Responsible Research and Innovation (RRI) in Plant Sciences.

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Zurich-Basel Plant Science Center

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Social transformation through innovation and research is a key element in the discussion as to how the global community can overcome its complex problems related to environmental and economic constraints in a resource-limited world. Innovation conflicts arise when transformation is mainly technology-driven and does not take up ethical, legal and social issues. In response, scientists are today being asked to play a role in the science-in-society dialogue.

Providing food security both in calories and nutrients for a predicted global population of 9.3 billion people by 2050, while at the same time dealing with scarce resources and environmental limitations, is a challenge that plant scientists currently have to face. It can only be solved by enhancing both crop productivity and crop nutrient content together with establishing agro-ecological approaches. However, scientific inputs need to be better integrated with the social, environmental, economic and political factors that influence progress or failure in building sustainable food systems (Ingram, 2015).

Recent technological innovations and developments – e.g. genome editing, large-scale genomics and phenomics, artificial intelligence and machine learning – are taking place in plant breeding technology and smart farming. They promise increased efficiency in the use of resources, closing the gaps between crop physiology and productivity and increasing the resistance of crop plants to major pest outbreaks. However, these new technological systems will also change existing farming practices and interact with the organization of the food value chain. Plant scientists need to consider the boundaries between technological developments and the human, social and environmental systems that these innovations interact with. They need to approach the implementation of their research from a social inquiry rather than a disciplinary angle. This means engaging in deliberation and dialogue to ascertain the values of those involved and uncover existing value tensions between individuals, researchers and stakeholders. Responsible science must take account of these tensions and develop measures to bridge them.

In the context of ongoing attempts to strengthen the responsiveness of research and innovation to societal needs and values – most recently within the framework of Responsible Research and Innovation (RRI) – scientists have been called upon to 'integrate broader societal considerations in their work'. But for all the compelling rhetoric, what does this actually mean at the level of day-to-day research? What sort of considerations are we talking about? Whose considerations are they? And how should they be applied to research?

Scientific and technological practices are certainly evolving to include more productive integration of societal considerations. But change is slow. The notion of the 'Two Cultures' – the divide between the sciences and humanities – introduced by British physicist C.P. Snow in his 1959 Reed Lecture (Snow, 1959) has not lost its relevance. In fact, the two cultures seem to be more thoroughly separated than ever with respect to topics addressed, questions asked, methods used, and worldviews. The number of exploratory collaborations between natural scientists, engineers, and social and human scientists may be increasing (Gorman et al., 2004; Schuurbiers and Fisher, 2009); however, due to longstanding institutional arrangements and educational structures that have fostered a 'laissez-faire' attitude to engagement with the broader implications of science (Beckwith and Huang, 2005; Mitcham, 2003), reflection on the social dimensions of research does not form an integral part of lived laboratory practice.

The laboratory is in many ways still a protected space, in which (especially young) researchers are effectively shielded from outside pressures by their lab directors (Rip, 2003). As the careers of young researchers still largely depend on publications in traditional – mostly monodisciplinary – journals, they often see broader societal considerations of their work as a digression from their demanding scientific curricula. They may well feel a responsibility for the broader societal impacts of their work, but they do not consider it to be their core business. The challenge for educational programs that aim to raise the level of attention to RRI issues is, therefore, to demonstrate the added value of social and ethical reflection for the researcher's own work.

In the Summer School we asked how RRI could allow early-stage researchers to participate in the ongoing public debate on plant breeding and agricultural digitization. The following recommendations were made:

- Scientists are increasingly aware that the so-called 'deficit model' of communication, where the decline of public trust in technological innovation is thought to be due to a lack of knowledge on the part of the public – and the resulting solution is hence to educate citizens into acceptance – is deeply flawed. Science can only find solutions to the major societal challenges of our time if it makes people partners in knowledge generation and exchange through processes of participation, and if it includes a correspondingly broad range of voices in decision-making.

- This requires the involvement of scientists in the social debate. Societal debate arises when people's values, needs and concerns are involved in decision-making. Scientists need to engage with the values of those targeted by their research to be able to **anticipate**, **reflect**, **deliberate**, and **respond**. This interaction can occur anywhere: in the laboratory, at the design table, or in the policy room; and it can operate at different levels: individually, in a network or community, or within political or institutional systems.

- Scientists must open themselves to the different worldviews and knowledge systems of stakeholders and citizens. In our experience early-stage researchers in natural science need encouragement that this is the right thing to do.

- Citizen participation in science can be a powerful tool: It can bridge the distance between the academic world and society at large. It can be used as a way to generate new solutions that would not be possible without social inquiry. It can serve as a benchmark for the relevance of ideas. These experiences can be used to integrate value-based designs and design thinking in research and innovation.

In our training sessions we regularly ask students what preparation they think is most relevant for carrying out science-in-society dialogue. Most frequently PhD students ask for advice in communicating research in an understandable, meaningful, respectful and honest way to different target audiences. They need practice in facilitating dialogue through open questions. They need insights into methods and tools to stimulate dialogue, deliberation and participation.

Our recommendation is that PhD students in the natural sciences should be allowed to spend 30% of their time in a 48-month fellowship on activities outside research work (= lab time, analysis, and publication). This 30% will include engaging in science-in-society activities and boundary work, training in curricular PhD programs, visiting summer schools, and internships with non-academic partners from the science-society interface or from industry.

Formats for teaching science-in-society methods include summer schools and other recurring workshop types, but also classes within a curricular PhD program.

Since 2010 the Zurich-Basel Plant Science Center has organized summer schools on tackling global challenges such as food security, sustainable transitions in agriculture, resilience in ecosystems and systemic risks.
The Zurich-Basel Plant Science Center has different training workshops on offer that increase students' capacity to act as socially engaged scientists and undertake science diplomacy beside their technical specializations. Students acquire a portfolio of competencies and skills for implementing Responsible Research and Innovation (RRI) and for evidence-based policymaking. The training workshops are part of the specialized *PhD Program Science and Policy* – a unique training program for researchers in the life sciences familiar to carry out science-policy and science-society dialogue.

https://www.plantsciences.uzh.ch/en/teaching.html

Outline of the Proceedings

In **Part 1** of these Proceedings, **Melanie Paschke** and **Daan Schuurbiers** introduce the concept of RRI. They argue that it is important to create spaces where science-society issues are negotiated through expression, participation and deliberation, and where scientists function no longer merely as experts, but also as partners and facilitators in social inquiry and the co-production of knowledge.
In general, technological development should take account of underlying values and norms. There are, for example, ways of making such values visible and transparent for different stakeholder groups in controversial current technological developments in the plant sciences. In this context, **Gregory Grin** introduces design thinking and summarizes the outcome of a workshop that used design thinking to develop ideas and concepts for a precision farming product.

Part 2 of the Proceedings is devoted to different stakeholder perspectives and related needs, values and concerns. Three case studies from the plant sciences are presented:

- Smart farming: **Franco Conci, Manuel Nolte, Seydinaissa Diop, Camilo Chiang**.
- Rewilding of crop plants: **Claudio Cropano, Daniel Grogg, Parfait Kezimana, Ina Schlathölter**.
- Charcoal from tropical forests: **Giacomo Potente, Florian Cueni, Maximilian Vogt**.

The following questions are addressed:

- How can societal considerations be integrated in case studies?
- What stakeholders are connected to cases studies: Who are they? How do they relate to your work? What are their questions, knowledge requirements and possible concerns?
- How can scientists address their needs, values and concerns through anticipation, reflection, deliberation and responsiveness? How can these questions be incorporated into the work of early-stage researchers?

A background article by **Foteini Zampati** provides guidelines and hands-on information on open data use in agriculture. However, RRI is also a narrative driven by case studies and role models that enable other researchers to follow suit. **Christine Rösch** summarizes lessons learnt from best practices in agro-photovoltaics.

In **Part 3** of the Proceedings, abstracts of all keynote lectures and workshops are available including the reference literature.

Editors and Keynote Authors

Melanie Paschke heads the education and science-policy section of the Zurich-Basel Plant Science Center. She has a PhD in ecology and environmental sciences, has led and supervised the development of higher education programs for more than ten years. She has a record of accomplishment as an educator and facilitator in several areas of sustainable development and system thinking. Her focus is on ethical and social inquiry in the plant sciences.

Daan Schuurbiers is director of DPF, a Dutch consultancy for responsible innovation. Throughout his research and advisory work he has encouraged early reflection on the possible social impacts of emerging technologies. He designs training courses for researchers, builds novel interdisciplinary collaborations, advises on research policy, and regularly speaks at conferences to raise the awareness of researchers for the broader societal dimensions of their work.

Manuela Dahinden heads the research and outreach section of the Zurich-Basel Plant Science Center. She has a PhD in molecular biology and expertise in management of international and public-private research programs. She is editor of several plant science-related newsletter, blogs, websites and social media channels, and organizer of symposia, public round tables and public engagement programs.

Grégory Grin is managing director of Fri Up, the official support organization for business start-ups in the Canton of Fribourg. As a non-profit organization, Fri Up welcomes projects from their very early stages and offers free-of-charge, field-oriented, and personalized support. He is a seasoned expert in design thinking, which he uses to support start-ups and large organizations in the development of new business ideas. He lectures on design thinking in several executive MBA and Master's programs in Switzerland. Grégory Grin holds an MSc in Information Technology from the University of Versailles and graduated in General Management from Harvard Business School.

Foteini Zampati is a data rights research specialist at Global Open Data for Agriculture and Nutrition (GODAN). She is based in Darmstadt at the Association for Technology and Structures in Agriculture (KTBL). KTBL is supported by the German Federal Ministry of Food and Agriculture. She is a legal professional with over 17 years' experience in legal counseling. She holds a Master's degree in European Union Law and European Business Law. As an expert on ethical and legal aspects of open data, she is currently participating in a GODAN initiative project to ensure fair distribution of the benefits of (open) data and increase motivation for the use of open data in agriculture. Project partners are GODAN, KTBL and the Centre for Agriculture and Biosciences International (CABI).

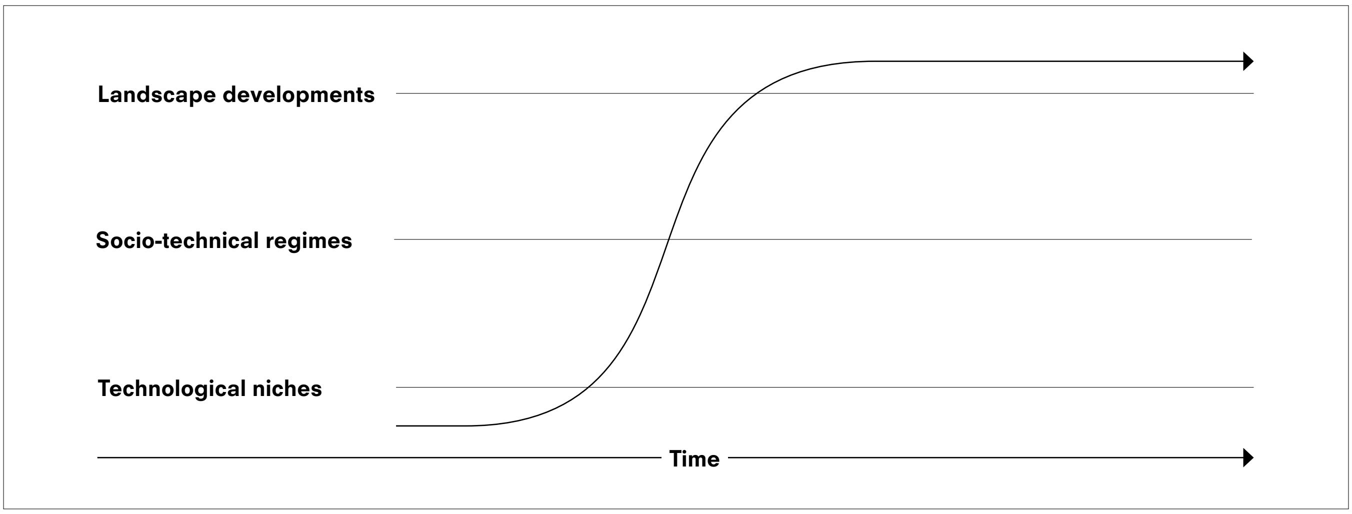
Christine Rösch was trained as an agricultural biologist and graduated from the University of Hohenheim. She is head of the research group "Sustainable Bioeconomy" at the Institute of Technology Assessment and Systems Analysis (ITAS), one of the major institutes of the Karlsruhe Institute of Technology (KIT). Most of her scientific work deals with technology and sustainability assessment in the field of bioeconomy and energy. Her inter- and transdisciplinary research comprises techno-economic, environmental and social investigations. In the APV-RESOLA research project, she was in charge of the involvement of citizens and stakeholders in the responsible design of the agrophotovoltaics technology.

Part 1
Introduction, Theory and Tools

Technological transition: how innovation transforms society – and vice versa

For Beck (2017) the translation of science into innovation would contribute to solving current societal challenges and transforming society. He saw this in terms of science laboratories creating experimental technologies that, for better or worse, would open up avenues of metamorphosis for human societies. A key question was, therefore, whether we can as a society control these new technologies and innovations so that the metamorphosis is for the better, not for the worse. Schot and Rip (1996) had already suggested the need for intervention in the research trajectory through Constructive Technology Assessment (CTA) as one element in the social shaping of technological innovation: "Clearly, to come closer to the original goal of achieving better technologies (in a better society), a concerted attempt at feedback into decision-making, and strategies of technology actors and other forms of leverage are an important next step."
Logical as that may sound, the adaptation of technological innovation to societal issues turns out to be far from self-evident. The dilemma was described by Collingridge (1980) in *The Social Control of Technology:* The consequences of technologies in terms of risks to human health and the environment might be foreseeable at an early stage, but their wider societal consequences even in the near future are hard if not impossible to predict. New technologies can change cultural values and regulatory structures, as well as responsibilities and institutions in a process that can be described as systemic response. A socio-technical system may exist in one configuration for a period of time but can be knocked into a different configuration by a perturbation or regime shift. Geels's (2002) multi-level perspective on technological transition illustrates the idea of sudden non-linear change that can result in a new technology landscape after a tipping point has been passed (Figure 1). In this multi-level perspective, established technologies might be locked in by the regime, due to economic and other path dependencies, even if alternatives might be more advantageous. It is difficult for new technologies to establish themselves in the landscape, because regulations, infrastructures, user practices, and maintenance networks are aligned to existing technologies. They are locked out by the established socio-institutional framework. The regime is resilient against changes and perturbations, whether these are for better or worse. For a transition, these measures need to change and to support the development of a new socio-technical regime and need to stabilize the newly developed landscape.

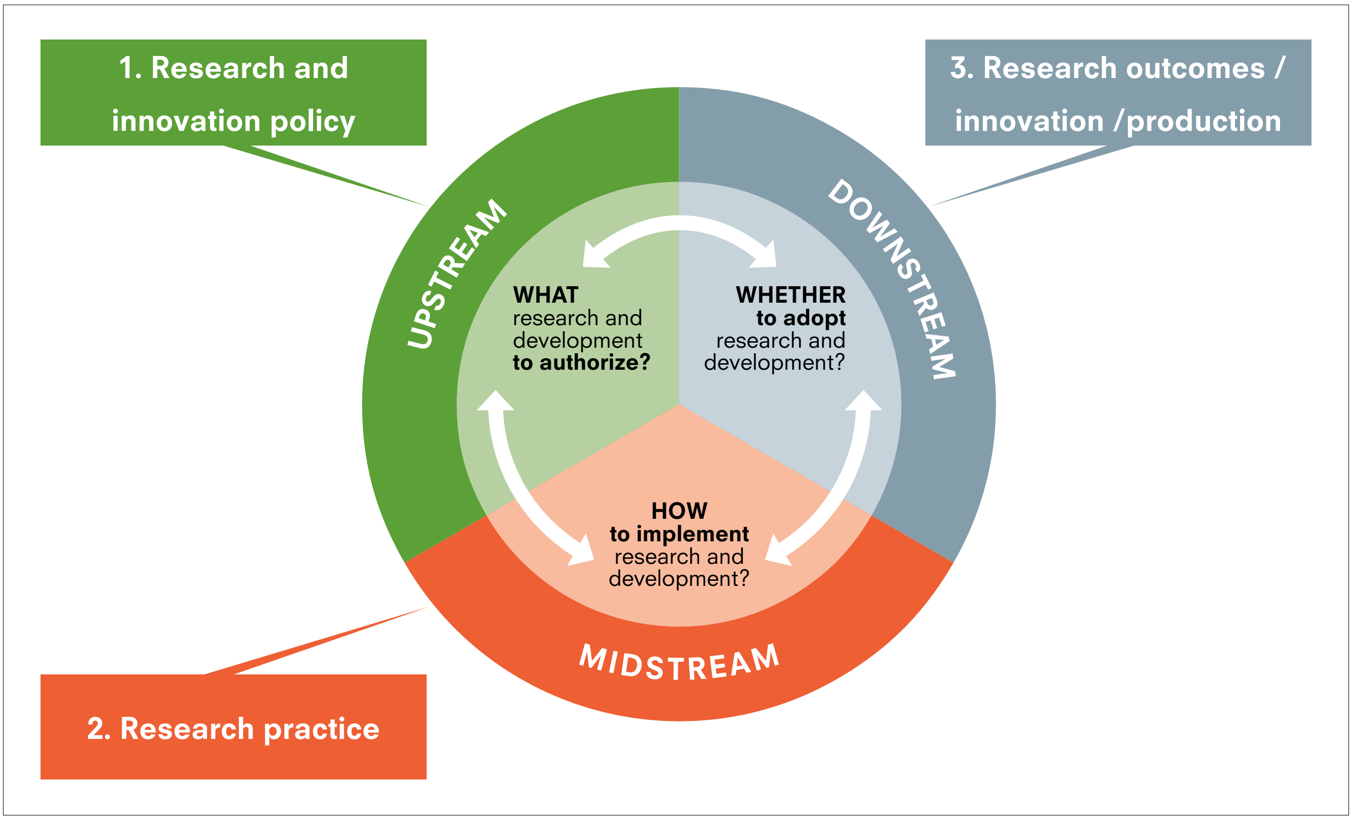
Figure 1. Transition of socio-technical systems from a multi-level perspective (Geels, 2002). Existing socio-technical regimes and responding landscapes are often resistant to change through buffering measures, i.e. industrial networks, existing techno-scientific knowledge, culture and symbolic meaning of existing technologies (e.g. the car), existing infrastructures (e.g. energy stations), sectoral policies, markets and user practices.



Despite the resilience of socio-technical systems, there is a rich history of approaches aiming to attune technological trajectories to societal considerations (Schuurbiers et al., 2013). These approaches operate at three different levels:

- By explicitly integrating social and environmental considerations in setting priorities for research.
- By opening up research decision making to a broader range of voices.
- By including social and environmental indicators beyond economic growth and competitiveness in the appraisal of technologies.

Figure 2. Areas of intervention for innovation governance (adapted from Schuurbiers & Fisher, 2009).



The concept of RRI

Responsible Research and Innovation (RRI) is a current approach to mediating science-to-society boundaries through anticipation, reflection, deliberation, inclusion and responsiveness (Horizon, 2020). Since 2011, the notion of RRI has gained traction both as a field of academic inquiry and as a key objective of European and national research policies. Academically, the concept is rooted in different traditions, including Constructive Technology Assessment (CTA), anticipatory governance, and studies of the Ethical, Legal, and Social Aspects (ELSA) of science and technology. Various definitions exist in academic discourse on RRI, but they share an emphasis on anticipation, inclusion, reflection and responsiveness (Stilgoe, Owen and Macnaghten, 2013). RRI builds on existing conceptions of early engagement (Schuurbiers et al., 2013) and seeks to move beyond reflection on consequences toward the societal uptake of innovation and technology (Von Schomberg, 2011). Rather than seeking to protect society against unwanted consequences, RRI aims, through the use of technologies, to produce innovations that address societal needs and values. Thus, in RRI design processes can be implemented – e.g. value-sensitive design – that take into consideration the values, needs and beliefs of those targeted by the technology in question (Friedman and Kahn, 2003).

The science-society boundary has been framed in different ways in recent centuries and decades (Stilgoe et al., 2013). Felt et al. (2013) described how our view of this divide shifted from science-*with*-society to science-*in*-society. In the first perspective, science held the primacy over society: Scientists aimed to generate solutions for society, to try them out (with the support of policymakers), and then evaluate them (Hoppe, 2005). In contrast, science-in-society links the terms together as partners who, through social inquiry, collaboratively generate new solutions to environmental, societal and economic problems. The knowledge thus created is produced by different actors, all of whom are committed to the fulfillment of societal needs. Citizens and stakeholders are welcome to express their values and interests in scientific, technological and innovation choices. Ethical, legal and social considerations are seen not as constraints, but as drivers of research and innovation. By working to re-design innovations to societal needs, they contribute to the realization of societal objectives.

RRI has a different understanding of the role of scientists. Scientists can mediate in the processes of social inquiry. They can contribute to different solutions and policy options through scientific evidence, models and scenarios, and they can share with society the responsibilities of interpretation, implementation and decision-making (Figure 2).

Science-in-society focuses on creating spaces where science-society issues can be negotiated through expression, participation and deliberation (Felt et al., 2013). Engaging societal actors is seen as a way to respond to public criticism and the erosion of trust in scientific self-governance. Crucial areas here are the ethical and social implications of scientific and technological research and innovation, exemplified in much publicized debates about the risks involved (Felt et al., 2008).

With the European Research Framework Program Horizon 2020, RRI became a cross-cutting issue (Van Schomberg, 2013). The framework includes several key points (Owen et al., 2012):

- **Anticipation:** describing and analyzing both intended and unintended impacts of research and innovation, whether economic, social, environmental or ethical.
- **Reflection:** on the underlying purposes, motivation, and potential impacts of research; what is known and what is not known; associated uncertainties, risks, areas of ignorance, assumptions, questions, and very important, of the underlying values of our research.
- **Deliberation:** opening up visions, purposes, questions and dilemmas to broad, collective deliberation. Facilitated through processes of dialogue, engagement and debate; inviting and listening to wider perspectives from public and stakeholders; achieving a consent on values and values hierarchies.
- **Responsiveness:** using this collective process of reflection to both (1) set the direction and (2) influence the subsequent trajectory and pace of innovation, through effective mechanisms of participatory and anticipatory governance. Also use widely endorsed values as the guiding principles of technological development.

Deliberation is seen as an especially important concept in RRI because it broadens societal perspectives and their inclusiveness. Deliberative formats and processes should maximize the decision-making power of those involved and enhance the responsiveness and accountability of scientists toward the needs, values and expectations of the target group. The process of deliberation can lead to understanding, respect, empathy, and a balance of power (Mansbridge, 2009). Deliberatively-organized research will move from participation (= giving those involved and targeted a voice) to giving them power to decide on the questions to be asked in the research process, the values and needs to be implemented, and the way in which the research results are to be implemented in society (Figure 3).

In participative and deliberative formats decision power is shared in the research process. Questions should be answered together by researchers and those societal groups that are targeted by the research (e.g. Stilgoe et al., 2013):

- What questions are relevant to society?
- What norms, values or interests are linked to these questions? Are underlying ethical, legal or social conflicts imminent?
- What are risks and benefits? How will they be distributed? What other impacts can we anticipate now and in future?
- Who will use the research? Have the researchers identified the problem that the users want to be solved? Is the research responsive to their needs and problems? Can research (or related technology development) serve the needs, values, and interests of this community? What are possible alternatives?
- Why are researchers doing this? Are their motives transparent and in the public interest? Who will benefit and what are they set to gain?
- Who is in control? Who is taking part? Who will take responsibility and for what?
- How can users be integrated into the research process and at what stages? What contribution can they make?

Figure 3. Research can include different levels of participation (Wright et al., 2010).

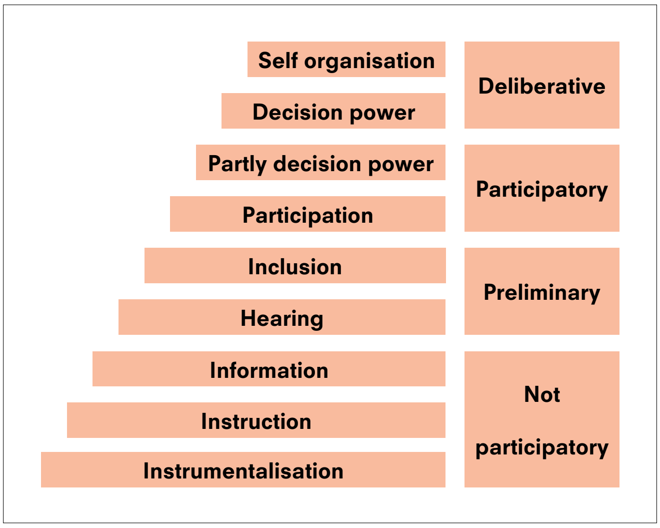
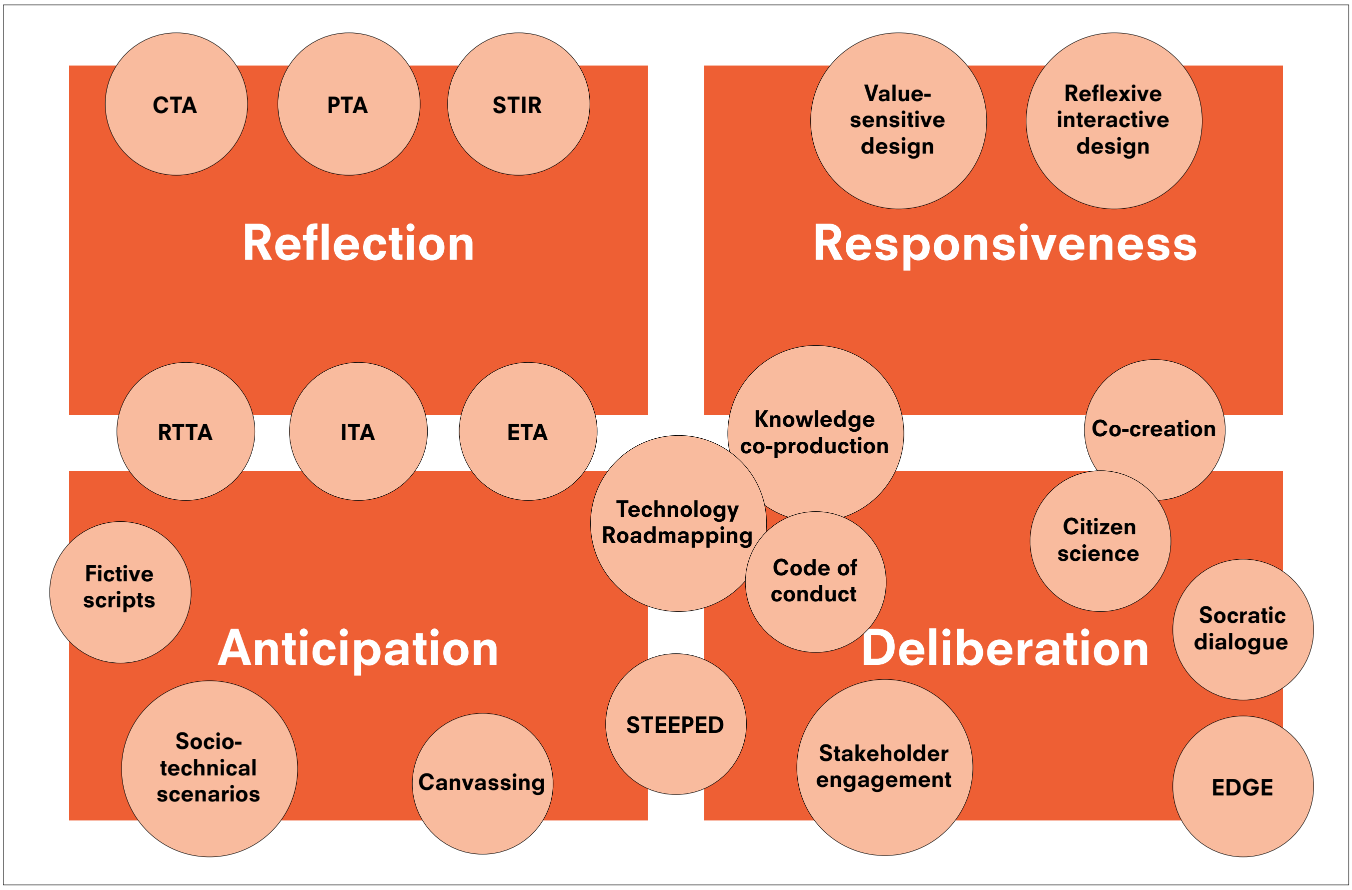


Figure 4. Examples of methods in the four dimension of RRI: reflection, responsiveness, anticipation and deliberation.



CTA= Constructive Technology Assessment
PTA = Political Technology Assessment
STIR = Socio-Technical Integration Research
RTTA = Real-Time Technology Assessment
ITA = Interactive Technology Assessment
ETA = Ethical Technology Assessment
STEEPED = Social, Technological, Economic, Environmental, Political/legal, Ethical, and Demographic Dimensions
EDGE = Embryonic, Developing, Gripping and Embedded approaches to supporting engagement

Values in technological innovation

Technologies and innovation can help to find solutions to some of our great challenges and hence improve our life quality. However, technologies should respect human society and its values, as well as the diversity of heritages and cultures and nature's role as partner and counterpart for human societies. This view of responsibility in technological development will make us stay within the just and sustainable space for humanity (Raworth, 2012).

Each new technology comes with opportunities and risks. Do we have the knowledge to comprehensively and reliably assess the technology in question? Are the values underlying – or supported by – these technologies transparent? In example 1 and 2 we highlight opportunities and risks related to current technology developments in self-driving cars and human enhancement.

In an instrumentalist view, technology is neutral; it is the instrument of human behaviour. Weapons don't kill people; their users kill people. In a non-instrumentalist view, new technologies are morally charged. They create different moral landscapes with different potential courses of action. Moral decisions on new technologies and changes in moral routines, should be negotiated and accepted by those involved and those targeted (Stemerding et al., 2010). Technologies are value-laden and inherit the values of their makers; different values generate different solutions. In this view, weapons are built with the intention to kill people.

Example 1 — Value-related opportunities and risks of self-driving cars (Srivatsa et al., 2017).

Opportunities	• Enabling non-drivers, especially in remote areas, to get more autonomy. • In the long-run fewer accidents and greater safety. • Enabling car-sharing and eventually more sustainability.
Risks	• More accidents and less safety in the short-term. • Disruption of public transportation through decreasing demand. Autonomous cars might bring together advantages of both worlds: the advantage of being able to read a book because you don't have to drive, which was a unique advantage of public transportation. The independence and flexibility (time, door-to-door transportation) of cars. Negative cascades in the transportation sector will have direct input on sustainability.

Example 2 — Value-related opportunities and risks of human enhancement (Miah, 2016).

Opportunities	• Enhancements such as brain modifications to increase memory or reasoning capabilities; enhancements to live longer; increase in well-being and health. • Duty to improve yourself as part of social and moral responsibility.
Risks	• Morally undesirable forms of enhancement because they transform the patient into someone else; dual use issues. • Violating the principle of inter-generational justice: preserving an open future for this generation and the next. • Enhancements might undermine some essential quality of human identity that we would rather preserve and is contrary to values such as human dignity.

What are values and norms?

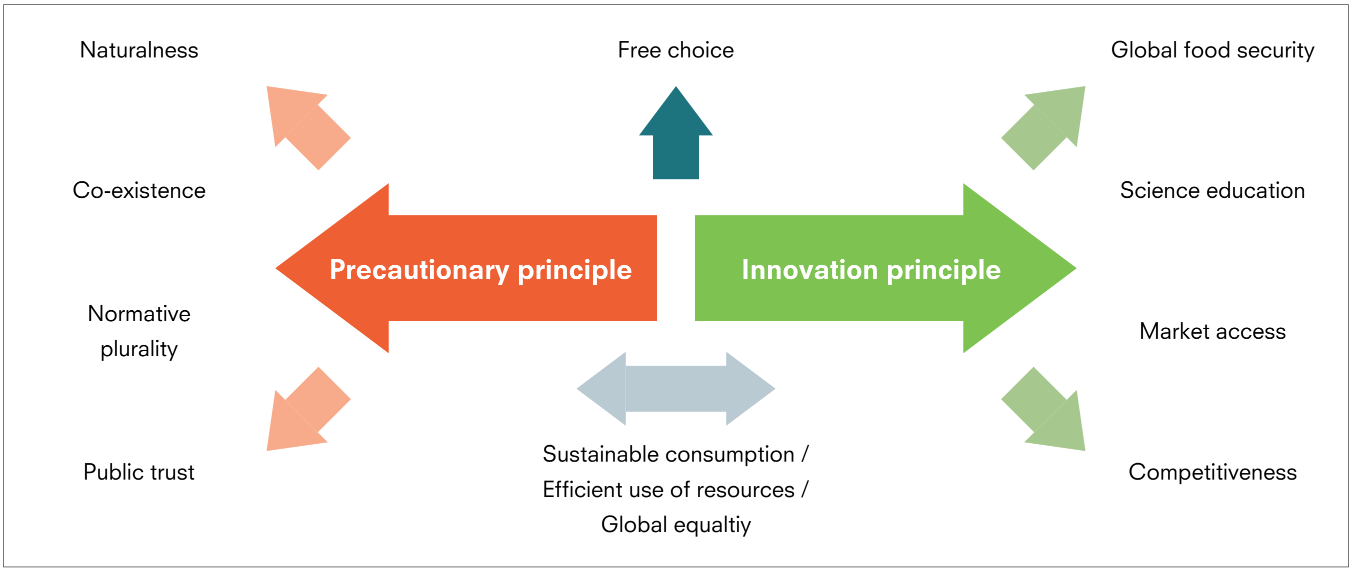
Values are moral principles or standards of behavior, for example autonomy, safety, transparency, privacy, fairness, accountability, health, quality of life, sustainability, care, animal welfare, animal rights, nature rights, self-sufficiency, democracy, human rights, equity, justice or dignity. Norms are binding and socially agreed values. They build on moral judgments and widely endorsed moral and public values. They are enforced by laws, regulations, directives and codes of conduct.

Value frameworks are the ethical lens through which we see the world. Different values thus lead to differences in the appraisal of biotechnological innovations. Some refer to the importance of naturalness, free choice and continued public trust, and advocate caution in biotechnological innovation; others point toward global food security competitiveness and market access, and support innovation. Some moral values, such as sustainable consumption, efficient use of resources, and global equality are used by both opponents and proponents of new technologies.

Figure 5 represents different values in the appraisal of biotechnological innovation. Those who advocate the importance of naturalness and co-existence between different farming practices invoke the precautionary principle, emphasising caution before leaping into new innovations that may prove disastrous. They note that there are both proponents and opponents of modern biotechnology and argue that biotechnology policy should respect the values and interests of both sides as a preconditions for maintaining public trust.

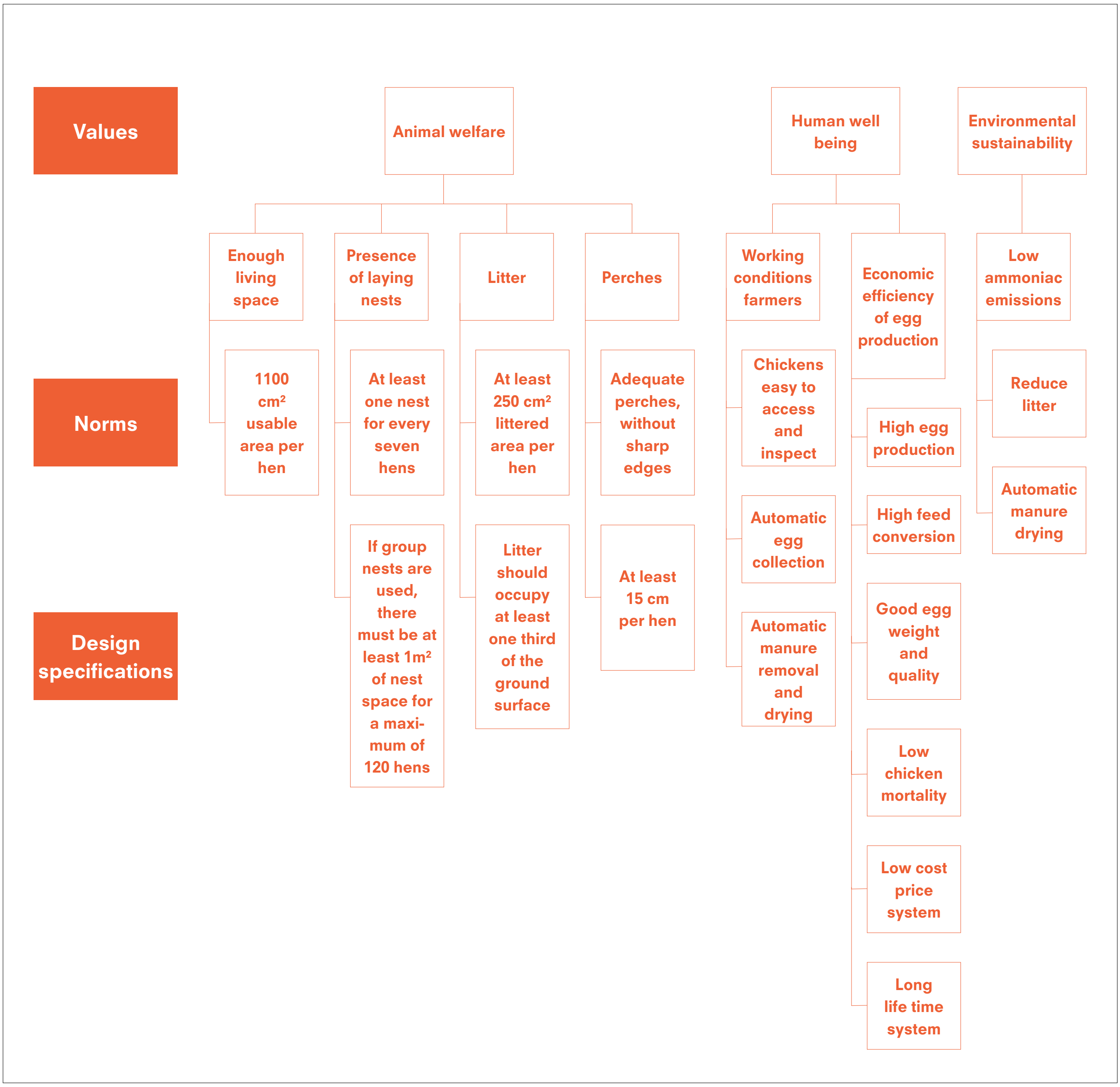
Those who see modern biotechnology as the key to global food security invoke the innovation principle: their aim is to ensure that legislation is designed in such a way that it creates the best possible conditions for innovation to flourish. They argue for biotechnology policies that ensure competitiveness and a level playing field. Interestingly, even though these two approaches may point to diametrically opposed policy prescriptions, supporters of both the precautionary and the innovation principle see their own approach as the best way to realise the values of sustainable consumption, efficient use of resources, free choice and global equality.

Figure 5. Different values in the appraisal of biotechnological innovation.



Value-sensitive design (VSD)
In VSD human values and norms guide the design process and are respected systematically throughout the process (Friedman and Kahn, 2003). Technological development starts with values, i.e. the moral landscape at the top of the design process. For example, value hierarchies constructed through stakeholder dialogue have resulted in the redesign of aviaries in chicken husbandry (Figure 6).
Example 3 shows how different value landscapes will result in different chronics for technology development.

Figure 6. A value-sensitive design for chicken husbandry (adapted from Van de Poel, 2013). Note, the model includes only values linked to animal welfare, while newly discussed and arising social / ethical values as animal rights are not yet integrated.



Example 3 — Unhealthy diets. Preventing unhealthy diets or supporting a healthy lifestyle.

Imagine that, as an innovator and researcher, you want to develop technologies that either prevent unhealthy diets or support a healthy lifestyle. What technology options could you think of that serve either of these two objectives? In the first case your design options might build on controlling the consumer, e.g. solutions such as a refrigerator that is sealed for a certain time of the day. In the second case you might prefer solutions that will nudge the consumer to make an informed choice. For example, developers came up with an App that uses laser mapping technology to estimate the calories and nutritional content on your plate[1]. Both design options build on values and social norms: In the first case, individual well-being and public health might be improved, while in the second option the informed choice and autonomy of the individual consumer are the yardsticks for the technology decision.

1 — NutriRay 3D: www.digitaltrends.com/mobile/nutriray3d-calorie-tracker

The ethical matrix

With the ethical matrix (Mepham 1996; 1999), ethical criteria in technological development can be assessed, and discussion launched on ethical concerns. The ethical matrix includes the following common sense ethical principles or values:

- **Autonomy** – respecting the decision-making capacity of individuals. Wellbeing:
  - **Non-maleficence** – avoiding harmful effects.
  - **Beneficence** – providing net benefits.
  - **Justice** – distributing benefits, risks, and costs fairly.

The matrix applies these principles to the deliberative consideration of specific practical questions involving a range of different stakeholder positions. For each cell of the matrix, the principle along the x-axis is applied to the interests of the stakeholders along the y-axis, and the result is used as the basis for discussion.
In table 1 we applied the ethical matrix in the context of genome editing as a novel plant breeding technology – based on current reviews (EPSO, 2019; EKAH, 2018, Nuijeten et al., 2017; Kochupillai, 2016).

Table 1. Ethical matrix on genome editing as a novel plant breeding technology.

	Well-being	**Autonomy**	**Justice / fairness**
Definition	Non-maleficence – avoiding harmful effects. Beneficence – providing net benefits.	Respecting the decision-making capacity of individuals.	Distributing benefits, risks, and costs fairly.
Consumers	Health and safety: Use the precautionary principle. Is product quality increased? Is it safe and healthy?	Informed choice, freedom of choice: transparency about the process and the product. Was the product derived with genome editing? What are the altered traits in the product?	Access to diverse products derived with or without genome editing and with or without altered traits. Is this choice possible without clear coexistence rules for crops derived with or without genome editing? Does labeling provide transparency?
Farmers	Health, safety, and environmental benefits: Do the new varieties with altered traits have agronomic advantages, e.g. resistance to existent and emerging pests and reduced use of pesticides?	Informed choice, freedom of choice: Evaluation of the product alone does not establish transparency and credibility of the farmer toward the consumer. Is coexistence of non- genome edited and genome edited crops in a farming landscape possible?	Ownership: no new dependencies on downstream players in the food value chain. Farmer's right to seeds should be guaranteed[2]. Does genome editing diminish farmers' independence in the choice of seeds and their ability to save their own seeds for crops?
Publicly funded research	Environmental benefits: shorter breeding times through genome editing could enhance reactivity to emerging threats (e.g. new diseases), and allow rapid application of bio-knowledge . Genome editing is more precise than conventional breeding. It does not cause more unintended mutations than conventional breeding.	Researchers should be able to choose their methods freely.	Publicly funded research should have access to genome editing technology to avoid unfair international competition between research groups. The same plants with the same (derived) traits are differently regulated if they have been developed with different breeding technologies. This puts unequal risk assessment obligations and costs on developers.

2 — Farmer`s right: access to **seeds** and the ability not only to choose them but also to produce, store, use, exchange, and sell them are therefore crucial issues for small **farmers**.

NGO, organic sector	Concerns over unexpected consequences, including controllability and reversibility of altered or new traits in plants derived with new plant breeding technologies and their spread in the environment resulting in systemic responses. This argument justifies the application of the precautionary principle for the possible release of gene-edited crops in the field. Undesired side effects such as environmental and health risks are seen as inherent to the reductionist view of genetic modifications: for example the wide-spread use of herbicide-tolerant genotypes in certain crops increased herbicide use and resulted in increased herbicide residues in drinking water and in rapid spread of herbicide-resistant weeds.	See: Farmers and consumers.	No seed monopolies for biotechnologically altered seeds under patents offered by few companies. No biopatents. Plant variety protection should remain a protective regime for intellectual property. Varieties without economic interests should be promoted by publicly funded research to save and develop agro-diversity. An open-source system allows free access to genetic resources. Sale of licenses for new varieties allows payment of breeders for investment in development and secures intellectual property.
Plant breeding companies	See: Publicly funded research.	Plant breeding companies must have autonomy to choose their methods; economic gains should be possible.	No unfair competition against SMEs through regulation and expensive risk assessment. No biopatents or exclusive breeders' rights to secure investments in developing a new variety through genome-associated technologies.
Future generations	Meeting the needs of the present generation without compromising the needs of the next generation through conserving an ecological balance by avoiding depletion or destruction of natural resources.		
Living environment	See: NGOs.	Respect for the integrity of life including plants. Life has not only an extrinsic value for humankind: it has an intrinsic value and needs to be respected in its wholeness and autonomy. Traits that are linked to reproduction etc. should not be altered, as this will change the integrity and autonomy of the affected organism. No overstepping of the species-species boundary through transgenesis.	

The role of RRI in plant breeding

Agricultural productivity needs to be secured with less resources such as water and nutrients and increased resistance to pathogens and climate change. With new plant breeding techniques (NPBTs) such as CRISPR/Cas, site-specific genome editing techniques are available for improving crop traits. NPBTs will allow to more efficiently use plant genetic resources for pre-breeding and breeding. Breeders will benefit not only from new plant varieties but also from more efficient breeding processes.

There is ongoing discussion on the use of NPBTs, particularly in the EU. The European Court of Justice (ECJ) ruled in July 2018 that organisms obtained through gene editing techniques are subject to the obligations laid down by the GMO Directive 2001/18/EC. Several science academies and research organisations called on policy makers to amend current regulation and exchange views on possible next steps to enable Europe better addressing climate change and achieving sustainable food and nutritional security (e.g. European Academies` Science Advisory Council (EASAC, 2020); German National Academy of Sciences Leopoldina, 2019). They argued, that the blanket legal classification as a GMO fails to consider the type of genetic modification present in the genome edited organism and whether this modification could have occurred naturally or through traditional breeding methods. In response to that, the Council of the European Union (2019) requested the Commission to submit a study in light of the Court of Justice's judgment in Case C-528/16 regarding the status of novel genomic techniques under Union law.

The application of plants developed by advanced genetic engineering is not hampered by technological shortcomings but by the understanding and acceptance of such technologies in society (Araki and Ishii, 2015). Although NPBTs are part of the current research and technology landscape; they are locked in the existing socio-technological regime. Opponents have concerns that through the use of NPBTs the monopolization of the seed industry will continue. Some of the ethical and societal questions that have been raised are:

- How can we capture the societal value of NPBTs for consumers and farmers?
- How can we implement NPBTs in sustainable farming systems?
- How will NPBTs change the future of crop production?
- What challenges do we face in adjusting IPR regimes for equal access to seeds?
- What challenges do we face in implementing access and benefit sharing in plant breeding with NPBTs?
- Bioethical questions around the manipulation of the genome of plants?
- Are there hidden risks and adverse effects on environment, biodiversity, sustainability and human health?

Can RRI activities in plant breeding help to bring NPBTs out of its lock in?
RRI activities aim to identify ethical and societal consequences of technology innovation at an early stage so that the dealing with these challenges can be embedded in the design process and societal acceptance is enhanced.

The European Union implemented RRI activities in its research framework program Horizon 2020. Research projects funded in H2020 are requested to include:

- **Multi-actor approaches**, involving different actors and stakeholders (such as farmers, food processors, retailers, logistics, advisors, consumers, industry, civil society organisations and policy makers) in the design of the research projects by means of participation as well as transparent communication.
- **Inter-/transdisciplinary approaches**, taking into account different viewpoints and involving disciplines beyond existing network. For example, social, agronomic, economic, environmental and data scientists from universities, public/private academic research institutions, industry and other stakeholder partners could be included in the consortium.
- **Integrated and holistic systems approaches**, considering interconnections, possible synergies or trade-offs between different aspects or actors that directly or indirectly affect the field of research on a system level e.g. economic, environmental, social, legislative, geographical, behavioural, business environment.

In Example 6, we highlight the EU-funded project CropBooster that implements an multi-actor approach.

Example 6 — Multi-actor approach in EU funded project CropBooster-P

The Challenge.
A doubling of global crop productivity is required to produce enough plant biomass to achieve food and nutrition security, as well as to meet the demands of a future bioeconomy. This increase in crop production must be achieved without any loss of nutritional quality to achieve full food security and to satisfy the nutritional aspects of a healthy diet. In addition, future agriculture will require crops that combine sustainability, efficiently using scarce resources like minerals and water and preserving Earth's biodiversity, with a high resilience to adverse climate conditions.

Future–proof plants.
In order to meet these challenging demands, our current crop plants will have to be re-designed and a "future-proof" profiling is urgently needed. CropBooster-P will identify opportunities to adapt and boost productivity to the environmental and societal changes. The 2-years project will produce a quantitative evaluation of the most promising practical approaches to be enacted from 2021 to achieve a sustainable food supply into the future.
Work packages (WP) to support RRI.

WP 1 "Research Toolbox" assesses the current scientific and technical options available to improve crop plants. Literature research and data-mining is used to get a comprehensive overview of the current state-of-the-art. In a **forward looking workshop**, stakeholders will develop **future scenario's** how the different options to improve crop plants would work out when extrapolating the current state-of-the-art.

An important part of WP 2 "Economic, Social and Environmental Impact" is the analysis of the effects that the scenario's that are developed in WP 1 will have on society. Different **expert workshops** are organised to assess the economic, social and environmental effects that the implementation of different options to improve crops will cause.

WP 3 "Societal Needs and Expectations" will coordinate RRI activities by involving **non-expert stakeholders** throughout the entire project in order to come to solutions that will have an as broad as possible support in society. **Regional workshops with farmers and consumers** will be organized throughout Europe. In addition, dedicated workshops to develop communication strategies towards industry, and towards European farmers, will be organized. Finally, almost at the end of the project, a pre-final draft version of the Roadmap will be scrutinized by a **Citizen Jury**.

WP 4 "International Cooperation" will bring together networks and community of researchers to build a consensus among requirements of sustainable strategies to improve crop yield and nutritional quality at European scale. **Joint meetings and conferences** will be organized and a **joint white papers** will be drafted.

WP 5 "Strategy Development" will digest and amalgamate the results of all WPs and will draft a Roadmap for the European Commission. This Roadmap will present the different scenarios that have been developed to future proof our crop plants, tested by expert panels and scrutinized by stakeholders from society. In addition, the Roadmap will include a fully worked out plan as how a large European research program could be developed and run to carry out the research proposed in the Roadmap.

Text adapted from: https://www.cropbooster-p.eu

The case study on "Rewilding crop plants using new plant breeding techniques (NPBTs)" on pages 43–47 discusses if society would accept the use of NPBTs as a way to restore favourable traits in crops. Rewilding with NPBTs has been highlighted as an efficient approach to restore genes from wild ancestors that have been lost during domestication and are linked to resource-efficiency and resistance and environmental adaptation. A multi-stakeholder dialogue could inform consumers about the scientific similarities and differences among random mutagenesis, transgenesis and NPBTs. It could highlight NPBTs as method for fast and smart breeding in areas were conventional breeding only makes slow progress, for example to improve orphan crops, establish pest resistance to old and vulnerable crop varieties, or for the rewilding of crops (Palmgren et al., 2017). Trust in plant biotechnology can be achieved, if consumers understand that potential risks of NPBTs are comparable or lower than other methods that have been used safely for decades.
The focus of this case study could have been expanded to an important question: could research establish positively connected use cases for crop plants derived through NPBTs that have impact for not only a resource-efficient agriculture but also for agro-ecological approaches?

The role of RRI in smart farming

Current agricultural production systems have a considerable impact on the environment, with more than 30% of CO_2 emissions and more than 20% of fresh water use through agriculture. A business-as-usual approach to satisfying food demand for a population of some 10 billion by 2050 is not sustainable (FAO, 2018). New approaches and technologies are necessary to reach sustainable development goals and stay within planetary boundaries (Raworth, 2012; Steffen et al., 2015; United Nations, 2015).

Agriculture 4.0 and smart farming

With agriculture 4.0 a new agricultural revolution supported by policymakers and global innovation governance systems is predicted. Smart farming focuses on increasing digitization of agriculture. Smaller, autonomous robots and unmanned drones in combination with high-resolution cameras and high-performance databases are being designed to enable farmers to check the condition of soil, field and crops in real time. Has the soil dried up? Is enough fertilizer and water available? Is there competition from weeds? Are the plants infected by pests? Farmers can react to the data by adding the precise amount of water, fertilizer, or pesticides dosed to individual plants, or by mechanical weeding.

The hopes are high that smart farming will reduce the ecological footprint of conventional agriculture, because e.g. less fertilizer or less water need be used (Walter et al., 2017). Although these digital technologies promise opportunities for sustainable agriculture in the field, the challenges must also be discussed.

Public debate – for example on genetically-modified (GM) crops – has been largely directed against industrialized agriculture and its aberrations in the form of monocultures, loss of biodiversity, excessive use of resources, responsibility for climate change, and monopolies in the seed industry (van den Daele, 2012). Social concerns persist that smart farming is another technology trajectory within the existing dominant socio-technological regime supporting the same agricultural values and goals as previous biotechnology developments: Higher production for distant and global markets, with the promise of making input-intensive practices more precise and cost-efficient (Bronson, 2018). In the longer term, smart farming may be rejected by the public with similar arguments as those for genetic modification (Macnaghten, 2015).

Experts and critics alike are concerned with possible adverse effects on farming, and hence on society:

- Re-scripting the ways farmers interact with their land and livestock, from hands-on to data-driven approaches that could result in loss of care for plants and animals (Rose et al., 2018).
- De-skilling of farmers and staff on farms in handling animals and plants, as well as in decision making (Eastwood et al., 2017).
- Dependence and loss of decision-making power to private companies who could get control over data, inputs on farms and products (Wolfert et al., 2017).
- Unfair price discrimination: data on soil or water could be used by private companies to charge different sums for the same product or service to different farmers (Guerrini, 2015).
- Data-intensive technologies involved in smart farming bring uncertainty about data management scenarios. Two extreme outcomes might be: (1) closed, proprietary systems in which the farmer is part of a highly integrated food supply chain; or (2) open, collaborative systems in which the farmer and other stakeholders in the chain can choose partners flexibly (Wolfert et al., 2017).

However, there are also positive opportunities. Digital technologies could absorb labor shortages in rural areas (CEMA, 2016). New job descriptions and the facilitation of work through digitalization could ensure that agriculture is again perceived as attractive in the job market.

The question, therefore, remains: Can technologies like smart farming be embedded in agro-ecological practices while respecting the values and needs of those involved? Can these technologies be embedded in practices that create and promote balanced interaction between animals, plants, and inanimate nature for the efficient production of food, using natural cycles and internal resources, ecological pest control, diverse mixed cultures, intermediate crops, and innovative management?

Current debate features value-based arguments focusing on food security and environmental benefits through resource efficiency, while critical voices highlight concerns about vertical and horizontal concentration in the food value chain, and related risks to food sovereignty. Issues of job losses in agriculture and the de-skilling of farm workers in interaction with the land are less dominant (Table 2).

Table 2. Ethical matrix on smart farming technologies in interaction with key stakeholder arguments.

	Well-being	**Autonomy**	**Justice / fairness**
Definition	Non-maleficence – avoiding harmful effects. Beneficence – providing net benefits.	Respecting the decision-making capacity of individuals.	Distributing benefits, risks, and costs fairly.
Consumers, (rural) communities, governments	Food security: 9.6 billion inhabitants of the planet and scarcity of resources pose a threat to food security. New technologies promise security.	Concerns that company-driven instead of public and community-driven data ownership / control and possible large vertical and horizontal concentrations in the food value chain will allow monopolization of smart technologies and data by big companies. Concerns that governments and communities will weaken their food sovereignty, e.g. the autonomy to define their own food and agricultural system / innovation and limit their choices from wide-tech to a single high-tech approach (Mooney, 2018).	Emerging technological and social biases: Concerns that decreased food sovereignty will increase food inequalities, e.g. unequal access to healthy food for all societal groups; malnutrition.
Farmers and farm workers	Smart farming might have high potential to drive economic growth and farmers' well-being because digitization of agriculture could increase production and efficiency, thereby reducing costs, at least in the short term. Concern that automation will increase losses of jobs in agriculture (WEF, 2016).	Privacy: Unclear data regulations undermine the right of farmers to determine what information they will share. Autonomy: Deskilling of farmers as mere assistants of algorithms and machines. Or does the farmer get a new role (Walter, 2017)? A new appreciation of the profession of the farmer might arise. New professions and education as data scientists and data managers.	Ownership and property of data: Who owns the data? Concern that data will be monopolized by large companies and thus lead to price discrimination against farmers (CEMA, 2016). Emerging technological and social biases: New dependencies on downstream players in the food value chain due to vertical and horizontal integration may occur (see: Companies). Bias against small farms and the livelihoods of farm workers is possible.
Companies	New opportunities for small companies to enter the market with new technologies and services.	Small companies could lose their autonomy if vertical and horizontal concentration in the food value chain increases.	Emerging technological and social biases: Bias against small companies is possible.
Living environment	Digitization enables resource-saving and may thus increase sustainable production.	Smart farming may make farmers less interactive with their land, animals and plants, thus devaluing traditions and history of land use in the countryside (Macnaghten and Chilvers, 2014). Concerns that smart farming will be another technology locked in dominant industrialized farming systems, thus itself driving loss of biodiversity and ecosystem services.	Environmental bias is possible; however, the opposite may also occur.

As Rose and Chilvers (2018) argue, the concept of RRI should underpin agriculture 4.0 to ensure that innovations are designed to provide social benefits, meet human needs, and show social responsibility, while at the same time improving productivity and reducing the environmental footprint of farming systems.

How can RRI activities for smart farming be carried out?
The following passage is taken from a report of the European Association of Remote Sensing Companies (EARSC), an organization that promotes the use of earth observation technology:

> *Poul is a typical user of the Fieldsense service, which provides digital information to around 100 farmers in Denmark. Fieldsense, the supplier of the service, is a small Danish start-up situated in Aarhus. […] Fieldsense has a really strong focus on information to aid decision making for cereal farmers. Satellite data is the key data source for their service.*
> *Data coming from imagery gathered by the Sentinel 2 satellites is processed into stress maps, which are overlaid onto farm field boundaries. If the crop-stress reaches a certain level, then an alert is sent to the farmer. The alert allows the farmer to investigate further the cause of the stress and hence to react.*
> *This provides value to farmers using the service by saving them time on inspections (crop scouting), reducing the use of chemicals, and increasing yield by enabling earlier detection of a problem. It also helps farmers gain a "digital picture" of their farm, hence improving overall management practices. […]*
> *Benefits accrue to the farmer through reduced costs of chemicals and time saved. These benefits are strongly focused on the farmer, although in time some of the benefit may be shared with others in the value-chain. The value-chain may change with time as farm suppliers look to expand their role.*
> *The reduced use of chemicals also has a beneficial environmental impact. […]*
> *It is important to realize that the increasing availability of satellite data and services based on data impacts heavily on the traditional role of the farmer. Having more land and crops to look after, the modern farmer has turned into a tech-savvy manager with a small staff working in the fields. Whilst the farmer will decide what action to take and when, he will mostly be in his office directing operations. The trend towards larger farms […] is both a driver and a consequence of increasing digitization and connectivity.*
> *This means that the farmer does not directly view his fields and crops on a daily basis; even the workers will only visit a field when there is a task to be performed. The farm workers are not skilled to recognise disease or plant problems, which is why a system like Fieldsense can deliver so much value. Satellites can provide imagery on a sufficiently regular basis that anomalies can be detected without having to be in the field. And this is only the beginning: in the near future tractors are expected to drive themselves, relying on on-board sensors that provide additional data complementing that coming from the satellites (EARSC, 2018).*

What kind of society do we want? What innovations will get us there? Is the scenario above what society wants? How can deliberation on this question be organized? Discussions around these questions can be facilitated using the indicators and activities for RRI processes of anticipation, inclusion, reflection and responsiveness as suggested by Eastwood et al. (2017) for smart dairy farming in New Zealand (Table 3). They can be adapted to smart farming on all scales: on individual farms, across farming landscapes, and throughout the food value chain (e.g. Rose and Chilvers, 2018).
Are these activities carried out when developing new smart farming technologies? Eastwood et al. (2017) concluded that most RRI activities are only used to overcome technological hurdles and weaknesses, but don't fully address systemic or societal perspectives.
Rose et al. (2017) concluded from interviews with farmers in the UK that uptake of smart farming technologies depends on farmers' involvement in user-centered design. In order to establish trust and confidence in the system, its usability and fit to farmers' workflows, as well as its overall benefits and drawbacks, must be clearly explained, discussed and understood. However, such mutual learning exercises are rarely carried out with farmers during the development of the technologies.
Bronson (2018) suggests that systemic approaches should be more inclusive for stakeholders and rights holders (i.e. those whose livelihood is linked to governmental decisions). Actions involving rights holders, for instance, should involve end users, small landholders, alternative producers, and citizens as citizen juries. They would be welcome to share their concerns and knowledge about societal and ethical risks, and provide critical feedback for researchers, developers, and policymakers. Participants would be asked only to reflect critically – they need not accept the technology or achieve consensus. Feedback about desired values and societal objectives and their implications for selecting innovations for support would be delivered in plain language reports.
Rose and Chilvers (2018) suggest that the concept of responsible innovation should not be attached solely to emergent "big" smart technologies but also to community-led innovations and sustainable low-tech solutions. This would stimulate discussion of possible alternatives in sustainable innovation trajectories. In the current dominant system, which favors monocultures, change in farming systems must avoid any lock-in of smart farming technologies, as previously happened with genetic engineering (Vanloqueren et al., 2009).

How can early-stage researchers be included in RRI in smart farming? A current example was carried out at ETH Zurich: The ETH Studio AgroFood, explained in example 7.

Example 7 — The ETH Studio AgroFood

The Challenge. The recent advent of digitalization in the AgroFood sector creates disruption in each step of the food- value chain with all farmers, food companies, retailers, consumers, and stakeholders affected. The surge in available real- time data influences everything from daily decisions of farmers and consumers to corporate business models. All components of the food system are now challenged to quickly adapt to keep pace with the evolution of the technology, trying to evade the disruptive effects of Digital Darwinism. In doing so, the dynamics of the whole food-value chain change, and unforeseen consequences enter the economic landscape.

The Studio. We often look to the young generation studying at universities to provide innovative solutions for burgeoning challenges. Organizations see this generation of digital natives as drivers of progress with the ability to help one navigate the waves of change caused by digital disruption. Unfortunately, academia often does not formally prepare university students with the knowledge and skills needed to help organizations within the food system deal with the pressing issues of digitalization.

In this context, ETH Zurich, through the AgroFood Studio, endeavours to support its students in the understanding of the complex, ever-changing issues arising from digitalization and the development of solutions.

By bringing their knowledge gained into practical applications, these students will assist stakeholders of the Swiss AgroFood sector transitioning to the so- called Food System 4.0.

The Core Questions. These questions are pressing issues for the Swiss AgroFood sector and formed the core of the ETH Studio AgroFood during its 2.5-year pilot phase:

- What's the current landscape of digitalization in the AgroFood sector in Switzerland?
- How could research help tackle the needs of stakeholders in this area?
- How could design thinking help to build technologies that take care of the needs of farmers and consumers?

Text adapted from:
https://worldfoodsystem.ethz.ch/research/flagship-projects/eth-studio-agrofood.html

Table 3. Indicators and potential RRI activities in smart farming (adapted from Eastwood et al., 2017).

Indicator	Description – key questions	Potential activities
Anticipation		
Foresight exercises	Have any recent / future scanning activities been undertaken to identify economic, social, and environmental implications for smart farming?	Conduct technology-use (or public opinion) surveys to assess farmers' (or public) perceptions of agro-technology.
Smart futures scenario building	Have any positive or negative future projections (e.g. changing role of farmers) been undertaken?	Evaluate potential social, economic, and environmental outcomes for (small) smart farms?
Inclusion		
Involvement of relevant actors	Are end-users and citizens already included in socio-ethical discussions relating e.g. to land-, biodiversity-, and farmer-technology interactions?	Are end-users and citizens already included in socio-ethical discussions relating e.g. to land-, biodiversity-, and farmer-technology interactions?
Private sector engagement	Are private companies included as partners in publicly funded smart agriculture R&D projects?	Ensure that private sector companies co-funding projects are represented in project governance.
Encouraging transformative mutual learning	Do processes exist for multiple stakeholders to engage in mutual learning within R&D projects?	User-centered design, open innovation, co-innovation
Reflection		
Reflective guidance	Do R&D teams have processes (e.g. codes of conduct and standards) guiding reflection on underlying assumptions and values in the development and use of technology?	Ensure someone is specifically tasked to facilitate reflection. Create and engage with codes of conduct and best practice guidelines.
Responsiveness		
Potential to adapt to projects	Can smart farming R&D projects change direction in response to stakeholder feedback?	Project reviews, structures for adapting milestones and deliverables.
Open research processes and access to research data	Is smart farming R&D transparent, and are processes accessible to private companies, farmers, and communities.	Open data exchange, open access to research results, declare conflicts of interest.

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Design thinking in RRI

Design thinking is an abstraction of the **principles** and **process** that designers use to solve problems. Tim Brown, president and CEO of IDEO, explains:

> Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for [business] success.

Great design is based on observed human needs (human centricity). It comes from understanding people's behaviors, thoughts (cognitive empathy), and emotions (emotional empathy). In order to make good design decisions, we must first create a range of **possibilities** to choose from.

Great design comes from a desire to create **real outcomes** for problems. It is **iterative**. It leverages continuous learning and never truly ends. It pursues a 5-step process of empathizing, defining, ideating, prototyping and testing (Figure 6).

Figure 6. Design Thinking Process (d.school, Hasso Plattner Institute of Design at Stanford).

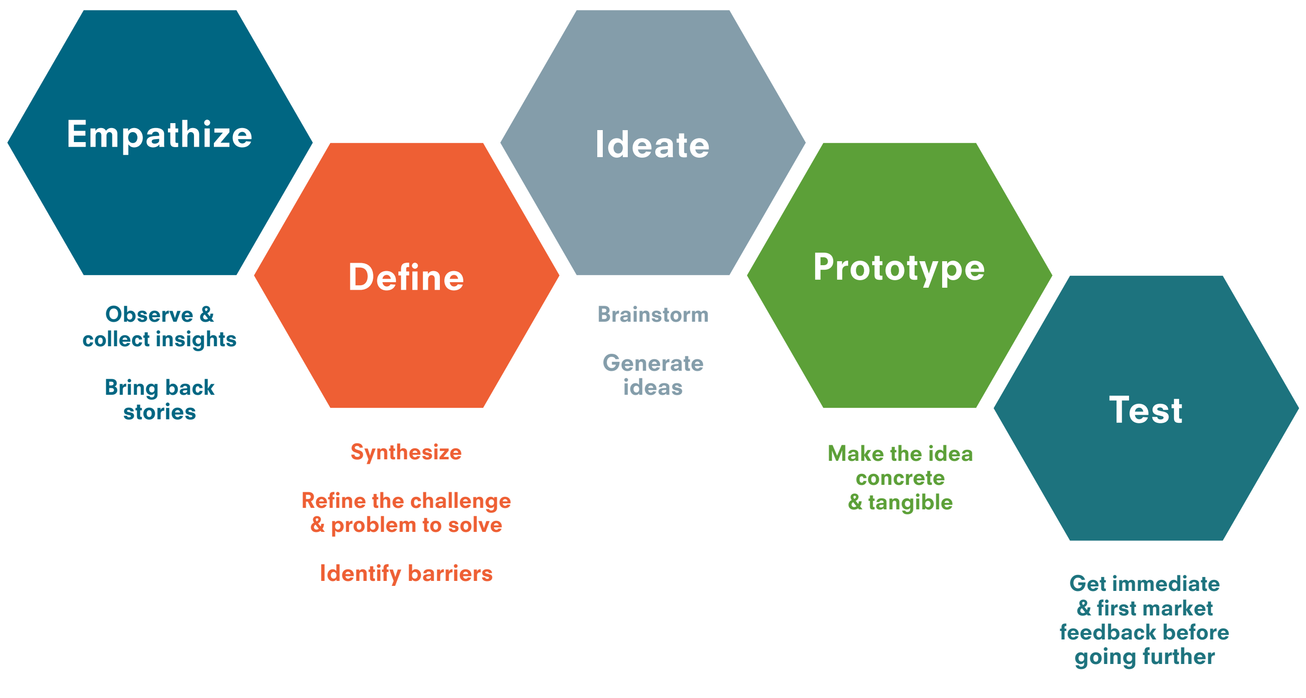
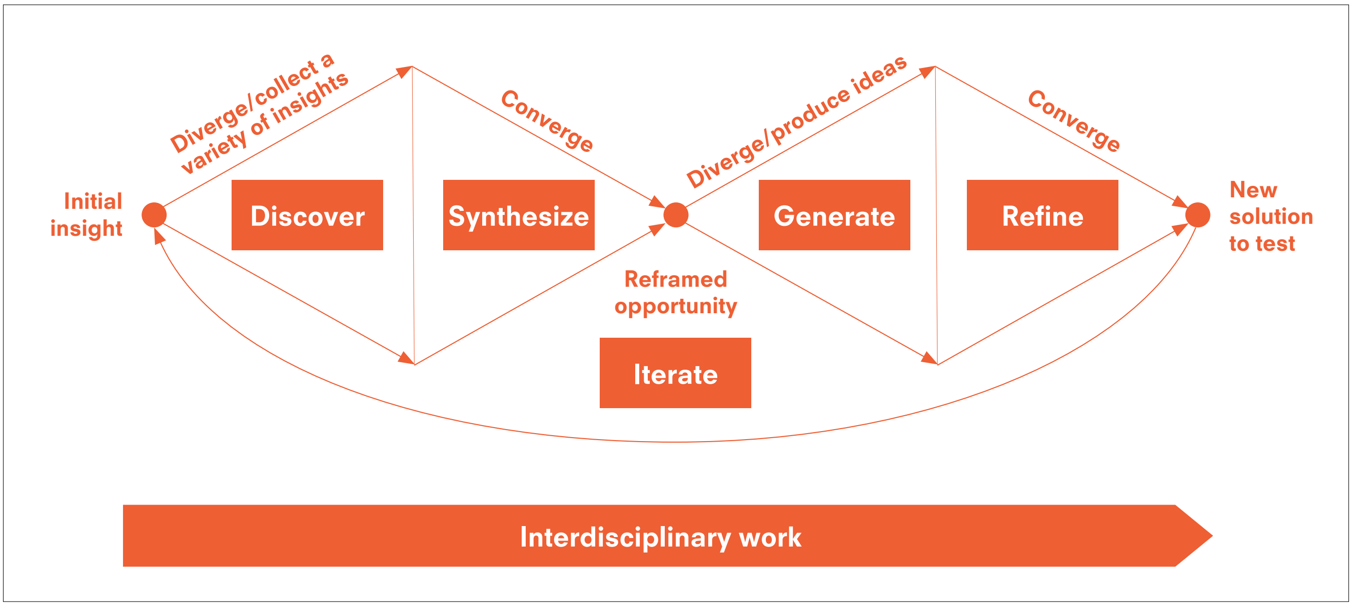


Figure 7. Design thinking is based on creating options and making choices (inspired by designthinking.ideo.com).



IMPLEMENTATION

Phase 1: Empathize
In this phase you need to understand the problem and don't ask for solutions. Problems are often composed of, or caused by, other problems. And often the problems you are asked to solve are not the ones that you need to solve.
Going into the field to collect insights through observation and questions is essential in this phase. We gain a lot of insights through observation. However, we cannot directly ask "What do you need?" To understand and identify potential customers' needs, you must observe and question people in their everyday life:

- Understand what they really do (not what they think they do).
- Capture what motivates them, their needs, their barriers.
- Build a consistent view from all collected insights, highlight patterns and profiles.
- Anticipate future needs.

Figure 8. **The multiple ways to gather insights.**

Phase 2: Define

Solutions are directly influenced by how we focus and frame the challenge. Synthesis is the process of making sense of data and insights through analysis by comparison, categorization, pattern recognition, and cleaning up. Among the tools that support this process are:

- Storytelling,
- Persona,
- Empathy maps,
- Task flows and scenarios,
- Journey maps,
- Environment maps.

Phase 3: Ideate

The goal of the ideation phase is first to come up with as many potential solutions as possible, no matter how valid/invalid. To find new options, it is important to generate a lot of ideas before reducing them to a limited number of practical ones. This is best done in two phases:

- Produce a large number of ideas.
- Choose the best ideas and select options.

It is important that somebody facilitates brainstorming: The facilitator animates, revives idea production, ensures everybody participates, refocuses if needed. The following brainstorming rules can/should be followed:

- Defer judgment,
- Encourage wild ideas,
- Build on the ideas of others,
- Stay focused on the topic,
- One conversation at a time,
- Be visual,
- Go for quantity.

Phase 4: Prototype

This phase is about determining the details of a design through structured description and the creation of a representation that people can interact with. A useful technique for systematically describing your idea is COSTAR:

- **Customer:** Who are your target customers? Everyone? Really? What are the needs you answer to?
- **Opportunity:** What is the market opportunity? What size and dynamic (growth, emerging, saturation…) is intended? Who are the important actors (potential partners, competitors)? Are there any emerging trends or helpful technologies?
- **Solution:** What is your solution to this need? How to catch this opportunity? What do you offer (features, services…)? What is your business model? What is your go-to-market approach? What intellectual property regulations are required? Resources? Costs?
- **Team:** Who should be part of the team to ensure the success of this idea? Partners, influencers, customers…? What skills and know-how do you need? Core competencies of your business?
- **Advantage:** What is your competitive advantage? How do you differentiate? What could be the alternatives and other options to your idea? What should be absolutely protected?
- **Results:** What are the measurable benefits for customers? For your company? What risks have to be taken?

Phase 5: Test

"Watering Hole" is a method for developing an idea by collecting feedback from others. Invite all kinds of participants (depending on the context): from all origins, departments, neighbours, customers, partners, friends, colleagues. The goal is to cover a variety of experience, know-how and expertise. No decision is taken in a watering hole. The idea providers can decide what to do with the feedback and the idea afterwards.

The team presents the idea enthusiastically in a clear and understandable way for example through an elevator pitch. They respect the given time. They listen to reactions and feedback. They take notes but don't try to answer back or to be defensive. They are grateful for the collected feedback and announce its next steps.

Figure 9. **Feebacks that are expected during a Watering Hole session** (source: Swisscom Human Centric Design approach).

Green Feedbacks	Red Feedbacks
• Underline key characteristics of the idea • What should be kept, even more developed? • Ideas and supplementary arguments to developp the idea • Concise and clear • No "yes, but …"	• How might we improve the idea? • Constructive feedback with the suggestion of alternatives, other options • Identification of weak point to be more developed, area of improvement • No pure negative declaration

APPLICATION

The following section summarizes in the form of a case study the outcomes of the design thinking process carried out during the summer school.

THE CHALLENGE: How can we persuade Swiss farmers to adopt remote sensing installations that go beyond their current technology?

1. Empathize
Task: Ideally, the group should prepare interviews and observations to be conducted in the field, then go into the field, come back, and share their insights.

At this stage, we only share "insights"; we don't develop ideas yet, or look for solutions.

What benefits does remote sensing provide for farmers?
- Added value to products.
- Reliability of data.
- Trust in technology.
- Being the first one.

What concrete needs of farmers does it fulfill?
- Share knowledge about management practices etc.
- Farmers want to decide what data to disclose.
- Farmers want to keep control over the data.

Do farmers adopt the technology easily? Why, why not?
- Is it worth the hassle?
- Is there proof of benefits?

What are the current barriers to the adoption of remote sensing?
- Is the technology user friendly?
- Is the interface and the technology easy to use?
- What are the necessary skills?
- Is big investment in equipment necessary?
- Data concerns.
- How to protect data?
- Miscellaneous.
- Will consumers accept the technology?
- How can the technology be adapted for small scale farmers?

2. Refine
Task: Define a more focused and precise "How can we…?"
How can we prove the benefits of remote sensing technology to Swiss farmers knowing that there is potential to share knowledge and data but concerns about privacy of data and limited investment?

3. Ideation

Task: Generate ideas to answer your "How can we…?" Select 1 idea.

The following idea clusters were established by participants. Every participant could vote for options they preferred to follow up. The participant selected the digital farm showcase for prototyping.

Real "digital farm" showcase visited by consumers and farmers:
- Bring consumers to "digital" farms,
- Demo trial,
- Multi-year,
- Several crops,
- Presentation (let farmers come),
- Exchange with other cantons,
- Free food / drink,
- Develop applicable methods (from trial to real use),
- Prototype: to promote the design/idea, show that and how it works,
- Train farmers in data science.

Start free-of-charge and / or by lease:
- Show farmers on their farm (lease and tailor it),
- Leasing technologies will reduce costs,
- Machines for free and leasing of software will reduce costs,
- Subsidies.

Concrete products:
- Applications for farmers,
- Personalized service,
- Ready-to-use platform/services,
- Updatable systems.

Cooperative association:
- Cooperations among farmers to lower barrier for sharing.
- Farmers rent technology from the cooperative to share investment costs.
- The cooperative hosts the database.

4. Prototype
Participants filled in the matrix for the digital farm showcase using the COSTAR method: Customers, Opportunities, Solution, Team, Advantages, Results. See Table 4.

Table 4: COSTAR applied to a digital farm.

Customers	Swiss farmers, consumers, politicians
Opportunity	Concerns and criticisms increasing in all stakeholder groups and among the public need to be addressed. Real showcases are missing.
Solution	iFarm.ch is a cooperative of farmers that: • Runs a showcase digital farm, • Manages a joint database, • Represents digital farmers in the institutions.
Team	Committee of farmers. Operational team. PR specialist.
Advantages	Engagement of farmers. Real showcase. Data and knowledge sharing is enabled.
Results	Interested farmers adopt the technology more easily. Learning experiences are shared.

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Part 2
Case studies

RRI IN SMART FARMING

Insights into digital farming: challenges, stakeholders and perspectives

Seydina Issa Diop, Franco Conci and Camilo Chiang

Introduction

The exponential speed at which technological innovation has developed in recent decades has changed many of our daily practices (King, 2017). Agriculture has been affected by these changes, leading to an increase in available sensor-based information. This approach exploits the use of collected data, through remote imaging and other sensing techniques to acquire data on almost any crop trait – growth, weather conditions, yields, resistance to diseases, soil fertility etc. – in a non-invasive and continuous way. The gathering of this information and its use to make decisions has created what today is called Digital Farming (DF) (Shamshiri et al., 2018).

One of the main benefits of DF is the improvement it brings to crop control and the efficiency of farming practices. Through the use of data from farm equipment, DF offers new posibilities to transform that data into knowledge (CEMA, 2017). With this, farmers can act to protect and manage their crops more efficiently.

These new farming practices – known collectively as the Fourth Agricultural Revolution – are the fruit of decades of evolution in our farming systems, combined with new technologies such as cheap and improved sensors, actuators and microprocessors, satellite and drone-generated data, high-band-width cellular communication, cloud-based IT systems, and big data analysis. A wide range of solutions are in development that are very different in application, accuracy and price, enabling various stakeholders – e.g. government institutions, NGOs and researchers – to create models and strategies and develop sustainable guidelines for local farmers. In the form of best agricultural practices for individual environmental conditions, these will predictably bring higher productivity from diminished resources (space, energy, water, nutrients etc.). Private companies can also use the data to satisfy their clients' requirements, extend their services and enhance their economic value.

For the transition from data to knowledge, data collected in different environments and communities of practice is required. This has great potential to redefine the management and perception of agriculture once the various hurdles to its deployment have been mastered. These include political and legal regulations; economic interests of private companies; lack of information on the importance and use of data from customers, smallholders, farmers and related stakeholders; and the many and complex aspects of data availability and management at the technological, legal and social levels.

Responsible Research and Innovation (RRI) in this field must take account of all these factors. As such, it constitutes a major step in promoting inclusive approaches in the design of research projects and has become a priority for European institutions and an indispensable framework for European researchers.

In this light, key points to be discussed in this article are:

(1) Opportunities and challenges of digital farming, in particular data generation, storage, management, sharing and ownership.

(2) Ways of addressing different stakeholders so that their feedback results in trajectories for future development of DF applications.

(3) Promotion of inclusive data ecosystems that allow for equitable sharing, exchange and use of information by all participants in agri-food value chains.

(4) Key aspects of the establishment and diversification of digital farming within an RRI framework.

Challenges in database management and usage

In recent years, the use of data in digital farming has increasingly encountered not only technological, but also ethical and legal barriers. This has led to the need to protect the ownership, privacy, and security rights of those from whom data originates, as well as those who collect, access and use it. On the technological side, the challenges are becoming more intense due to the growth in data collection using agricultural machinery, sensors, remote sensing etc. (Wolfert et al., 2017). Extensive networking and data exchange over the internet by stakeholders in the agricultural environment, including machine manufacturers, service providers, scientists and farmers themselves, is another aspect of this challenge.

Moreover, access to most DF databases used in research or in private companies is restricted to isolated instances. Private companies, institutions and farmers still benefit from their limited dataset, but the value of data increases drastically through the aggregation of its sources (Wolfert et al., 2017). Hence actors around the agri-food industry have a pronounced interest in breaking through the mystery surrounding DF data and embedding it in a more transparent and efficient framework. An option here might be to set up open data platforms that allow interconnected datasets. This would promote both the quality and quantity of accessible datasets.

Previous approaches to data ownership – i.e. who controls and has access to data – constitute major obstacles to data legislation. Clarity is needed in the definition of external and internal, public and private data, and in ruling when, with whom and to what extent data can be shared. In order to respond to these questions, one must understand and include all related stakeholder needs and interests. Only then can data protection, data privacy and data ownership rights be designed that ensure benefits for both the private and public sector.

Needs and concerns of stakeholders

Many different stakeholders are involved in the value chain of data-driven agriculture. These include agri-businesses, service providers, scientists, governments, policymakers, consumers and farmers, among them NGOs, research and governmental institutions that may benefit from the existence of a larger and more detailed dataset for their models. This structure will per se induce a downstream data flow to the consumer, who will predictably react to the implications of enhanced technological approaches in agriculture and to the revision of data ownership and management. The following paragraphs will summarize the needs and concerns of different stakeholders regarding open data platforms in digital farming.

Both public and private **researchers** will stand to benefit from precise and extensive datasets, especially considering that open-field research is expensive for most institutions. Researchers are likely to be least opposed to an open-data format, and also least directly interested in the economic value of digital farming data. Researchers will also push for the creation of a shared platform and standard metadata formats. However, they need to be responsive to the needs and concerns of policymakers and farmers regarding disclosure of private data.

Governmental institutions and NGOs may look positively on the technology in terms of its potential, but will at the same time take into consideration the issues and risks linked to the use of data. For example, they must take into account the threat of data misuse by service providers to obtain private benefit from farming data without the farmer's consent and the risk of creating economic and social imbalances between large- and small-scale farmers (Zhang et al., 2017). Governmental institutions may well be in favour of open-data DF platforms if the fair use of data is taken into account, but they might at the same time push for a compromise between open-data for public research and management and private data to protect intellectual property. For example, farmers might be more willing to share their data if they know that aggregation of data shared by all actors will result in better services for them. In light of past evidence of farmer exploitation in favour of corporate agendas (e.g. Forbes, 2017), NGOs may require a strict regulation of data ownership and use (Sykuta, 2016).

Like NGOs, society – especially consumers – may react in various ways to DF. Strict agriculture and growth control have been shown to increase transparency and with it consumers' trust in product quality and production methods, especially if negative environmental impacts are minimized by reducing space and energy requirements while maintaining the well-being of the crop (e.g. Beulens et al., 2005).

Farmers' response to the technology is likely to vary depending on type of farm and field size, as well as complex social, political, geographical and economic parameters. Despite the abundance of technological solutions, a transition to digital farming is only possible for farmers who can afford – and have access to more advanced technology and its related data.

Small farmers are more likely to be put off due to the high investments necessary for the new infrastructure. They may also question the advantages of DF technologies developed and used currently in big fields with intensive cultivation. Considering that 80% of the world's food is produced by family farms, and that these represent 98% of all farms (ETC Group, 2019), the successful implementation of digital farming must of necessity consider the interests of these smallholders and small family-owned businesses. DF should not enlarge the gap between large-scale, intensive and small-scale farms, or aim to replace traditional farming. Moreover, farming consultants are generally unable to provide a precise assessment of the technology's benefits, leaving the scene open to niche early adopters (Euroactiv, 2018).

Clarifying the ownership of data and data rights may increase the acceptability of DF to farmers concerned about the diffusion of their private data and its exploitation for corporate economic interests. The risks arising from an information leak in this direction could range from reputation damage to legal issues concerning farming practices.

Technology providers and other companies concerned with DF technologies and databases may have an interest in binding farmers to their products with closed DF data standards. Private companies may be even more opposed to open data, since losing control and ownership of data may restrict revenues in the short-term. For this reason, companies may also seek to create a platform with enough users to become the de facto standard. However, as legislative boundaries for farming data are blurred, companies may also want to avoid being portrayed as unfair and exploitative in their data management approach.

Importance of RRI: Why deliberative practices are necessary

Digital farming is currently being promoted in research, industry and agriculture for several years, but participative stakeholder inclusion has not yet been taken far enough for a shared vision or even shared deliberative approaches. The current challenge is to turn what today amounts to a niche application of an innovative approach into a set of accepted and useful applications for many different farming environments and practices. At this stage, the technology is facing a pit of disillusionment, where incremental innovation yields diminish and the existing technology's cost/benefit ratios make it difficult to include small farmers in the process (Zhang et al., 2017). Some DF applications are in a phase of deep reflection, where they have to be reimagined and readapted on the basis of observed peaks and pitfalls, while the more hands-on applications implemented by early adopters are further along the road of deliberation, where the need for a shared vision to shape the way forward is more evident.

How can RRI ensure that DF technologies are used to their full potential without harming existing practices and avoiding data misuse? Regardless of legislation and corporate plans, the ultimate test of DF lies in consumer response. It must, then address societal concerns and strive to become environment- and farmer-friendly.

We suggest that future development of DF applications target the following stakeholder needs:

- **Diversification of digital farming tools to address the needs of small-scale farms as well as large-scale intensive farms:** For example, small-scale farmers may want to make use of low-cost entry-level digital farming tools to reinforce their existing selling points, like 0-km products and a slow-food philosophy, while intensive farmers could benefit from the positive impact of DF on resource efficiency. For example, AgroPad by IBM recently presented a soil/water analysis tool that relies on a simple smartphone camera. When a soil-water sample is placed on the business-card-sized device, a microfluidic chip returns a photometric result for each parameter measured. A picture of the coloured test strip can then be analysed with a deep-learning algorithm, resulting in a continuous valuation of the soil parameters (IBM, 2018). While laboratory-based soil analysis is often too expensive for small-scale farmers, this new AI approach reduces analysis costs and may lead to better availability of highly relevant information.
- **Definition of clear, universal terms and laws that ensure fair use of digital farming data:** Farmers using DF should be able to decide the final use of their data. Fair terms guaranteeing them better control would enable them to disclose or sell their data on their own terms. Moreover, use of conditionally disclosed data for private ends or revenue by third parties should be regulated and protected from illicit practices. Companies should be enabled to generate and access large-scale DF data within a precisely regulated framework.
- **Creation of an open, shared platform with universal standards for metadata,** in order to ensure proper classification and access to aggregated data. Creating open databases for DF data with a universal open data format will need coordinated global efforts by public institutions. An open data platform could boost stakeholder benefits through open, more comprehensive datasets shaped and managed by the public sector.
- **Definition of terms of use by public and private institutions:** Ideally, in an open data environment, NGOs, public and academic researchers will have unlimited access to datasets, while private institutions will be subject to tighter regulations, helping to keep control in the use of the data for private interests.
- **Implementation of incentives for the use of an open, shared platform.** In order to build services from the knowledge gained from data collection, there should be an interest in its exploitation. State subsidies might incentivize new habits. This would also promote the inclusion of farmers in remote locations where generated data is especially valuable.

The role of (especially early-stage) researchers in RRI in digital farming

In the development and implementation of fair regulations for data protection, the role of academic researchers may well be pivotal, even thought the final decision is in the farmers' hands. Innovation requires moving from an idea to its implementation and doing so with positive impact for society: that is the essence of responsible research and innovation. Together with the different stakeholders, academic researchers, given their level of education and moral awareness, should be able to pursue the implementation of ideas in an ethically responsible, inclusive and sustainable way.

Researchers are ideally situated to set up an open platform for data sharing. Given the worldwide collaborations already in place at the level of universities and research institutions, adding a layer of data sharing should not be difficult to achieve. The organization of workshops, training sessions, and excursions with consumers, farmers and the public on the importance of data ecosystems in agriculture and how to implement them inclusively would activate the benefits of that sharing on the local level.

Early-stage researchers are generally integrated in both academic and industrial environments – for example through internships or in academia-industry collaborations – so they are well situated to play a connecting role between public and private sectors. Knowing the needs of science as well as the private sector, they can contribute to building inclusive data ecosystems for both environments. Their experience and knowledge can facilitate implementation of RRI processes in the ongoing development of DF technologies.

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FAIR data principles for best practice in agricultural research data management

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Introduction

We live in a digital era, where services, decisions and technologies rely on data. The agricultural sector specifically, creates increasing amounts of data from many different sources – from farmers, agri-businesses, tractors equipped with GPS tracking, from public sector actors to researchers. Data is becoming even more valuable, as agricultural business development and global food policy decisions are being based upon data.

When it comes to data and technology, these differences in resources translate into strong power imbalances in data access and use. The best-resourced actors can delve into new technologies and make the most of these insights, where others are unable to take any such risks or divert any other limited resources. Access to and use of data has radically changed the business models and behaviour of some of these well-resourced actors, but in contrast, those with fewer resources, such as smallholder farmers, are receiving the same limited access to information that they always have.

Farmers in principle should be in the centre. While farmers may currently be at a disadvantage in data sharing, they could very well benefit from it if data flows were more transparent and equitable. They could then, for instance, receive better aggregated data and more accurately tailored services from their providers.

The sharing of research agricultural findings, as well as other data, is believed to increase the pace of innovation, research breakthroughs and collaborative problem-solving. Often, however, this data is not readily available, visible, or accessible, resulting in needlessly duplicated research or critical gaps in information.

The most frequent challenges in research are related to privacy, data security, the protection of intellectual property, and conflicting attitudes of ownership. More specifically, concerns often arise on behalf of researchers about stolen work or misuse of data. Funders' contractual requirements and lack of resources are also crucial issues. Grantees struggle to ensure data quality through effective data management and the provision of pathways for responsible data reuse. Lack of proper budgeting and institutional open data policies hinder the process of opening up and publishing data correctly. In addition, lack of clear directives on where to publish, and low awareness of how researchers can access published data, create barriers to compliance. This is especially true for researchers without a mature disciplinary or institutional repository.

This has led many public research funders, as well as private donors, to require public universities, research institutions and other higher education institutions to develop or enhance data management plans that allow for open access and data sharing. While creating a culture of open access and open data, with appropriate policies and infrastructure platforms, is a challenge, it is one that researchers must increasingly address.

It is essential to understand that there are different types of data. Data exists on a spectrum from closed, shared to open. Open data is data that is available for anyone to access, use and share. It is published under an open licence that allows it to be used for any purpose.

The most useful type of open data, when appropriate, is data that is accessible to those who need it, machine-readable and high quality, has a unique identifier, is continuously updated, can be linked to other data sources and has an open licence to reuse it in any way as long as the original source is credited. Open access is usually the lowest "tier" of open data.

Europe acknowledges: open where possible, closed if necessary

Some data cannot be made open, because it may contain sensitive information about individuals or groups. But it may still be possible to share that data with specific organisations, so long as there are appropriate safeguards in place.

An enormous amount of agricultural data is generated from universities and research institutions and the open data movement is encouraging these organizations to make data discoverable, reusable and reproducible.

By making data as open as possible – while protecting privacy, commercial confidentiality and national security – we can unlock more value from it. More specifically, the benefits from open data and open access in research represent a public good. Data that is as open as possible will be available to more people, with fewer restrictions on how it can be used. This increases transparency, creates more opportunities for innovation, and facilitates citation and recognition of the faculty / university / researcher and identification of research collaborations.

FAIR data principles for best practice in agricultural research data management

The **FAIR** data principles identify four important characteristics of datasets (**F**indable, **A**ccessible, **I**nteroperable and **R**eusable) that will make them easier to use:

- **Findable** – Datasets should have a unique identifier, metadata which describes its contents, sources and structure, and be published so they can easily be found with a search engine or in a data portal.
- **Accessible** – Datasets and their metadata should be easily accessible – e.g. over the web, with appropriate access controls for shared data.
- **Interoperable** – Datasets should be published and organised using open standards, so they can be easily accessed using a range of tools, and combined with other sources.
- **Reusable** – Datasets should be published with a clear licence and / or terms of use, and have appropriate documentation and metadata that describes how the dataset has been collected and processed, allowing users to understand its potential and limitations.

These principles have been developed to help publishers assess whether individual datasets are published in a FAIR and open way. They have been adopted by the research community, where they capture a set of best practices that apply when publishing any type of dataset.

FAIR data principles can be applied to data that exists at any point on the data spectrum. The principles emphasise clear licensing and recommend standard licences – like those of creative commons – but do not suggest data should be either closed, shared or open. For instance, sensitive personal data only available to researchers under limited data sharing agreements can still benefit from being FAIR to ensure researchers can easily find, access and reuse that data.

Data should be FAIR and open as possible in order to maximise potential value, for example to promote more effective decision making, foster innovation and drive organisational change through greater transparency. At a more basic level, FAIR data can enable farmers to harness decision making tools, researchers to access information more readily, policymakers to make evidence-based investments, and other private or public sector and civil society stakeholders to develop services that will improve the efficiency of the food supply chain.

When implementing these principles within a specific programme, there are often choices and trade-offs to be made. For example, which licences will be most compatible with the range of datasets to be collected and used as part of the programme? Which standards, data formats and other technologies will make those datasets most accessible to the expected user? Which data portals or other infrastructure will enable data to be found and accessed by the community of researchers and innovators participating in the program?

Attaching a licence or reuse notice to data is an important element of research data management and is contingent upon drafting organisational policies, establishing data management capabilities and procedures, and clarifying the provenance, ownership and custodianship of the organisation's data assets.

Researchers benefit not just from better access to data, but also by using open source tools and code that are created by funded projects. It is important for researchers to understand the licensing of the data they use, and furthermore to ensure that their collection and use of data conforms to ethical research guidelines (e.g. codes of conduct). Researchers should also understand the benefits of openly licensing their own outputs (including data, code and reports) to help ensure that their work can have the greatest impact.

The FAIR principles form the basis of a trusted environment where researchers, innovators, companies and citizens can publish, find and re-use each other's data and tools for research, innovation and educational purposes. In general, they provide guidance for the creation of standards, protocols and best practices that will support the creation and longevity of a global data ecosystem.

Agri-data ecosystems

Agri-data ecosystems are a combination of governance principles (ranging from societal norms and community ethics to policies, codes of conduct, laws, treaties etc.), institutions, capacities and infrastructures dedicated to the management and flows of agri-food data, as well as the actors providing and using that data. Creating maps of data ecosystems can help understand and explain where and how data can be used to create value. The map of an agricultural data ecosystem will also pinpoint its actors – specifically the key participants in a programme – as well as the relationships between them and the different roles they play.

Certain issues that arise here should be carefully considered by researchers: e.g. privacy, security, data protection, ownership, data rights, intellectual property rights:

- Who owns data?
- Can data be both open and owned?
- Who is entitled to the value of the data?
- How will that data be used or potentially shared?
- Farm data: Is it considered personal data or not?
- What about data protection? What do we mean by data rights and most specifically farmers' rights?
- What is the state of recognition of these rights at the national and international level?
- What's the role of GDPR in the agricultural sector?
- How should these rights be implemented in local and international laws, guidelines and policies and how can they be protected?
- What should be done to include farmers in the mechanisms of data collection, evaluation, transmission and use?

Data ethics

Data ethics is the branch of ethics that studies and evaluates moral problems related to data (including generation, recording, curation, processing, dissemination, sharing and use), algorithms (including artificial intelligence, artificial agents, machine learning and robots) and corresponding practices (including responsible innovation, programming, hacking and professional codes), in order to formulate and support morally good solutions (e.g. right conducts or right values) (Royal Society 2016, researchers Luciano Floridi and Mariarosaria Toddeo). Or according to the Open Data Institute (ODI) definition: Data ethics is a branch of ethics that evaluates data practices with the potential to adversely impact on people and society – in data collection, sharing and use.

Data ethics is a rapidly emerging area. Increasingly, those collecting, sharing and working with data are exploring the ethics of their practices and in some cases, being forced to confront those ethics in the face of public criticism.

Trust is an essential component of society. When trust breaks down, the public lose faith in the institutions that provide them with services, and organisations lose the ability to share data and collaborate in ways that could improve all our lives.

Data ethics is about the impact that all data activities have on people and society. Collecting and sharing data only about certain groups of people may disadvantage them relatively to other groups. All activities should be subject to ethical examination. It is essential to raise awareness about the ethical issues and legal frameworks – involving both personal and non-personal data – that arise from how data is collected, who it is shared with and what is shared.

Researchers' responsibilities in managing data

Each member of the research team has a different role and different responsibilities in managing research data. These responsibilities should be well defined and understood by everyone in the team.

Responsible data management is important in all phases of a research project, from proposal writing and data collection to data analysis and dissemination.

Each research team member should know what role he or she plays in data management and his or her specific responsibilities, regarding data ownership, anonymization techniques, privacy and security, understanding protocols and procedures, ensuring optimum storage, analysis and dissemination of data and also addressing research misconduct and data mismanagement.

Recommendations

- **Develop competencies** for data planning and management. Understand open data and its management.
- **Use open data resources.** For example, the open data certificate is a free online tool developed and maintained by ODI to assess and recognise the sustainable publication of quality open data. It assesses the legal, practical, technical and societal aspects of publishing open data, using best practice guidance.
- **Create a data inventory.** A data inventory is a list of datasets with metadata that describes their contents, source, licensing and other useful information. A data inventory can be a useful tool for any organisation or project dealing with multiple types and sources of data. Creating a data inventory is also an important part of creating a data management plan for a research project.
- **Sign a data sharing agreement.** A data sharing agreement is an agreement between two or more organisations about how to share data. It will define what data is being shared and for how long and any restrictions on its use. Data sharing agreements can take many forms, depending on the scale and complexity of the data sharing. For example, memoranda of understanding, service level agreements and formal legal contracts could all be data sharing agreements. A data sharing agreement is a set of common rules binding all the organisations involved in a data sharing initiative. The agreement should be drafted in clear, concise language that is easily understood. If the data is already published then a sharing agreement may not be needed.
- Regardless of legislation, there may be ethical considerations that affect whether you can publish and share data. Tools like the data ethics canvas can support researchers in exploring these issues.

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RRI IN PLANT BREEDING

Rewilding crop plants using new plant breeding techniques: closing the gap on public opposition through RRI

Claudio Cropano, Daniel Grogg and Ina Schlathölter

Introduction

Modern agriculture is in many cases based on a limited number of high yielding crop varieties bred to be productive in a broad range of environments rather than being adapted to a specific environment. Caused by genetic bottlenecks imposed on crop plants during domestication, this restricted diversity jeopardizes the ongoing ability to rapidly improve and adapt crops in a changing climate (Palmgren et al., 2015). But the restoration of genetic diversity by exploiting natural accessions (landraces) and wild relatives stored in gene banks can contribute to ensuring a sustainable and efficient future for agriculture (Peres, 2016). Together with an increasing understanding of the molecular basis of agronomically important traits, the transference of alleles, or beneficial mutations, from wild relatives into modern germplasm – a concept knows as "rewilding" – appears in this context to be a powerful tool for sustaining future crops (Palmgren et al., 2015).

Plant breeders have always used the alleles of wild progenitors to improve agronomical traits or enhance the nutritional properties of modern varieties by conventional introgression breeding. Although effective, this is often time consuming and challenging – for example due to sexual incompatibility between domesticated crops and their wild relatives (Jacobsen & Schouten, 2007; Ashraf, 2010; Tester & Langridge, 2010). However, recent developments in molecular biology, referred to as New Plant Breeding Techniques (NPBTs), offer valuable alternatives to introgress and rewild elite genetic backgrounds in a more time- and resource-effective manner (Cardi, 2016; Chen et al., 2019; Hua et al., 2019). NPBTs encompass the latest genome editing technologies CRISPR/Cas (clustered regularly interspaced short palindromic repeats associated nuclease), TALENSs (transcription activator-like effector nucleases), ZFNs (zinc-finger nucleases), and cisgenesis, defined as the transfer of gene(s) from the same species or genus through molecular cloning and genetic transformation (Gaj et al., 2013).

In this article, we are focusing on CRISPR/Cas as a promising tool to specifically induce mutations at a desired locus. This would allow restoration of "wild" alleles into modern varieties without altering the rest of the genome and preserving the desired features of the variety. Farmers cultivating edited or "rewilded" cultivars for one or more target traits, will not have to change their cultivation and management system, as all other agronomical traits (e.g. flowering time, growth habit or productivity) will remain unaltered.

Following its initial demonstration in 2012 as a genome editing tool (Jinek et al., 2012), the CRISPR/Cas system has been widely adopted and successfully used to target important genes in different organisms (Knott and Doudna, 2018, Hsu et al., 2014). However, the use of CRISPR/Cas or other NPBTs for crop improvement in agriculture is facing strong public opposition. Specifically, induced mutations at sites other than the intended on-target site (commonly referred to as off-target mutations) are a major concern (Zhang et al., 2015). In addition, the recent ruling of the Court of Justice of the European Union (2018) classifies crops obtained via NPBTs as genetically modified organisms (GMOs), thus seriously limiting their use and release (Hartung and Schiemann, 2014). This has led to protests in the scientific community. The surge in scientific literature over the last two years demonstrates the importance of this topic and the need to improve the situation on the scientific, public and political side (amongst others: Kok et al., 2019, Zimny et al., 2019).

In this article, we ask: Would society accept the CRISPR/Cas breeding technology in agriculture as a way to restore favourable traits? Can Responsible Research and Innovation (RRI) help respond to public needs and concerns? To this end, we will first summarize some of the challenges that CRISPR/Cas edited crops face in society. We will then propose an advanced multi-stakeholder dialogue and define our role as early-stage scientists in this process.

The challenges for CRISPR/Cas-edited crops

In the European case, where CRISPR/Cas-edited crops are regulated as GMOs, the time, amount of data and money required for risk assessment and deregulation holds back small breeding companies from using this technology. This regulation is partially driven by a society that has a negative perception of GM crops, mainly due to lack of trust in developers and regulators, poor communication of risks and benefits and low science literacy, as well as ethical values (Araki & Ishii, 2015). Since the first GMOs entered the market for human consumption, several countries have adopted the precautionary approach to gradually introduce agricultural biotechnology into society. The precautionary principle has been embedded in EU law since the 1990s to aid policymakers justify decisions in situations where there is the possibility of harm for the environment or human health, even if the probability of such an occurrence cannot be adequately assessed by scientific means. Scientific uncertainty is used as a criterion for risk assessment, but to what extent and how to balance this uncertainty with regard to innovations is not clear (Craig et al., 2008). Each country regulates agricultural biotechnology differently, and there is as yet no shared risk assessment methodology. Moreover, it is impossible to give a safety statement on NBTs in general, as each case – including type and scope of modification – is different.

Rewilded plants generated through introgression breeding or CRISPR/Cas are in principle genetically identical. However, the discussion on potential unintended mutations, the invasiveness of the novel plant in its natural habitat, or its impact on non-target species tends to be focused on GM organisms. Moreover, it has been shown that no genetic modification generated either by conventional breeding or by NPBTs can be considered devoid of unintended effects (Cellini et al., 2004; Kok et al., 2008; Schnell et al., 2015). Traditional breeding is associated with deletions, insertions and rearrangements that might lead to phenotypical alterations; but in contrast to GM crops, no formal safety assessment is needed to uncover these (Weber et al., 2012). Indeed, plant genomes are dynamic systems; single-nucleotide changes are common, with a rate of seven new mutations per billion base-pair (bp) of DNA (Ossowski et al., 2010). In comparison, chemical mutagenesis, e.g. ethyl methanesulfonate mediated mutagenesis, which is exempt from GM regulation, has been found to result in 6 and 11.8 mutations per Mbp in two Curcubita pepo families, randomly distributed along the chromosomes with only 0.4% and 0.2% of mutations having a moderate and high putative impact on gene functions (García et al., 2018).

RRI to respond to the needs and concerns of different stakeholders?

Multi-stakeholder dialogue as part of RRI concepts should accompany efforts to use CRISPR/Cas in rewilding (Figure 1). For a participatory approach, all stakeholders should be involved in more than informative and consultative levels of participation, and researchers should decide and act together with other stakeholders in the research process. As stated in the European Union (EU) concept of RRI:

> Societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society (Eriksson and Chatzopoulou, 2018; European Commission, 2018).

Figure 10: An engagement process including different stakeholders regarding the use of genome editing to introduce wild alleles in commercial varieties.

1st — Define the research focus
Crop rewilding using genome editing

↓

2nd — Identify actors	
Identification of actors and their roles, objectives and scope of action in crop rewilding.	Reflecting the different perspectives, views, interests and arguments. Make societal debates transparent and include issues of participants into the research question.

↓

3rd — Formulate a specific problem to be addressed in research
Using CRISPR/Cas for crop rewilding

↓

4th — Stakeholder analysis		
Who has a "stake" with regard to the problem/issue and why?	Who has power, interest, knowledge, resources … ?	What are the relationships between stakeholders?

↓

5th — Select participants
Which stakeholders should participate in the research project?

↓

6th — Integrate stakeholders in the research process

In the case of CRISPR/Cas, different opinions among stakeholders, ranging from interests to concerns about the technique have already been publicly formulated (Table 10). However, we expect that a multi-stakeholder dialogue on CRISPR/Cas in rewilding will allow responsiveness to more specific needs.

The concept of "rewilding" as the restoration in modern varieties of alleles present in wild progenitors could potentially bridge the gap between the need for an effective plant biotechnology tool and the public and legislative opposition this need is currently facing. One reason is that the ability to fully recreate old alleles could leverage the "back to nature" sentiment that is increasingly supported by both environmental organizations and the general public. Applying CRISPR/Cas to restore traits lost during domestication in modern cultivars, like resistance genes, flavours and secondary metabolites would represent a valuable step towards meeting the consumer demand for a reduction of pesticide applications on the one hand and tastier and healthier food on the other (Nekrasov et al. 2017; Shang et al., 2014; Li et al., 2017). For example, purple tomatoes with higher antioxidant levels will help consumers appreciate the positive effects that NPBTs can have (Čermák et al., 2015).

A multi-stakeholder dialogue could inform consumers about the scientific similarities and differences among random mutagenesis, transgenesis, and NPBTs. Trust in plant biotechnology can be achieved, if consumers understand that potential risks of NPBTs are comparable or lower than other methods that have been used safely for decades.

Table 5. Examples of interests and concerns that have been formulated by different stakeholder about using CRISPR/Cas as a tool for plant breeding (Kochupillai, 2016).

Researchers	Interest in using CRISPR/Cas as a more precise tool in breeding, as it is site-specific and results in fewer genomic alterations than traditional breeding. There is concern in the scientific community that strict regulation of NPBTs could block research opportunities in plant breeding and biotechnology.
NGOs	NGOs have concerns about the social and ethical implications of genome editing. For example, they fear that liberalization of genome editing will only help multinational companies to enlarge their profits (ownership, patents) and exploit the agricultural system at the expense of smallholder farmers (Helliwell et al. 2019).
Producers	Farmers are concerned about the performance of their crops and about their placement in the market. In light of climate change, new varieties need to be tolerant and high yielding with fewer resources, and to be compatible with current farming systems. If biotechnology can meet these demands and remain affordable, farmers will be willing to cultivate genome-edited varieties, as long as consumers buy their products.
Consumers	Consumers are suspicious of the use of biotechnology in plant breeding. One major concern is safety: As long as long-term environmental safety cannot be guaranteed, consumers remain reluctant (Ishii & Araki, 2016). While purchasing decisions are based on emotions and values, consumers also want to make an informed choice about the products they buy (Lucht, 2015; Falk et al., 2002).

Conclusions

In this article, we discuss the concept of a multistakeholder dialogue to gain public and stakeholder acceptance for using CRISPR/Cas to achieve rewilding in crops. We argue that such acceptance could positively impact agricultural and environmental policymaking, leading to better-adapted product-based instead of process-based regulation (Ricroch et al., 2016). The goal of the multi-stakeholder dialogue should be to raise awareness among stakeholders of the potential of genome editing, and to define an initial framework for its implementation, with rewilding as a general scope. All stakeholders involved in such a process will benefit from mutual collaboration, contributing to the social cohesion between science and citizens needed for successful implementation of RRI practices.

As **early-stage-researchers**, we consider the supportive role of scientists in this field to be more than merely that of technical experts. Scientists must also learn to get actively involved and to be more sensitive to the needs and concerns of society regarding scientific methods and approaches. They should, for example, reduce the complexity of scientific concepts when speaking or engaging with the public. This will also contribute to encouraging next-generation scientists to make better use of science in connecting the dots between scientific innovation and social needs.

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RRI IN CHARCOAL PRODUCTION

Sustainability with biomass: burning neutral

Giacomo Potente, Florian Cueni, Maximilian Vogt

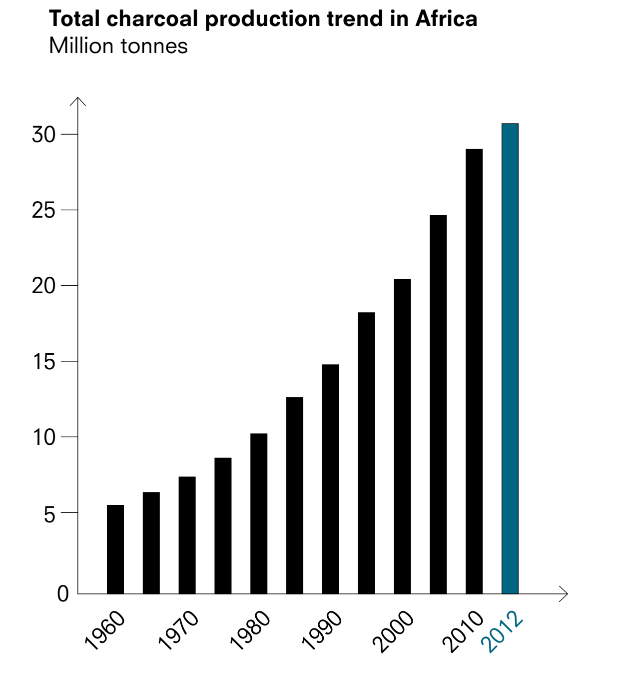
Introduction

Increasing populations and urbanization in combination with poor infrastructures are leading to a rising global demand for food, water, energy, and networks for their proper distribution. Tropical areas, which hold most of the global biodiversity and biomass, are expected to undergo major population growth, with corresponding increases in energy demand and consumption. In tropical regions charcoal typically serves as the main source of energy for cooking and other purposes, providing a large fraction of the energy needs of households and small industries. It is mainly used in urban areas, while rural areas largely rely on wood fuel. However, fuelwood is regarded as inconvenient and dirty, requiring large storage and transportation capacities, whereas charcoal is relatively clean, easy to handle and accessible with the available infrastructure.

Modern energy carriers will only replace traditional biomass-based energy providers when there is an infrastructure that allows for this transition. To achieve such transition, governments may propagate programmes and policies influencing consumers' behaviour and subsidizing infrastructural development. Nevertheless, fuelwood remains a widely used source of cooking energy especially in rural rainforest regions, while with increasing urbanization – and consistently with the habits and traditions of migrating people – there is a visible trend to increased demand for charcoal (Girard, 2002). Most importantly this is the cheapest source of energy compared to more modern energy carriers such as gas, kerosene and other fossil fuels (Foster, 2000).

Charcoal is produced globally, but the availability of biomass, without the feasible alternatives provided in developed countries, as well as the higher incidence of poverty in tropical areas, makes its production there more widespread (Steckel, Edenhofer and Jakob, 2014; for societal development and increasing living standards, energy sources and consumption change see Wolfram, Shelef and Gertler, 2012). With current and projected demographic developments, the demand for forest biomass is, therefore, set to increase, challenging capacities for sustainable production (Girard, 2002). A consequence may well be accelerated deforestation, bringing with it disturbed forest ecosystems and negative impacts on the socio-economic structures of both rural and urban areas.

Figure 11: Charcoal production trend in Africa. Charcoal production is growing exponentially in Africa, becoming a real threat to tropical forests (Pravettoni, 2013).



Why is charcoal production unsustainable in tropical forests?

Consumption of energy increases with population size (Wolfram, Shelef and Gertler, 2012). Especially in heavily populated and expanding regions, this can lead to unregulated production of charcoal. Charcoal is produced with an efficiency rate of 10-30%, meaning 100 kg of wood originating mostly from managed forests yield around 10-30 kg of charcoal. However, charcoal production can exceed the natural growth rates of tropical forests, leading to unsustainable practices in vulnerable ecosystems (Figure 11). Selected trees for production are mostly large hardwood trees, causing a shift in the composition of forests and disturbing the natural habitats of other species (Ndegwa et al., 2016).

Figure 1 not only shows a surge in charcoal production but also demonstrates the urgent need for regulation policies and changes in traditions. Programmes initiated by governments to provide predominantly liquefied petroleum gas (LPG) have successfully replaced the use of electricity for cooking in South Africa. However, in rural areas it partially failed because people did not accept the new form of energy or the required equipment. Equipment failures and the inability to fix these in a time- and cost-effective manner was the main reason discouraging users from keeping LPG as a source for cooking and heating (Kimemia and Annegarn, 2016). The replacement of charcoal with different sources of energy has even proved counterproductive, for several reasons. First, it causes an increase in unemployment in forest areas, since charcoal production is one of the few existing sources of income (FAO, 2017; Tropenbos International Ghana, 2015). Taking away this source leads to acute poverty, which is a key driver of urbanization, triggering ever higher demands for cheap energy and hence charcoal consumption. Secondly, banning charcoal promotes illegal deforestation. Producers will keep their businesses alive as the only affordable source of both energy and jobs (Girard, 2002). To avoid illegal production of charcoal, bans have been lifted, but then replaced with overly regulated procedures (FAO, 2017). In this article we ask how responsible research and innovation could improve the current situation for both the users of charcoal and those who are affected by long-term degradation of the rain forests.

Challenges

In tropical areas cultural habits and traditions relating to energy consumption rely largely on the use of charcoal, with the result that its production accounts for almost 7% of total forest consumption (Chidumayo and Gumbo 2013). Hence, in order to preserve tropical forests, measures must be taken to regulate charcoal production. These can, however, only be effective if they are accompanied by improvements in the fuel supply chain and by an enhanced awareness of the value of the forests that lie at its source.

Major challenges are the introduction and maintenance of stable infrastructures to cope with growing populations and increasing urbanization without detriment to local ecosystems. Improved energy infrastructures in urban areas will give people disconnected from reasonable supply chains the opportunity to trade, sell and buy sustainable energy (Caro et al., 2014).

Another crucial step in this direction is to raise urban people's awareness of the value of forests. According to a study by Hadi et al. (2018) only 31% of rural and urban area inhabitants in Indonesia are aware that using fuelwood or charcoal is likely to support deforestation and cause ecological problems. Even if consumers are aware of the ecological damage through the daily use of charcoal, they often lack the means to switch to a more sustainable energy source. Therefore, governments or institutions need to support agencies that interact with communities. Programs aiming to inform people about the problems of charcoal and fuelwood should be implemented, ideally supported by appropriate policies. Public engagement needs to reach out to rural and urban areas to support people in their efforts to change energy consumption (Babalola et al., 2010) and to make them aware of other beneficial uses; for example, many products of healthy forests can be collected for food or medicine. Introducing participatory forest management would be a major step forward, promoting a protective attitude towards the forests among local people, who also strand to benefit from healthy forests as a long-term source of income (Matiku et al, 2013).

Figure 12: Forest recovery rates with (1) good, (2) poor, and (3) no forest management (Chidumayo & Gumbo, 2013).

Thirdly, charcoal production methods could be improved. Traditional methods make use of earth-kilns, which are likely to have unpredicted combustion events, lowering the charcoal yield and endangering the safety of workers. A more efficient method is the low-cost retort-kiln. With this method, the final charcoal yield can be increased by 35–40%, greatly reducing biomass input (Adam, 2009).

A fourth factor is sustainable forest management. Commonly, selected hardwood trees are chosen for charcoal production, leading to a change in the composition of the forests, rather than to full deforestation. Sustainable forest management allows the accelerated recovery of tropical forests to optimize biomass production and the fixation of CO_2. Figure 12 shows different forest recovery rates with (1) good, (2) poor, and (3) no forest management (Chidumayo and Gumbo, 2013).

To prevent illegal deforestation, close-meshed monitoring systems combined with regulated property rights can lead to better conditions, increasing local employment and establishing responsible communities that manage their own forests sustainably (Achard et al., 2007). However, large-scale monitoring of tropical forests is a challenging task using ground-based techniques. The physical labour is likely to exceed available capacities and financial resources. Novel approaches, such as the use of remote satellite sensing combined with sophisticated algorithms and software to provide a comprehensive user interface are promising and have already been implemented in some areas. They are also available as mobile applications to detect, prevent and trace illegal deforestation and its dependent economic chains[1].

Needs and concerns of different stakeholders

Urban people in tropical countries value charcoal for its reliable and relatively clean combustion properties, as well as for its energy density. They are familiar with this source of energy and their households are fully adapted to it. Most cooking stoves in African rural areas are made for charcoal or wood, and local people can only afford this source of energy. Consumers in developed countries also require high quality charcoal for barbecues and specialized industries. Both groups have a high interest in keeping the price of the end-product low. At the same time, many consumers in western countries want to buy more eco-friendly charcoal (Mwampamba et al., 2013).

On the producer side, there are many actors, ranging from woodcutters to kiln-operators, transporters and retailers. Charcoal production relies on a complex supply chain in areas, where paid work is rare. Environmental protection agencies need to adjust their goals to the well-being of the affected communities. The shift to sustainable charcoal production has to start with shifting the needs of consumers and forest owners in mind and should not overrule them.

1 — https://blog.globalforestwatch.org

Scientists from research institutes and universities around the world are developing approaches to improve the sustainability of charcoal production, but most approaches are difficult to implement in existing supply and consumer environments (Kituyi, 2004). Scientific input is important not only for developing better monitoring systems and screening forest regeneration, but also for ecological-diversity and socio-demographic studies on whose basis policymakers and intergovernmental agencies can set up conditions and environments for sustainable charcoal production (Achard et al., 2007). Specifically, intergovernmental agencies have two main duties: first, they are responsible for funding research projects developing novel methods for sustainable charcoal production; secondly, they should bring together relevant stakeholders to seek agreement on implementing sustainable charcoal production (Musinsky et al., 2018, Achard et al., 2007).

National policies should establish incentives for sustainable charcoal production and increase its practicality e.g. by allocating forests for such purposes, and promoting sustainable woodland management (Doggart and Meshack, 2017). Misconceptions over sustainable charcoal production have, especially in developing countries, resulted in policies that marginalize and discriminate against charcoal producers (Mwampamba et al., 2013). This has spilled over into the policies of developed countries such as Tanzania, the fifth largest charcoal producer in Africa (FAO, 2016), where the marginalization of sustainable charcoal production has resulted in loss of the potential benefits of sustainable charcoal production for both the national economy and smallholders (Doggart and Meshack, 2017).

Position statement

Charcoal consumption is increasing, contributing to deforestation, ecological damage in tropical rainforests and climate change[2]. However, charcoal production in tropical areas supports the livelihoods of millions of poor people and a supply chain that connects rural and urban segments of societies. Charcoal is also traded at the global level.

To achieve sustainable production of charcoal a better understanding of these links is necessary, integrating different dimensions of sustainability: from improved forest management, increased production efficiency (e.g. through better yield in kilns) to enhanced consumer awareness of the environmental impact of buying charcoal. Thus producers and retailers must ensure that their charcoal comes from sustainable managed forests. Sustainable farmed charcoal could be labelled with certificates, and origin could be monitored by an organization based on the European Timber Regulation (EUTR), which already uses forensic methods (Zahnen, 2017). Such forensic methods include government and privately-owned reference

2 — http://www.ke.undp.org/content/kenya/en/home/presscenter/articles/2015/sustainable-charcoal-production-using-energy-efficient-kilns.html

datasets of authentic samples, where stable isotopic, DNA and metabolomic fingerprints are used to verify the authenticity of unknown samples (Camin, 2017). Model-based approaches that limit the need of the expensive and time-consuming collection of authentic reference data are currently in development. Moreover, charcoal users from developed countries should be directed to purchase FSC-certified products, which are more probably derived from sustainable managed forests. Governments, for their part, should enforce policies in forest protection to defeat illegal deforestation with the aim of enlarging sustainable-managed forest areas distinct from the protected natural forests where charcoal production is prohibited.

Higher demand within producing countries needs to be addressed by improving infrastructures, and by giving people alternative sources of energy. These must fit their needs and social traditions and provide them with livelihood alternatives to meet those currently filled by charcoal production. Gas and electric stoves would be the eco-friendly way to go; however, transitions in this direction need to address social needs and acceptance. Learning from the communities themselves about their needs could be a way to get them involved in the process of transformation.

Science and data management deliver tools for observing and managing forests used for charcoal production: for example, improving trees with de novo domestication techniques in order to regenerate tropical rainforests more quickly (Markham, n.d.). And market studies and surveys of energy needs (taking into account demographic developments) must be conducted to expand our understanding of this important problem – specifically to avoid any unexpected consequences and locked-in effects of regulations (Horta Nogueira and Teixeira Coelho, 2010).

Charcoal has the potential to be sustainable when all stakeholders work together to build an appropriate supply chain. The implementation of pilot projects and best examples for charcoal production as a sustainable farmed renewable energy source in tropical countries should, therefore, be a high priority. However, efforts to introduce other sustainable energy sources in tropical countries are also necessary, as charcoal will not meet all the future energy demands of this most populous region of our planet (Demirbas et al., 2016).

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RRI IN AGROPHOTOVOLTAICS

Citizen participation for the responsible design of innovative technology – the agrophotovoltaics case study

Christine Rösch

Sustainability trade-offs between renewable energy and food production

Humankind is on an unsustainable path. The present patterns of global development threaten societal cohesion and undermine prosperity (Rickels et al., 2018). Consumption of natural resources and services is far faster than their regeneration and has negative impacts on climate, ecosystems and biodiversity (Jering et al., 2013). The universal 2030 Agenda for Sustainable Development, adopted by world leaders at the United Nations in September 2015 (United Nations, 2015), presents a turning point towards the design of more sustainable national and international policies in which all countries, both rich and poor, can take part. The Agenda emphasizes that the interlinkages and integrated nature of the Sustainable Development Goals (SDGs) are crucial to ensure the realization of the new Agenda. Nevertheless, it will be challenging to create synergies between SDGs and deal with the trade-offs. Only few SDGs have, once achieved, the potential to bring progress in other SDGs. SDG 1 (end poverty in all its forms everywhere) is one prominent example. Advancement in some SDGs, however, has negative trade-offs with other SDGs, which may impair the achievement of these goals. For example, the achievement of SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all) requires an increase of renewable energy, which can only be attained if all energy sources, such as wind, water, sun and biomass, are used.

Bio- and solar energy production is interlinked with food production, since all three are based on the collection of energy from the sun. Feedstock production for biogas plants and ground-mounted photovoltaics (also known as open-space PV or solar parks) reduce the availability of land for food production and vice versa. In Germany, about two million hectares are used for renewable energy production, mainly for bioenergy, to achieve SDG 7 (IRENA, 2015). This area is no longer available to support the achievement of SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture). There is also evidence of trade-offs between SDG 7 and SDG 15 (protect, restore and promote sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, and halt and reverse land degradation and biodiversity loss). In regions with a high biogas plant density, farming is intensified and energy crop cultivation is concentrated. This can decrease the food supply for insects and reduce biodiversity (FAO 2017, BMU, 2018).

Regarding SDG 7, social conflicts between urban and rural areas can arise, since renewable energy production takes place almost exclusively in rural areas to satisfy the growing energy demand of urban areas.

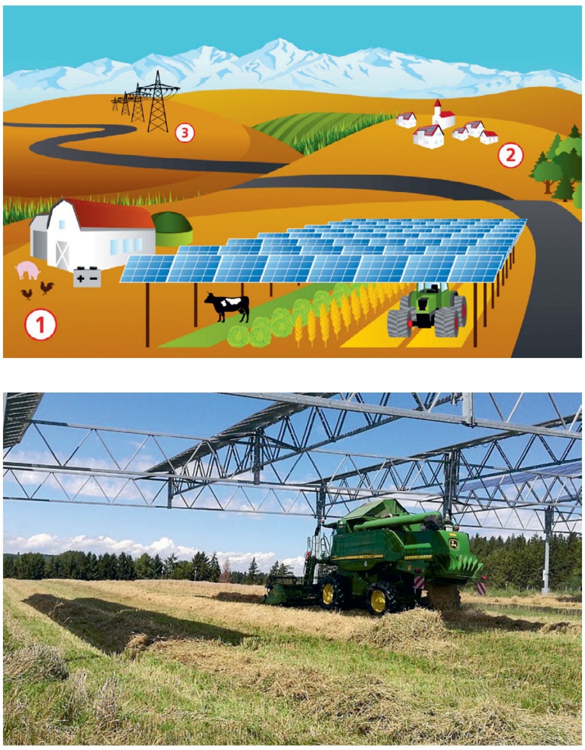
The integration of individual, often competing or conflicting SDGs or their targets, and developing innovative strategies and technologies to achieve the triple bottom line of economic development, environmental sustainability and social inclusion is a crucial, but complex task for science and politics. The Responsible Research and Innovation (RRI) approach can help to tackle this challenge. This paper shows how the RRI approach is applied in a research project to anticipate and assess implications and societal expectations with regard to agrophotovoltiacs technology and its promise for sustainability.

Agrophotovoltaics technology

Agrophotovoltaics (APV) technology offers an apparently simple and unique technological approach to interlink SDGs 2, 7 and 15 and create synergies by adopting this multi-purpose solution. The technical innovation of APV compared to ground-mounted PV is the installation of solar panels high above the ground so that food production with agricultural machinery is still possible. In this way, APV reduces land use competition, since it allows for both solar-based electricity generation and organic farming at the same time and on the same site. Besides, the field strips support the preservation of biodiversity where the APV pillars are placed, as no agricultural production is feasible there.

The electricity produced by APV can be used to cover the energy demand of nearby farms or to supply electricity to local communities (Figure 13). If the APV electricity supply exceeds the local demand, electricity can be fed into the grid according to the German Renewable Energy Sources Act (EEG). Grid-based energy export to urban areas creates economic added value in rural areas. Farmers can achieve additional and reliable income from electricity production without jeopardizing their traditional agricultural business.

Figure 13: Agrophotovoltaics concept (top: © Fraunhofer ISE) **and pilot plant** (below: © Hofgemeinschaft Heggelbach).



The solar panels of APV reduce photosynthetic active radiation. On average, the plants under the panels receive about 30% less radiation compared to a reference field without APV. This has an impact on the microclimate, water balance, biomass yield and food quality. The direction (increase or decrease in yield) and amount of change is not easy to assess since different factors influence the biomass production. These include, among others,

- site characteristics (e.g. soil, climate) and weather conditions;
- design of the APV plant (height of pillars, number of solar panels, sun exposure, buffer areas around the installation);
- plant species and varieties and their light requirements;
- agricultural production system (organic or conventional).

Preliminary results from agronomic studies in the APV-RESOLA project (for more information please visit the project website at www.agrophotovoltaik.de) indicate that the change in yield depends heavily on the culture and weather conditions. While some cultures such as wheat and potatoes need full sun for high yields, others such as clover or celery prefer to grow in shady conditions. Assuming different weather conditions and crop rotation, plants will respond to the shading by APV with a decrease in yield in wet and sunless years and an increase in dry and sunny years. However, long-term studies with different site characteristics, cultures, weather conditions and agricultural production systems are needed for reliable statements regarding changes in yields and food quality under APV modules.

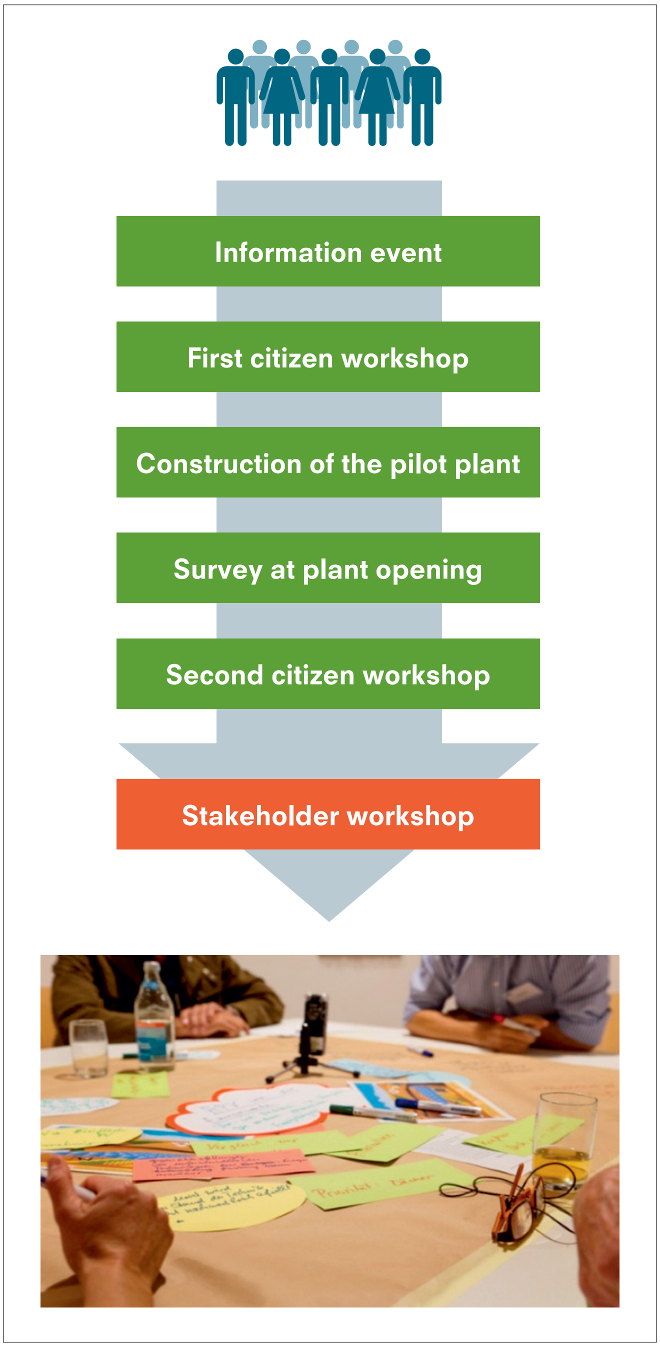
RRI design in the agrophotovoltaics case study

Proof of the technological concept and agronomic feasibility of APV is not sufficient for a comprehensive RRI approach. Lessons learned from renewable energy technologies, such as wind farms and solar parks, indicate that societal knowledge, experience and expectations have to be integrated in the design and framing of technologies (Hoppe et al., 2015, Schweizer et al., 2016). We can assume that the public will in general accept the concept of APV, as it contributes to three main SDGs: food production, renewable energy supply and biodiversity preservation. However, its acceptability can be challenged during the site selection process for APV plants and the start of construction work. This is not surprising, since energy infrastructure installations are an intervention in the living environment of citizens (Habermas, 1995). Consequently, public concern, rejection or even resistance may arise at the local level. The reasons for this are manifold, the main ones being:

(1) The need and planned location for individual plants is controversial.
(2) The benefits and disadvantages of the technology and specific plants are unevenly distributed.
(3) There is a discrepancy between the perspectives of experts and those affected, such as citizens, especially with regard to the balance between advantages and disadvantages.
(4) There is criticism of the decision-making process itself, including the insufficient (formal, but also informal) public participation.

The RRI concept plays a key role in the APV-RESOLA project. The objective of the project is to design the APV technology in a responsible, socially acceptable and sustainable way. To reach that goal, we – the APV research group at the Institute for Technology Assessment and Systems Analysis (ITAS) of the Karlsruhe Institute of Technology (KIT) – applied an inter- and transdisciplinary research approach by integrating citizens and stakeholders. With this technique, we intended to pick up their knowledge, ideas, opinions, expectations and apprehensions as well as their values and evaluations. And we also we aimed to investigate the factors influencing the acceptability and acceptance of the APV technology and to identify any points of conflict and possible solutions.

Figure 14: The multistage RRI concept integrating citizens and stakeholders.



For the APV-RESOLA project we developed a multi-stage RRI concept (see Figure 14). First, all citizens of the community Herdwangen-Schönach (where the APV pilot plant is located) were invited to join an information event about the APV-RESOLA project. Long before the APV pilot plant was constructed, we invited citizens living in the neighbourhood of the planned site to become part of a citizen workshop on APV technology. Out of over 2,000 citizens who were asked to apply for participation, we invited 30 people, of whom 26 actually took part. In a brainstorming session conducted in a focus group format, we identified and ranked the topics proposed by the participants. Then we discussed the highest rated topics in four World Café rounds. In particular, the findings on technical and technological issues were discussed in a timely manner with the project partners responsible for the design of the APV technology.
Based on the summarized main statements of the first citizen workshop, we conducted a survey with paper questionnaires at the opening ceremony of the APV pilot plant. After one year of plant operation, we invited the participants of the first citizen workshop to attend a second workshop. The objective was to find out if their opinion had solidified or changed and, if so, in what respect. In addition, we invited the citizens to a simulation game with the aim of identifying suitable locations for commercial APV plants in their hometown community. Finally, we organized a workshop with stakeholders and representatives of the citizen workshop to discuss the outcome of both citizen workshops.

Citizens' recommendations addressing the socio-technological interface

There was broad consensus among the participants in the first workshop that the concept of APV is a sustainable approach to reducing land use competition by dual land use. Citizens prefer APV to solar parks (open-space solar panels) and to biogas plants based on maize feedstock. At the same time, they agreed that APV should only be used when all available roofs and industrial areas have first been covered with solar panels. Citizens' opinions on technical issues mainly addressed the stability of the construction and the safety for farmers and citizens working or walking below APV panels. One participant was concerned about electro smog produced by APV. Another one proposed replacing the steel pillars with wooden pillars for a less technical and more natural appearance of the plant. Several citizens highly recommended combining APV technology with energy storage in order "not to lose one single kilowatt of the precious APV energy". This recommendation was taken up by the engineering and electricity company in the project team. They installed an electricity storage unit on their own account despite the high investment involved.

An interesting outcome of the citizen workshops was that most recommendations addressed the socio-technical interface and socio-economic embedding of APV technology rather than the technological design itself. This is because PV technology is highly developed. Besides, the consequences for agriculture and society have not been sufficiently researched. People's biggest concern about APV was related to the loss of untouched natural landscapes and their beauties. Citizens were afraid that APV technology would transform their landscape, which is characterized by small-scale agricultural structures and practices, into industrial landscapes with technical artefacts. Regions roofed with APV would decrease the recreational value for citizens and tourists. Some citizens compared the appearance of APV with those of (ugly) hail nets. In their home region, Lake Constance, and in the South Tyrol huge horticultural areas are covered with these nets. Citizens recommended preventing such undesirable developments by responsible framing, embedding and governance of APV. Local characteristics should be considered and citizens should be involved in decisions about suitable locations for APV. Referring to the lessons learned from biogas plants, citizens pointed out the risk of uncontrolled spreading of APV plants (like biogas plants) if plant size and number per region were not limited.

Citizens liked the idea of dual land use for energy and food production. However, they were concerned that under real-world conditions, an imbalance between electricity and food production could occur over time. Income from electricity production is higher than from food production and requires less field and bureaucratic work. Hence, they recommended that agriculture should be mandatory under APV. In addition to considerations about the yield, some citizens were also concerned about changes in food quality. They stated that they would not tolerate any decrease in food quality. Agronomists in the project consortium took this statement seriously. They extended their research design to investigate the impact of APV on food quality, such as the size of potatoes. Under APV, potatoes are usually smaller and sometimes not big enough for the market.

Citizens' views of APV technology were in general surprisingly lacking in self-interest: they often took a systems perspective and were concerned about environmental justice in the snse of a fair distribution of environmental benefits and burdens. They stated that APV could be accepted despite drawbacks for the landscape if the local population could gain clear benefits.

Lessons learned

It is clear from the literature that citizen participation that only serves the purpose of gaining acceptance for a technology usually fails to deliver the desired result. Instead, research suggests that early and inclusive involvement of citizens is more effective than just providing information (Von Schomberg, 2013. Hübner and Pohl 2015).

The prerequisites for a successful participation process include openness to other interests and the willingness of technology developers to consider alternatives and conceptual changes and to make compromises. There is evidence that technology can be improved if dissents and conflicts are taken up and dealt with at an early stage in a participatory project (Geissel, 2009; Schweizer, 2008; Kamlage et al., 2017). Nevertheless, citizen participation does not guarantee the successful development and implementation of a responsible technology that meets the criterion of acceptability.

In the APV project described here, citizens participated from the start. They accompanied the project and were asked twice about their opinion, once before and once after construction of the pilot plant. Overall, the question arose how to ensure that long-term energy infrastructure facilities such as APV plants are operated in a sustainable way. On the one hand, they require responsible governance to control land use, ownership and plant operation, in particular the balance between energy and food production. On the other hand, accompanying processes, such as the monitoring of plants, are needed to enable long-term use of APV technology without adverse sustainability effects and public resistance. This leads to the third point, the changeability of boundary conditions that can influence overall evaluation of the technology. Fourthly, an open relationship between citizens and experts is indispensable – i.e. acknowledging others and questioning one's own perspectives. Fifthly, those involved in the research process must possess sufficient reflective ability to guarantee fruitful involvement of societal actors and to allow revision of the problem definition and/or adaptation of the research design.

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Part 3
Abstracts

Presentation 1

The responsible research and innovation framework – participation and deliberation

Melanie Paschke, Zurich-Basel Plant Science Center, ETH Zurich and Universities of Zurich and Basel

Abstract

Introduction to the Summer School: Responsible Research and Innovation (RRI) is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim of fostering the design of inclusive and sustainable research and innovation (Horizon 2020, European Commission). In this introduction, we explore these concepts and their meaning for research practice.

Deliberation is seen as an important concept in RRI, because it allows greater inclusion and a broadening of societal perspectives. Deliberative formats and processes aim to maximize the decision-making power of those targeted and to heighten the responsiveness and accountability of scientists towards societal needs, values and expectations. As such they can lead to understanding, respect, empathy, and a balance of power. Hence deliberation in science is a yardstick for scientists in modern democracies and global governance.

This presentation provides an introductory overview of tools and techniques used in deliberation and practised in the Summer School.

Literature

Felt, U., Barben, D., Irwin, A., Joly, P.-B., Rip, A., Stirling, A., Stöckelová, T. (2013). Science in Society: caring for our futures in turbulent times. European Science Foundation Policy Briefing, 50, 1–36.

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Bellamy, R., Chilvers, J., Vaughan, N. (2016). Deliberative Mapping of options for tackling climate change: Citizens and specialists 'open up' appraisal of geoengineering, Public Understanding of Science, 25, 269–286.

Presentation 2 & Workshop 1

Co-producing knowledge

Christian Pohl, D-USYS td lab, ETH Zurich

Abstract

In this presentation and workshop we will apply the 10-step approach for co-producing knowledge in interaction between transdiscisplinary experts and researchers. Ten questions open discussions around research issues, identifying and reviewing the societal problems they entail, identifying relevant actors and disciplines, and clarifying the purpose and form of the interaction.

Outcome of the workshop and case study work: identification of actors and disciplines involved in your research.

Literature

Pohl, C., Krütli, P., Stauffacher, M. (2017). The reflective steps for rendering research societally relevant. Gaia 26/1, 43–51.

Workshop 2

Enabling inclusiveness

Integrating societal considerations in your research through constructive technology assessment

Daan Schuurbiers, De Proeffabriek, Arnhem, The Netherlands

Abstract

As part of ongoing attempts to strengthen the responsiveness of research and innovation to societal needs and values – most recently within the framework of responsible research and innovation – scientists are called upon to 'integrate broader societal considerations in their work'. But for all the compelling rhetoric, what does this actually mean at the level of day-to-day research? What sort of considerations are we talking about? Whose considerations are they? And how can they be applied to research?

In this workshop, we will explore how to integrate societal considerations in your own research. After a brief introduction to the notion of RRI and its implications for research practice, we will identify the questions, knowledge requirements and possible concerns that societal actors might have. Subsequently, we will explore how you might incorporate these questions into your own research through constructive technology assessment.

Literature

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Elzen, B, Bos, B. (2016). The RIO approach: Design and anchoring of sustainable animal husbandry systems. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2016.05.023

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Workshop 3

Ethical inquiry into emerging technologies

Melanie Paschke, Zurich-Basel Plant Science Center, ETH Zurich and Universities of Zurich and Basel

Abstract

Previous experience and examples in several fields of technological innovation and sustainable development have shown that behind deep and far-reaching societal concerns are often conflicts on overlooked values. An important idea of responsible research and innovation is that engaging in ethical inquiry down-stream in the research process – i.e. in pre-research or at the very start of a research project – can result in greater acceptance. However, ethical inquiry is still seen as a burden and not as an opportunity for deliberation. Efforts to integrate tools such as Constructive Ethical Technology Assessment in the research process are built on the idea of technical mediation or co-construction of the human-technology interactions.

In this workshop, we will see how ethical inquiry can be built in the research and innovation process.

Literature

Kiran, A.H., Oudshoorn, N. & Verbeek, P.-P. (2015). Beyond checklists: towards an ethical-constructive technology assessment. Journal of Responsible Innovation, 2(1), 5–19. https://doi.org/10.1080/23299460.2014.992769

Workshop 4

A practical introduction to design thinking

Grégory Grin, Managing Director of Fri Up, Fribourg, Switzerland

Abstract

During this workshop, participants will discover design thinking – an innovative, human-centred approach to problem solving that starts with a specific challenge and goes through multiple stages of iteration: observation, interviews, brainstorming, and prototyping.

After an introduction to the tools and methods, participants will practise in groups on a real-life challenge, from reframing the challenge, generating and describing ideas, prototyping them and exposing them to external feedback.

Literature

It is recommended to watch the 8 minutes "ABC Nightlife" report about how the company IDEO works. This video can be found on Youtube, for example at: https://youtu.be/M66ZU2PCIcM

Presentation 4

Citizen participation in designing an agrophotovoltaics system

Dr. Christine Rösch, Karlsruhe Institute of Technology (KIT), Institute for Technology Assessment and Systems Analysis (ITAS), Head of research area: Sustainability and environment, Germany

Abstract

Even though the technical feasibility of many renewable energy technologies has been proved, their success depends crucially on public opinion. Since acceptance of renewable energy plants is still a controversial issue, public opposition remains a hurdle for new installations despite their climate friendliness. Hence the integration of citizens in the decision-making process plays a key role in designing new technological solutions that are both socially acceptable and address the objectives of sustainable development.

In this context, we have investigated citizens' perceptions of agrophotovoltaic (APV) system technology by applying the RRI concept. APV combines biomass and solar power production on the same site. It increases renewable energy production without triggering land use competition and conflict. The RRI concept comprises two citizens' workshops, one before and one after construction of the APV pilot plant, as well as a survey at the opening ceremony of that plant. The talk will present the RRI concept and the findings from citizens' participation in the design of the APV system.

Literature

Rowe, G. and Watermeyer, R.P. (2018). Dilemmas of public participation in science policy, Policy Studies. https://doi.org/10.1080/01442872.2018.1451502

Presentation 5

Participatory breeding and valorization strategies a practice example – Insights from case studies

Bernadette Oehen, Research Institute of Organic Agriculture (FiBL), Department of Crop Sciences, Frick, Switzerland

Abstract

The EU funded project DIVERSIFOOD aims at increasing food and crop diversity. In the course of the project, we conducted case studies across Europe involving seed conservation, seed sharing and participatory plant breeding. From a socio-economic perspective we asked how different initiatives evolved and developed and what was relevant for joint action. In the presentation the focus will be on the results of the cases studies and recommendations for strategies to valorize participatory breeding products.

Literature

S. L., van Bueren, E. T. L., Ceccarelli, S., Grando, S., Upadhyaya, H. D., & Ortiz, R. (2017). Diversifying food systems in the pursuit of sustainable food production and healthy diets. Trends in Plant Science, 22(10), 842–856.

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Workshop 5

Sustainability transitions: firms, consumers, policies and politics.

Dr. Jochen Markard, Sustainability and Technology within the Department of Management, Technology, and Economics of ETH Zurich, Switzerland

Abstract

Sustainability issues such as climate change, lack of clean water and sanitation, depletion of natural resources, waste, poverty and hunger pose extraordinary challenges for societies. Research in the field of sustainability transitions addresses such major sustainability challenges and analyses how existing sectors (energy, transport, food) change in response. A focus of this perspective is on the role of innovation in larger societal transitions. Transitions research sets out from the normative assumption that established sectors need to change fundamentally to become sustainable in the long run. Sustainability transitions are purposive transitions of sectors and industries associated with sustainability goals and guided by public policies.

In the workshop, I will introduce key concepts of sustainability transitions research (radical innovation, transition pathways, multi-level perspectives) and provide examples from the ongoing energy transition. Then we will discuss the challenges of sustainability transitions in the food sector. We will focus on actors (esp. firms and consumers), public policies and the role of politics.

Literature

Geels, F.W. et al. (2017). Sociotechnical transitions for deep decarbonization. Science, 357(6357),1242–1244.

Hinrichs, C.C. (2014) Transitions to sustainability: a change in thinking about food systems change? Agriculture and Human Values, 31(1),143–155.

Presentation 6

Digitization in agriculture a practice example

Eduardo Perez, World Food System Center, ETH Zurich, Switzerland

Despite the opportunities offered by smart farming to rethink the way we produce our food, the implementation rates of these new technologies remain relatively low. Trying to translate a purely technological approach into the development of new applications in agriculture has proven unpractical. Furthermore, providing a legal framework remains incredibly challenging for governmental institutions all around the world, as technologies are in constant change and questionable cases of data use/sharing are daily news.

Within this context ETH Studio AgroFood was created in order to explore the challenges of digitization in the agricultural sector, with special emphasis on research, networking and teaching. A more inclusive approach that restores agricultural expertise and farmers' needs as key elements in the innovation process is a core element. Support in the development of interdisciplinary research projects, implementation of a teaching setup that encourages entrepreneurship in the agricultural domain, and coordination of events with the public are currently in process to help accomplish a new vision for agriculture in Switzerland.

Presentation 7

FAIR data principles for best practice in agricultural research data management – a practice example

Foteini Zampati, Global Open Data for Agriculture and Nutrition, (GODAN)

An enormous amount of agricultural data is generated from universities and research institutions and the open data movement is encouraging these organizations to make data discoverable, reusable and reproducible. Few guidelines and standards exist on best practice in open research data management. However, the FAIR Principles, developed by the Dutch TechCenter for Life Sciences are gaining traction in the donor and research community as a best practice for the collection, use, and management of data in the agricultural sector.

Presentation 8

Sustainability with biomass: burning neutral – a practice example

Maria J. Santos, Department of Geography, University of Zurich

This presentation provides an overview of past, current and future projections of biomass based energy. We will focus on charcoal, due to its growing demand to meet urban dweller needs in many areas of the global south.

More than half the global population now lives in cities, and urban-dwellers are restricted to charcoal use due to ease of production, access, transport, and tradition. Increasing demand for charcoal, however, may lead to increasing impacts on forests, food, and water resources, and may even create additional pressures on the climate system. There is pressure to switch charcoal use to other energy carriers. However, how do we deal with values and societal norms incorporated in the heritage of a country? What models can be used? Is innovation compatible with traditional values? How can feedback from communities be integrated in the modelling and innovation building process?

The presentation and case study will give participants an insight into the complexity of responsible innovation at the socio-environmental boundary. Here we will look into the potential of charcoal as a not only renewable, but also carbon and deforestation neutral energy source. This will involve concepts such as nexus thinking and charcoal life cycle analysis. Discussion will focus on whether and how innovation in the plant sciences (in a broad sense) can meet this demand.