Agriculture, Food Security
and Climate Change

FACCE-JPI Workshop on Technologies:

Fostering the adoption of existing (and emerging) technologies for primary production in the context of climate change that are on the edge of being mature but not yet widely adopted

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I) Introduction: FACCE-JPI – a research based initiative, focusing on the intersection between agriculture, food security and climate change

The goal of the joint programming initiative on Agriculture, Food Security and Climate Change (FACCE-JPI) is to provide coherence in research programming across Europe to meet the societal challenge of *jointly* ensuring food security, adaptation to climate change impacts and mitigation of greenhouse gas emissions. FACCE-JPI therefore focuses on research in the areas where agriculture, food security and climate change intersect. The aim is to provide expertise and tools for decision support to relevant European policies and initiatives through stimulating national research agendas, aligning research programmes, fostering collaboration within and between communities of researchers, funders and policy makers and stimulating knowledge transfer, education and training.

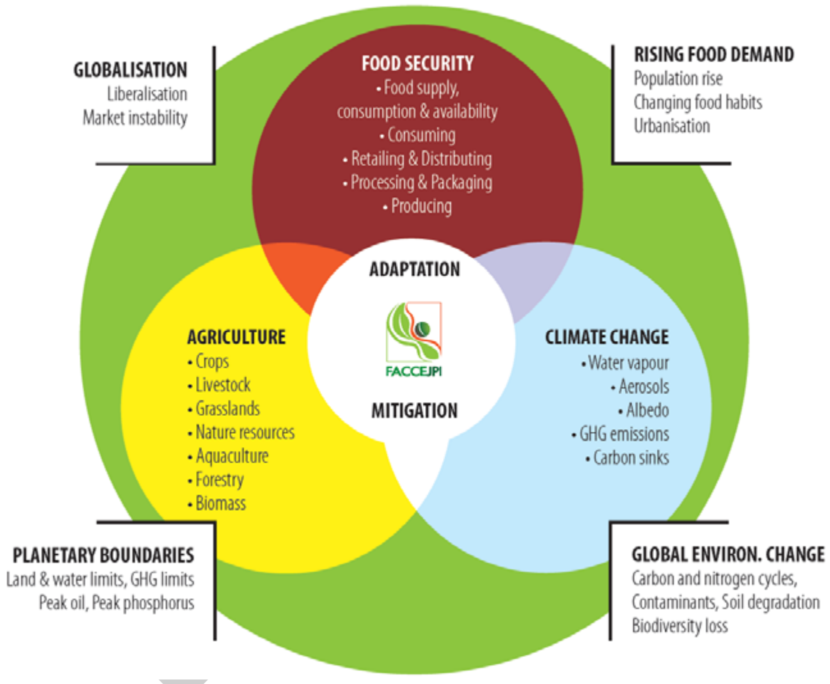
FACCE-JPI

Research-based initiative

Intersection of agri-food & CC

Alignment and collaboration

FACCE-JPI first developed a Strategic Research Agenda in 2012, which was refreshed in 2015. During that revision one of the priorities identified for research going forward was "*assembling existing (and emerging) technologies for primary production, fostering the adoption of improved technologies that are (on the edge of being) mature but not yet widely adopted*". Given the number of technologies which could have relevance to the aims of FACCE-JPI, the Governing Board (GB) decided to host a workshop to bring together experts on technologies in a number of key areas (identified by stakeholders) with members of the FACCE-JPI community to identify where investment should be targeted.



II) Objective: Expected outcomes and key questions

Objectives

Proposal of topics to be addressed by FACCE-JPI

Awareness rising

Mutual understanding of barriers

The FACCE-JPI workshop on technologies brings together researchers, stakeholders and policy makers and will deliver a report and recommendations identifying next steps to the FACCE-JPI GB. Expected outcomes are:

- A list of proposed key actions and topics to be potentially addressed by FACCE-JPI in its next Implementation Plan.
- Possible opportunities for networks on technologies to increase awareness within the agricultural research sector
- A better mutual understanding of the barriers and constraints which hinder the adoption of new technologies by the agricultural industry, stakeholder (groups) and farmers.

The **goals** and **key questions** of the workshop are:

Goals

Identification of:

- Technologies in the remit of FACCE-JPE

- Barriers

- Enablers

- Infrastructures & tools

- To identify the potential of technologies (cf. section IV) Technologies, state of the art, p 9) to contribute to the goals of FACCE-JPI (e.g. the intersection of agriculture, food security and climate change):
    - What can research add to the benefits of the technology i.e. does the technology need further research to enhance its potential impact or does it need adaptation for use in agriculture?
- To identify potential barriers to their adoption and how these could be explored through research:
    - Are the barriers associated with public perception, the economics of adoption, or mismatches between policies?
    - Is further research required to identify how these barriers could be removed?
- To identify crucial enablers to capitalize full potential of existing (and emerging) technologies from different perspectives:
    - If the potential of the technology is not well recognised who is best-placed to give it a higher profile with potential users?
    - Which partners are required in FACCE-JPI relevant research?
- To identify infrastructures and tools to be used by FACCE-JPI at joint action level:
    - Which resources, infrastructures, actions and activities do exist, and how can FACCE-JPI play an active role if necessary?
    - What sort of instrument is most appropriate e.g. a Knowledge Hub, a research call / ERA-NET, a follow-up workshop?

III) Key players: Technologies in agriculture – a multi-disciplinary and multi-stakeholder interrelation

Multi-disciplinary & multi-stakeholder approach

In the past decade technologies in the area of agriculture have made huge progress confronting farmers, advisors, supplying industry and policy makers with difficult choices. A complex system of interrelated processes and stakeholder groups throughout the agri-food chain does not simplify the decision process.

The following section describes in brief the perspective of different key players and lists potential key questions. All questions and key issues will be considered with regard to the intersection between agriculture, food security and climate change.

1) Policy perspective

Policy

Agricultural policy: a macromolecular approach facing uncertainties

In the past decade agricultural production has become a more complex system changing from a purely productive system into a macroeconomic approach. Agricultural policy has to consider employment stability and global trade relations at the same time as ensuring environmental sustainability, food safety and quality and animal welfare. The impact of agriculture on climate change (and vice versa) is alarming and needs to be reduced. However, policy makers are facing uncertainties of both the effects new technologies will have throughout the agri-food chain as well as the impact governmental decisions will have on the agricultural systems.

Key issues and questions from a policy perspective

- How can policy support the uptake of existing technologies by farmers to support the development of a more sustainable agricultural approach?
- Development of new technologies to support a climate-resilient agriculture and to maintain leadership in R&D globally
- Increase of transparency, food and feed-safety and trust between the different actors
- Are there opportunities to adopt European or national agricultural legislation to enable further uptake of technologies in the context of sustainable agriculture in an ERA of climate change?
- How can FACCE-JPI support policy makers in the European context to adapt their strategies?
- Are there opportunities for FACCE-JPI to collaborate with different (operational) groups to develop strategies to leverage the development and uptake of new technologies?

2) Research perspective

Research

Modern agricultural technologies can help to mitigate the influence of CC on agriculture and vice versa

More details cf. Section IV, p. 9

The following section gives an overview about the progress of agricultural technologies. A more detailed description can be found in section IV) Technologies, state of the art, p. 9.

Climate change will have significant influence on crop and livestock production and therefore places new demands on crop and livestock breeding and arising challenges in veterinary medicine. More *robust plants and animals, adapted to climate change and resistant to pests and diseases*, need to be developed. Additionally, the impact on the environment by livestock as a major producer of greenhouse gases must be decreased.

- Technologies in the context of altering biological material: plant and animal breeding technologies in agriculture
  - Animal and plant breeding technologies, which allow for much faster and more precise genome modification with limited side-effects. (e.g. SDN-1/-2, TALENs, and CRISPR/Cas9)

- Technologies, approaches and equipment in the context of LIVESTOCK. This includes automated phenotyping approaches, pharmaceuticals and disease monitoring, precision livestock farming (PLF)
  - Automated phenotyping approaches for a quick and affordable characterization of an immense number of phenotypes for desired properties in animals and livestock
  - Pharmaceuticals for livestock / veterinary medicine including drug development, disease monitoring, and geospatial prediction and monitoring of emerging pests and diseases

- Technologies and equipment for precision livestock farming (PLF): Sensors for collecting all sorts of physiological and environmental (grazing and buildings) data on livestock

- Technologies, approaches and equipment in the context of CROPS / ENVIRONMENT. This includes automated phenotyping approaches, sensor technologies, precision agriculture (PA)
  - Automated phenotyping approaches for a quick and affordable characterization of an immense number of phenotypes for desired properties in plants
  - Sensors for data collection about soil, water and condition of crops
  - Remote data collection as e.g. devices attached to UAVs or satellites, with focus on physical, chemical and biological characteristic of land, water and climate; integrative approaches as precision agriculture (PA)

Common to all technologies and approaches mentioned above is not only the need for a multidisciplinary approach including several stakeholders but also the necessity for common data standards and data sharing policies as well as sophisticated ways for data management.

Key questions associated with the research process:

- How to achieve a multi-disciplinary and multi-stakeholder approach to improve technology development and knowledge but also the implementation of existing technologies and approaches?
- How to increase the acceptance of new technologies by farmers and by consumers?
- How to improve the transnational collaboration and exchange between researchers?
- How to accelerate the implementation of new technologies in practice?
- Which ethical considerations must be taken into account?
- Which privacy issues concerning data generation and sharing need to be considered?
- Data issues in general (as e.g. lack of standards, limitations on the exchange of data between systems and machineries, costs for data processing, license fees, software and hardware products) will be addressed in the FACCE-JPI workshop on “big data”

3) Consumer’s perspective

Consumer

Acceptance of new agricultural technologies by consumers:

Uncertainties, trust and knowledge

With climate change being one of the major challenges of the 21st century today’s society is greatly sensitised to positive and negative effects of technologies to minimize the impact of human actions on the environment. Increased awareness and demand for protecting the nature and environment as well as for animal welfare are key drivers for consumer behaviour. Today’s society wants to have adequate information of products on the market, how and where they were produced and also what their impact on the environment is. With trade liberalisation such information is difficult to obtain. With regard to genetically modified (GM) food crops or animals the acceptance by society is still limited. There is an urgent need to build trust in the relevant regulations and to inform consumers and society clearly about all the benefits and the risks of novel approaches. The fact that climate change will affect local food production in terms of yield and quality and that landscape preservation alongside food quantity and quality can only be assured if modern agricultural technologies and approaches are put into place needs to be discussed in a more vivid and integrative way with the civil society.

Key concerns hindering the acceptance of new technologies by consumers:

- Can evidence provided by research enhance trust?
- How to build / increase trust in products / labels?
- How to encourage scientist and the society to join public debates to sensitize each other for respective needs and to strengthen trust?
- How can knowledge generated by research lead to better awareness of the interdependency of climate change and agriculture?
- Societal attitudes to new technologies could be improved by increasing the active participation of the society in data collection?

4) Farmer's perspective

Farmers today face a complex situation in managing their day-to-day business. The driver for investing in new technologies was largely determined by the increase of production, profits and productivity. Nowadays agriculture needs to be internationally competitive, produce agricultural products which are safe and of high quality, meets sustainability goals, whilst endeavouring to achieve an adequate economic return. In addition to being profitable, they need to meet standards and regulations, as well as dealing with direct and indirect consumer and lobby group pressures. Minimising the environmental impact and risk of agricultural production is still a low priority for the majority of farmers, whilst climate change will affect farming systems undoubtedly.

Farmers

A complex business facing regulation, profitability and CC risks

Access to training and education

However, it is clear, that market forces alone will not be able to accelerate the uptake of new technologies for eco-friendly agriculture on farms. Public policy must give incentives and an appropriate and clear policy framework to support the adoption of agriculture in an integrative manner. There is need to balance the level of voluntary approaches and legislation while ensuring consistency and coherency of the policy framework taking into account regional needs and objectives. Access to further education and training as well as the establishment of independent advisory and consultancy services are crucial steps to ensure a smooth introduction of new technologies. Uncertainties, the complexity of technologies, costs of equipment and devices, their incompatibility and the lack of profitability are major constraints for the adoption of new approaches at the farm level.

Key questions on how stakeholder participation in research could be enhanced:

- How can farmers be integrated into the development or improvement of new agricultural technologies?
- Is there an opportunity or even necessity for FACCE-JPI to collaborate with European / national Farm Advisory Services in providing support and advice to farmers with regard to new technologies?
- How can FACCE-JPI improve the awareness, knowledge and technology transfer of farmers?
- How can FACC-JPI improve the viability of new technologies in the remit of sustainable agriculture for European farmers?

5) Industry perspective

European companies have played, and continue to play, a prominent role in providing innovative solutions with advanced technologies and new concepts for ensuring food security, adaptation to climate change impacts and mitigation of greenhouse gas emissions. Challenges for industry include the development of systems that produce high-quality food and forage at the same time being efficient and complying with environmental acceptability and sustainability. However, continuous advances in science and technology have provided precise and robust tools with respect to plant and animal breeding, machineries, sensors and digital farming.

Industry

Driven by societal challenges, farmers and consumers;

Need to provide solution for high quality food and forage whilst complying with sustainable farming practices.

New breeding technologies, which enable a more efficient, more precise and faster progress in achieving the desired breeding goals, are rapidly being developed and utilised internationally and across sectors. High yielding crops of superior nutritional value that can be grown more resource efficiently are becoming more important for a sustainable, yet highly productive agriculture. With respect to the animal sector, which is confronted with antimicrobial resistance and increased attention for animal welfare, so-called industrial livestock farming has to become more sustainable to operate in a way that the societal challenges are being met.

Advances in breeding technologies are complemented by improvements in agricultural engineering and remote-sensing, improved biological knowledge and increased access to agricultural and environmental data which are all enabling rapid progresses in autonomous precision-farming. The combination of remote sensors, robotics, large-scale and real-time data analytics has a huge potential to enable timely and precise interventions to significantly increase the sustainability of farming.

Key questions associated with the industry perspective:

- How to increase the acceptance of new technologies by farmers and by consumers?
- How to foster the public debate about sustainable intensification of plant and animal breeding?
- How to further develop and improve relevant technologies (e.g. sensor technologies, engineering, breeding, etc.)?
- How can industrial agricultural production (especially livestock) become more sustainable?
- How to limit regulatory costs, accelerate approval processes and long timelines to enable particularly Europe's small and medium-sized companies to develop and use modern approaches, thereby increasing their competitiveness?
- What can FACCE-JPI do to facilitate the improvement and adoption of existing technologies?

IV) Technologies, state of the art

A) Technologies in the context of altering biological material: plant and animal breeding technologies in agriculture

(Text by Aleksandra Malyska, Heiner Niemann, Jan Venneman and Bruce Whitelaw)

Plant and animal breeding technologies

SDNs, TALENs, CRISPR/CAS9 enable efficient and precise genetically alterations;

Controversial technology with need for an improved multi-stakeholder dialogue

Climate change will have a significant influence on crop and livestock production and therefore change demands for crop and livestock breeding. More robust plants and animals, adapted to climate change and resistant to pests and diseases, need to be developed. Additionally, the impact on the environment by livestock as a major producer of greenhouse gases must be decreased.

New genome editing technologies allow for a much more targeted and thus faster breeding process by immediately and solely targeting one or more genetic loci, identified to be responsible for a useful trait in a suitable variety. Time-consuming back-crossings to breed out a potential multitude of unwanted mutations and traits are circumvented.

The application of site directed nucleases (SDNs) allows easy and efficient targeted genetic modification in plants and farm animals, including the production of SNPs, and could thus be useful in the development of precision breeding based sustainable concepts. The latest methods include Oligo - Directed Mutagenesis (ODM) and several Site - Directed Nucleases (such as SDN-1/-2, TALENs, and CRISPR/Cas9). Current knowledge indicates that application of SDNs is safe with regard to the edited plants, animals and the products thereof.

SDNs have been rapidly employed to produce genetically altered plants and animals for various agricultural and biomedical purposes. With regard to livestock, the application of SDNs improved disease resistance, growth performance and reproduction, facilitated the production of allergen-reduced or allergen-free animal derived products and improved animal welfare, i.e. by producing hornless cattle. In respect of plants, modern breeding with new concepts including exploitation of genome editing technologies, epigenetic changes (variations in gene expression without alteration of the DNA sequence) and genomic selection allow for developing new varieties with high yield, improved nutrient and water uptake, increased tolerance to extreme weather conditions and improved disease resistance. In turn, this will enable the development of production systems on marginal land as well as improve resource use efficiency and resource stewardship. Some of these results are directly related to the aims of FACCE-JPI.

One of the major challenges of genome editing approaches in crops and livestock is the acceptance by end-users such as farmers and consumers. However, issues such as climate change, food safety and the environmental impact of large-scale cultivation have raised awareness in the general public and might foster the communication between public, developers and policy.

B) Technologies, approaches and equipment in the context of LIVESTOCK. This includes automated phenotyping approaches, pharmaceuticals and disease monitoring, precision livestock farming (PLF)

B1) *Automated phenotyping approaches for a quick and affordable characterization of an immense number of phenotypes for desired properties in animals and livestock*
(text by Georg Thaller)

Livestock: automated phenotyping

Impact of livestock on CC and vice versa: Need for solid and harmonized measurements of multiple indicators to advance genetic selection of animals

Climate change is of growing concern and it is well known that livestock, especially ruminants, contribute substantial amounts of greenhouse gases to the atmosphere. Therefore, genetic selection for lower-emitting animals is an important greenhouse gas mitigation strategy. However, there is still a lack of sufficiently large datasets of individual animal measurements. Different techniques are available to measure/estimate methane output, e.g. breath measurements (for direct selection) and indicator traits like milk spectral data, archaeol concentration in faeces, and rumen microbial communities (for indirect selection). Many of the studied traits are expensive and/or difficult to record and to date there is no consensus on either the best way to measure methane output or the best phenotype to select for (methane in litres per day, methane in litres per kilogram of energy-corrected milk or dry matter intake etc.). Furthermore, genetic relationships between methane emissions and other important breeding goal traits need to be studied prior to setting up a new breeding program. International collaboration through projects like the COST Action METHAGENE bringing together experts from different disciplines (animal breeders, animal nutritionists, animal physiologists, rumen microbiologists, gas analysis experts and statisticians) is the key to solve this global problem in an effective way. Longitudinal studies under field conditions considering more than one proxy at a time are needed to compare and rate the different methods, particularly because it has also been suggested to combine different proxies to gain prediction accuracy. Such research projects should also take into account additional traits that are of interest for future breeding goals (e.g. tolerance to heat stress).

B2) *Pharmaceuticals for livestock*
(text by Stefan Schillberg and Stefanie Margraf)

Pharmaceuticals for livestock

Need for advanced development of sustainable drugs, sophisticated disease detection and improved monitoring

Climate change has an enormous impact on host-pathogen interaction: altered weather conditions, rising temperature, changes in drought and humidity or greater incidence of extreme weather fluctuation increase the susceptibility of animals to infection. In turn it also creates ecological niches for emerging diseases: distribution of pathogens and of parasites as vector for pathogens alters as does their amplification and persistence in novel habitats. Indirect effects, associated with climate-driven ecosystem changes or socio-cultural and behavioural adaptations, are expected to increase vector-pathogen-host contacts likewise. The rise in parasitic and infectious diseases will accelerate the use of veterinary drugs to improve welfare of farm animals and food security. Though, it represents a major threat with respect to accumulation of drugs in food and the selection of resistant pathogens. Therefore, challenges in veterinary medicine include the development of new drugs with improved efficacy and environmental sustainability as well as the early detection of diseases and the monitoring of drug application and mode of action:

Drug development and production

- Development of biopharmaceuticals with improved efficacy and environmental sustainability
- Recombinant pharmaceuticals including multi-subunit vaccines
- Cost-effective production of biopharmaceuticals
- Production of biopharmaceuticals in animal food crops at low cost, “edible” drugs (without the need of purification)

Disease monitoring

- On-site detection systems for fast and reliable detection of pathogens from farm to slaughterhouse

Monitoring of drug application and mode of action

- Monitoring and database system to collect data on drug application and mode of action with the aim to improve drug usage and to identify strategies to improve drug efficacy and application

A major challenge in the area of pharmaceuticals for livestock is the prediction of geospatial disease distributions in the context of climate change. Still, scientists are unable to predict whether new diseases will emerge into specific regions or not. Further investigations are needed to determine the interactions between climate change and the use of pharmaceuticals in livestock as well as a systematic approach for future drug application and disease management.

B3) *Technologies and equipment for precision livestock farming (PLF): Sensors for collecting all sorts of physiological and environmental (grazing and buildings) data on livestock*
(text by Stefanie Margraf)

Precision livestock farming

Automatic monitoring of livestock for an improved and integrated approach on animal (health) surveillance

Modern livestock production is a complex system facing numerous challenges simultaneously: animal health and welfare need to be considered equally alongside food safety, nutrition factors and affordable prices. Moreover, increasing regulations and reduction of the environmental impact of livestock need to be considered. Lastly, the production of animal products needs to be economically reasonable and profitable.

PLF is an integrated system approach and offers the advantage of continuous, automatic monitoring, modelling and respective warning and management to benefit all stakeholders of the supply chain including farmers, government and consumers to make better choices. Examples of monitoring livestock include measurements of the environment (i.e. temperature, humidity, air speed), physiology (i.e. body temperature, respiration rate, body weight) and behaviour (i.e. feed/water intake, movement and activity). Modern, wireless data transmission enables easy and affordable transfer of data captured by sensors to smart phones or computer devices, which will help the farmer to make precise decisions and take action. Though livestock farming is considered the main producer of GHGs such as methane and nitrous oxide, automatic monitoring of their production is still problematic. Accurate and reliable measurements depend on continuous monitoring of flow rate and gas concentration, which is considered too expensive and complex for routine use in livestock. Furthermore the variety of production systems as e.g. mixed and grazing systems for dairy cattle requires individual tailored monitoring systems.

Besides the fact that sensing technologies are reasonably developed, PLF faces the challenge of active integration into running farms and not to stop at the experimental stage or being applied on pioneering farms. Thereby various disciplines need to be involved in the process including farming, agriculture, engineering and mathematics but also stakeholders such as consumers, government and regulatory agencies to define standards, needs and concepts for PLF.

C) Technologies, approaches and equipment in the context of CROPS / ENVIRONMENT. This includes automated phenotyping approaches, sensor technologies, precision agriculture (PA)

C1) *Automated phenotyping approaches for a quick and affordable characterization of an immense number of phenotypes for desired properties in plants*
(text by Ulrich Schurr)

The phenotype of a plant or a plant stand/ community develops from the dynamic interaction between the existing plant and the spatially and temporally variable environment within the present genetic competence. Climate change will affect the environment of plants significantly: it is not only expected that e.g. mean values of temperatures or rainfall will change, but also the dynamics of environmental factors in extreme and less extreme conditions.

In recent years, novel phenotyping technologies using non-invasive technology are becoming increasingly available. These devices with sensors using the entire electromagnetic spectrum often allow imaging plant structure, function and environmental conditions and their dynamics. Such quantitative data are the pre-requisite to understand dynamic plant-environment interactions in crops as well as in natural vegetation, to develop ideotypes that can be used by breeders to design cultivars that are more resilience to stress, to improve resource use efficiency in modern cultivars, and to predict adaptation of plant communities to climate change.

The portfolio of phenotyping technology is vast: it includes high-tech systems using tomographic devices in a highly controlled environment, as well as high-throughput systems to increase the speed of analysis in lab, greenhouses and field that are combined with dynamic environmental simulation and analysis. Very recently, low cost systems based on smartphones and other cheap and portable devices are becoming increasingly available. They will also allow novel approaches to phenotype environmental impact of crops and natural communities - extending even into citizen sciences approaches requesting big data analytics.

Crops/plants: automated phenotyping

Progress in technology useful for breeders to measure physical characteristics of plants;

Need for multi-disciplinary and multi-dimensional approach

C2) *Sensors for data collection about soil, water and condition of crops*
(text by Bruce Grieve)

The measurement of soil moisture, to maintain healthy soils, is not simply a measure of water content but the combination of moisture with the major nutrients (notably N, P & K). This is both critical to the efficient production of crops as well as the management of greenhouse gas emissions (GHG) and flood risk. Over usage of N fertilisers results in the excess N being converted to NO2 which is one of the most potent GHGs. Further contributors to loss of soil health are the infiltration of the ground water with river water as well as flood risk and environmental damage from nutrient run-off into the surrounding water courses.

Sensor technologies

Soil moisture and nutrient composition measurements: complicated approaches, which need to be integrated into existing technologies

Soil moisture is typically measured directly through fixed sensors that detect physical changes or electrical factors. The latter techniques have the potential to infer nutrient content in the soil electrolyte. Various, sophisticated measurement techniques are mandatory to analyse soil biology as moisture is held disparately in the various soil types and solubility of nutrients varies. In addition to laboratory analysis of soil moisture and composition, the three dimensional soil moisture content can be captured by techniques such as motile ground penetrating radar or by fixed sensor systems i.e. Electrical Impedance Tomography (EIT), the latter also inferring abiotic stresses caused by nutrient and / or water deficiencies or excesses. Further indirect measurements i.e. by measuring the turgor pressure with plant leaves or multispectral effects of soil moisture on foliage complete the list. The latter is a complex relationship, which requires significant metadata, however they have the advantage that they may be measured remotely by satellites or air-borne sensors.

As a consequence, the future development of soil moisture and nutrient composition measurements may be influenced by existing networks in remote sensing, and by the mass deployment of low cost sensors, through networks such as the IAgrE Internet of Things (IoT) Network and similar European bodies. An integrative approach including farmers, agriculturists and scientists is needed to increase knowledge about soil quality globally and to further improve soil quality and farm productivity and to mitigate climate change.

C3) *Remote data collection on field / farm level via UAVs (unmanned aerial vehicles), satellites, planes (text by Stefanie Margraf and Uwe Rascher)*

Remote sensing technologies and precision agriculture

Vast portfolio of detection techniques via UAVs, aircrafts, farm vehicles and satellites

Need for better integration on farm level plus improved data access and compatibility

In the past decades sensor technologies developed rapidly resulting in increased knowledge about physical, chemical and biological characteristics of land, water and climate. Remote sensing (data acquisition of objects or phenomena without having physical contact with the object of study) can produce precise data of e.g. air and soil temperature, humidity, crop height, plant width and diameter, wind conditions, and more. Devices are often attached to equipment such as UAVs (i.e. drones), aircrafts but also to farm vehicles to collect data at ground level. Geo-positioning via Global Navigation Satellite Systems (GNSS, e.g. the European GPS) and data collection via satellites have further modernised farming, data collection and climate projections. Especially satellites, such as the Sentinel-2 satellites (c.f. ESA/EU programme www.copernicus.eu/), which focus on vegetation observation, generate an unprecedented source of global vegetation data. In combination with ground based data, generated locally and compiled by phenotyping networks as e.g. IPPN, high performance information on plant functional traits will become available in selected areas.

In recent years remote sensing technologies became more reliable and affordable, leading to an increased usage at the farm level. The combination of sophisticated sensor technologies with farming practices facilitates site-specific agricultural management that is often termed Precision Agriculture (PA). PA aims to optimise production and quality resulting in economic benefit for the farmer while simultaneously minimising environmental impact and risk. For instance, selective pesticide or fertilizer application to specific areas of need reduces cost while protecting soil, water, biodiversity and climate, thus resulting in a more sustainable agricultural management. However, PA profitability is critical to the adoption decision by farmers. Currently, profitability cannot be demonstrated in all cases under all scenarios. For instance, cost-effectiveness often requires a minimum farm size to depreciate the investments over the entire farm.

The potential of remote sensing in agriculture is immense. Still, barriers and absence of driving factors hinder the optimal utilization of these technologies: Barriers in research technology comprise the integration of data generated locally / ground based with satellite data, inter-comparability and lack of standardisation, limits in spatial resolution, access to remote sensing data, big data handling as well as the absence of a strategy to bundle knowledge and technological developments. Obstacles in PA include limited knowledge of the cost-benefit aspects, lack of awareness, technical experience and advisory services. The integration of key players and different stakeholders (scientists, policy makers, farmers and land managers) will be crucial to increase scientific, economic, environmental and even social benefits reciprocally.

ANNEX 1: Existing initiatives

This Annex is a non-exhaustive list of relevant initiatives and (stakeholder) networks in the context of technologies FACCE-JPI could work with or should be aware of. Representatives of them will be present at the workshop to help identifying possible ways for collaborations. Further initiatives, networks and enablers and the mode of action how FACCE-JPI can collaborate with them shall be identified during the workshop.

COPA-COGECA[1] **-** The first European representative organisation to be created, COPA-COGECA represents the European farmers and agricooperatives in Brussels and promotes collaboration between the agricultural sector and the European institutions. COPA-COGECA is member of the FACCE-JPI StAB. http://www.copa-cogeca.be

EIP-AGRI[1] – The European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) works to foster competitive and sustainable farming and forestry that 'achieves more and better from less'. Its Focus Groups are temporary groups of selected experts focusing on a specific subject, sharing knowledge and experience and tackling questions from different angles. Thematic intersections within the field of technology are e.g. the focus group on livestock emissions, on precision farming and on water and agriculture. Furthermore, EIP-AGRI launches thematic networks, which are multi-actor projects collecting existing knowledge and best practices on a given theme to make it available in easily understandable formats for end -users such as farmers, foresters, advisors etc. https://ec.europa.eu/eip/agriculture/en

EMPHASIS[2] **-** ESFRI has identified "Plant Phenotyping" as a priority for the European research area and EMPHASIS has been listed on the ESFRI Roadmap as an infrastructure project to develop and implement a pan-European plant phenotyping infrastructure. Within EMPHASIS European partners from academia and industry are working together. Existing national and European phenotyping networks are integrated in this program. http://emphasis.plant-phenotyping.eu/

EU-PLF - Precision Livestock Farming (PLF) could assist livestock producers through automated, continuous monitoring of the animals. The observation data can be translated into key indicators on animal welfare, animal health, productivity and environmental impact. A number of PLF tools have been developed at laboratory levels and as prototypes. The project has allowed the development of new business models while linking high tech SME's to European industry players to create new PLF-products with global impact. http://www.eu-plf.eu/

The European Technology Platform 'Plants for the Future' (Plant ETP)[3] **-** Plant ETP is a stakeholder forum for the plant sector with members from industry, academia and the farming community and serves as a platform for all stakeholders concerned with plants. Plant ETP produced a Strategic Research Agenda4 for Europe's plant sector, sets up strategic action plans to promote Innovation, Research and Education in the plant sector and brings key issues to the attention of European bodies such as the European Commission and the European Parliament. Plant ETP is member of the FACCE-JPI StAB. www.plantetp.org/

Farm Animal Breeding and Reproduction Technology Platform (FABRE-TP)[3] - FABRE TP promotes research and innovation for sustainable animal breeding and reproduction in Europe. The platform brings together key stakeholders around a common vision for the development of technologies and practises around farm animal breeding and reproduction. FABRE TP is member of the FACCE-JPI StAB. http://www.fabretp.eu/

ICT-AGRI 'ICT and robotics for sustainable agriculture'[3] **-** The overall goal of ICT-AGRI is to strengthen the European research within the diverse area of precision farming and develop a common European research agenda concerning ICT and robotics in agriculture, and to follow up with calls based on funds from the participating countries' national research programmes. The purpose is to pool fragmented human and financial resources, in order to improve both the efficiency and the effectiveness of Europe's research efforts. http://ict-agri.eu/

[1] Attendance tbc.
[2] Attendance confirmed
[3] Member of the working group, attendance confirmed

Internet of Food and Farm 2020[1]: Large-scale project granted €30 million from Horizon 2020 to foster a large-scale take-up of Internet of Things (IoT) technologies in the European farming and food value chain in the next 4 years. It will consolidate Europe's leading position in the global IoT industry by fostering a symbiotic ecosystem of farmers, food industry, technology providers and research institutes. The project brings together 73 partners from 16 countries under the coordination of Wageningen University & Research. https://iof2020.eu/iof/iof2020

TP Organics, European Technology Platform for organic food & farming research – TP Organics integrates views of the organic sector and civil society to represent a broad perspective on research and development priorities that can leverage organic food and farming's potential to address contemporary challenges. As other European Technology Platforms (ETP) TP Organics plays a key role in highlighting where the focus of research and development funding should be placed. TP Organics is member of the FACCE-JPI StAB. http://tporganics.eu/

[1] Attendance tbc.

ANNEX 3: Working group members and contributors

FACCE-JPI working group members

Governing Board	Niels Gøtke	Danish Agency for Science, Technology and Innovation, DK
Scientific Advisory Board (SAB)	Maggie Gill	University of Aberdeen, UK
Stakeholder Advisory Board (StAB)	Aleksandra Malyska	European Technology Platform (ETP) 'Plants for the Future'
Stakeholder Advisory Board (StAB)	Jan Venneman	Farm Animal Breeding and Reproduction Technology Platform (FABRE-TP) (ETP) (EFFAB)
Secretariat lead	Stefanie Margraf	Project Management JUELICH, DE
Secretariat support	Paul Wiley	Biotechnology and Biological Sciences Research Council (BBSRC), UK
Secretariat support	Nicolas Tinois	Project Management JUELICH, DE
Additional support	Stefan Lampel	Project Management JUELICH, DE

External contributors

Bruce Grieve	University of Manchester (UK); Director of the e-Agri Sensors Centre; Chair and Academic Lead for Manchester
Heiner Niemann	Institute of Farm Animal Genetics, Federal Research Institute for Animal Health (DE), Director
Uwe Rascher	Research Centre Juelich (DE), Head of research area Ecosystem Dynamics
Stefan Schillberg	Fraunhofer Institute for Molecular Biology and Applied Ecology, Head of Division Molecular Biology
Ulrich Schurr	Research Centre Juelich (DE); EPPN, EMPHASIS, DPPN coordinator, IPPN
Georg Thaller	Christian-Albrechts-Universität zu Kiel (DE), Institut für Tierzucht und Tierhaltung (Institute for animal breeding and welfare)

Workshop on Technologies:

Fostering the adoption of existing (and emerging) technologies for primary production in the context of climate change that are on the edge of being mature but not yet widely adopted

21 November 2017, Copenhagen, DK

ANNEX 4: Agenda

08:30 – 09:00	***Registration - Coffee***
09:00 – 09:15	**Introduction**
15’	**Welcome, Introduction to FACCE-JPI and aims of the workshop** *Niels Gøtke, FACCE-JPI Governing Board; Hartmut Stalb, FACCE-JPI Chair*
09:15 – 10:15	**Setting the scene I** *(each: 15’ presentation, 5’ discussion)*
60’	**Policy perspective** *Valeria Forlin, European Commission, DG Clima* **Farmer’s perspective** *Hans Roust Thysen, Copa and Cogeca* **Society perspective: How are new technologies /approaches accepted by the society?** *Dr. Armin Spök, STS – Department and Technology Studies, Alpen-Adria-Universität Klagenfurt/Vienna/Graz, Austria*
10:15 – 10:45	***Coffee***
10:45 - 12:30	**Break-out group, session I: gaps, potential, priorities**
15’	Setting the scene II: Technologies - Research perspective
75’	What are major needs for each technology with respect to driving forces / context (e.g. research, networks, integration of key players, etc.)?
15’	Prioritize needs / requirements
12:30 – 13:30	***Lunch***
13:30 - 14:30	**Presentation of results**
60’	*Presentation of results*
14:30 - 15:15	**Break-out group, session II: Mapping**
45’	*Map existing resources, existing actions and activities / identify enablers*
15:15 – 15:45	***Coffee* + prioritize technologies**
15:45 - 16:30	**Break-out group, session III: possibilities for FACCE-JPI**
45’	*Identify possibilities for FACCE-JPI to get involved / to launch new actions*
16:30 - 17:30	**Common discussion**
60’	
17:30 – 18:00	**Wrap up**

Chair: Professor Margaret Gill, Professor of Integrated Land Use at the University of Aberdeen, Chair of the FACCE-JPI Scientific Advisory Board

Moderator Group 1 “Crops& Environment”: Professor Katharina Helming, Head of Research Group Impact Assessment, Leibniz Centre for Agricultural Landscape Research (ZALF), Germany