate products and water needed per tank or by area.
In 2014, the plant science industry in Australia provided the world-first app which will help to protect bees from crop sprays and pesticides. The app allows farmers to let beekeepers know where chemicals are being sprayed.
The Belgium-based biological pest control specialist launched a smartphone application version named ‘Side Effect Manual’, which lists crop protection agents and their compatibility with pollinators and biocontrol agents.
In 2013, the global fertilizer company YARA developed various tools to help growers use fertilizers in a more efficient way. Fertilizer planners and crop monitoring tools are helping to fine-tune nutrient requirements for individual crops in the fields.
The Indian company Nano Ganesh enables farmers to use their mobile phone turn water pumps on and off by remote control, which is a great way for farmers to save water, money and time.
During the last couple of years, numerous mobile agriculture apps have been introduced among farmers and agricultural value chain actors in Kenya to increase productivity, efficiency and safety in agriculture. Fortunately, the number of mobile smartphone users is significantly increasing in Africa and relevant apps will be made available. Apps will enable farmers to diagnose and fix problems more quickly and without the need to call experts to remote sites.
These are only some examples within the booming field of new agriculture apps. The socio-economic benefits will be great!

2. Within the next couple of years, **unmanned autonomous vehicles (ULVs)** such as **unmanned ground vehicles (UGVs)** and **unmanned aerial vehicles (UAVs)** will help farmers and extension services to improve agricultural production systems. **Drones** will be used for monitoring pests and diseases, calculating crop health status, identifying weeds in real time, documenting weed resistance, targeted application of pesticides, targeted application of *Trichogramm*a, e-Integrated Crop Management, triggering autonomous vehicles, localizing feral hogs in corn, protecting wild life animals, analyzing fertilizer demand, targeted application of fertilizer, documenting irrigation problems, documenting microclimate, determining plant height, comparing crop genetics, documenting crop yields and assessing hail and drought damage - the list could be continued. The agricultural robots market will reach $US 16.3 billion by 2020 (*ReportsnReports, 2014*).

In China unmanned 'helicopters' are being developed for the treatment and prevention of pests in vegetable and crop production. ULVs can prevent crop damage caused by traditional mechanical work and increase economic returns by more than 10 percent (*Beijing Agricultural Bureau*, *2013*). In 2014, drones called "3ZD-10A Extreme Low-altitude Remote Controlled Crop Protection Flying Machines" help farmers in China to cut the use of pesticides by half, reduce water consumption by almost 90 percent, and reduce the labor and material costs by 70 percent (*gbtimes Beijing*, *2014*). Currently, Japan has an operating fleet of roughly 2,400 flying rotorcrafts used in agriculture (*Fuji Heavy Industries, 2014*).

3. **Robots** are more and more on their way to being implemented in agriculture. Some autonomous robots for large-scale agriculture are listed by Precision Agriculture (*2014*): autonomous robot tractors with a wide range of maneuvers and high accuracy; '*Hortibut*', an autonomous robot for removing manually spraying or cutting the weeds; '*Lettuce Bot*', a robot with 98 percent accuracy to exterminate weeds without affecting the lettuce; '*Wall-Ye*', a pruning vine robot with soil sensors and a complex vision system; John Deer '*Spraying Robot Tractor*', designed to work continuously day and night; Mitsubishi 'Soil Sterilization Robot', a robot for injecting substances into the soil to control weeds, bacteria, fungi and viruses; 'Armadillo', a robotic platform to work with high accuracy in agricultural applications. In France in 2014 autonomous robots such as the *'Vitirover'* were offered to cut grass and weeds between grape vines. The little robot uses a solar panel to produce energy for powering the electric motor and electronic parts (*Precision Agriculture, 2014*).
In the US in 2012, Blue River Technology developed robots to replace hand labor work or the use of chemical herbicides. Robots for future automated weed control equipped with different sensors and computer technologies on board a tractor will identify the species of every weed in a field, and then apply one of several weed-fighting tools (mechanically, physically, chemically), to each plant based on its biology.
Another development in the US in 2013 was the controlled flight of biologically inspired **'Insect-Scale Robots'**. Tiny flying robots are being built to pollinate crops instead of real bees. Researchers are looking for ways to include robot swarms in agriculture. Swarms are able to identify weeds and administer chemicals, using less herbicides to do so (*Lentink, 2013*; *Shield, 2014; Werfel et al., 2014*). "The '*RoboBee Colony*' challenges are shared with many other fields in computer science – for example multirobot and robot swarm systems, distributed sensor networks, programming languages research, and even synthetic biology" (*Harvard University, 2014*).
Agriculture robots will take over essential functions and contribute significantly to sustainable agriculture.

Nevertheless, three key areas have to be addressed here: safe use of drones, data ownership and management of big data.
1. **Safe Integration of Drones into the Airspace**: Practical regulations have to be implemented in order to support precision agriculture in time as well!
2. **Data Ownership**: Who owns or receives access to data? How data are recorded and who handles them? Where is the data hosting located? Who is responsible for data security? How to ensure a secure access to online data? How will the data be shared? Which country-specific legal requirements exist? What are the legal requirements for handling data? Operative answers and solutions will have to be found in time.
3. **Big Data Documentation**: Big Data involves more than just hardware and software. Data creation is growing at exponential rates from nearly every source – including genomics, environmental and remote sensing, and in different other fields that impact agriculture. Consequently, all stakeholders within agricultural production processes have to have the skills to handle Big Data, which means that e-learning is a key prerequisite.

Finally, the Big Data documentation in agriculture enables to assess and monitor progress in sustainable/precision agriculture. Agriculture will become more like an exact science documenting and using data covering yield, energy uses, plant health status, biodiversity patterns, water use

efficiency, nutrient use efficiency, GHG emissions, pollination, distribution of pest and diseases, welfare, soil qualities, soil fertility, water quality, water flow, profits, costs in real time.
The analog world in agriculture is becoming increasingly digitized, and last but not least: a digitized Ag-World and implementation of ***IGREEN ®evolution*** will enable key resources to be preserved sustainably – more than 30 percent by 2050.

Sustainable production of food, feed, fiber, fuel, freshwater and industrial products will depend for its success on a future-oriented, knowledge-based, resource-conserving, and added-value agriculture – that, finally, will eradicate hunger, enable freedom and safeguard global peace.

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