# Ethical issues of developing new technologies in agriculture

Key issues in agricultural ethics

Gremmen, Bart

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# Chapter 11

# Ethical issues of developing new technologies in agriculture

*Bart Gremmen, Wageningen University, The Netherlands*

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## 1 Introduction

Contemporary society faces a series of grand challenges on topics like transport, energy production, and healthcare. Innovation is the preferred solution for resolving these grand challenges, and, therefore, the concept has become 'the emblem of the trendy society' (Godin, 2015). An important grand challenge is the anticipated rise of the worldwide demand for agricultural products (FAO, 2012). However, agriculture already faces a range of problems, regarding the reduced welfare of animals, the utilization of pesticides, susceptibility to infectious diseases, housing systems, soil degradation, and the high use of antibiotics and vaccines. These problems will decrease the number of obtainable future agricultural products. Could most of those problems be solved by a series of innovations?

Incremental innovation has always been at the center of agriculture (Klerkx and Rose, 2020). From the start of agriculture, farmers have developed ways to use plants and animals for human consumption. Step by step, using trial-and-error breeding processes, they slowly domesticated crop plants and animals. This process of thousands of years of domestication has led to an expansion of cultivated fields, with only a few crop plants that are produced in monocultures, and to the use of mainly five species of animals in livestock farming (ibid). The

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results of incremental innovation are integrated quite easily into existing agro-ecosystems. Any ethical issues are immediately dealt with. In case of any bad outcomes, it is still possible to reverse the changes or interventions.

In the last centuries, incremental innovation has continued and agricultural research has led to several radical innovations in agriculture. These innovations, starting from mechanization to hybrid cultivars and to the development of modern biotechnology, have shaped conventional agriculture on a world scale (Zambon et al., 2019). However, non-governmental organizations and policymakers have raised serious ethical issues which are the results of these radical innovations (Gremmen et al., 2019). The results of radical innovation transform existing agro-ecosystems into new ones. If any ethical issues are not immediately dealt with, the changes are often irreversible. As a consequence, agriculture has lost an enormous part of its license-to-produce from society. To regain this license, the Responsible Research and Innovation (RRI) initiative urges all radical innovators to identify and help solve moral problems in the early stages of innovation (Von Schomberg, 2013). The idea is to deal with potential ethical issues that threaten radical agricultural innovation as soon as possible in the developmental process (Grunwald, 2010). This will lead to radical, responsible reorganizations of farmers' practices.

From the perspective of agricultural ethics, I will investigate potential ethical issues threatening radical innovation in agriculture, and what kind of questions these ethical issues entail for innovators. First, the role of ethics in the development of radical new technologies in general will be described. My conclusion is that innovators have to be able to deal with emergent ethical issues in the development of new technologies. Second, the RRI initiative will be described and analyzed to apply it to agriculture. Third, four potential ethical issues will be identified for developing new technologies in agriculture. These ethical issues signal the possible occurrence of criticism from stakeholders, consumers, and policymakers and thus lead to specific normative questions innovators must answer. Two samples of developing agricultural technologies that aim to change organisms: genetic modification and the toolbox of new plant breeding technologies (NPBTs) will be analyzed.

## 2 Ethics and developing new technologies

In a number of innovation areas, such as genomics and synthetic biology, moral problems occur in the early stages of innovation (e.g. Singer, 1986). According to Collingridge, social control of technology is necessary to avoid the harmful social consequences of a new technology (Collingridge, 1980). This may be done by changing technology in its infancy or by imposing controls and restrictions. Two conditions are necessary to avoid the undesired consequences of a new technology: it must be known that a technology has, or will have, harmful effects, and it must be possible to change the technology in some way to avoid the effects (Collingridge, 1980). One or both of the conditions are often lacking, and attempts to control technology seldom succeed. According to Collingridge in such cases, there is a ‘dilemma of control’. The first horn of the dilemma is that the harmful social consequences of the fully developed technology cannot be predicted with sufficient confidence to justify the imposition of control. The second horn of the dilemma is that by the time a technology is sufficiently well developed and dispersed its unwanted social consequences may not be apparent, it is no longer easily controlled. Control may still be possible, but it will become very difficult, expensive, and slow. What happens is that society and the rest of its technology gradually adapt to the new technology, so that, when it is fully developed, any major change requires changes in many other technologies and social and economic institutions, making its control very disruptive and expensive (Collingridge, 1980).

An important assumption of the Collingridge dilemma is the consequentialist/utilitarian perspective in ethics. The normative starting point of the dilemma is the need to avoid the harmful social consequences of a technology, but the message of the dilemma is that a consequentialist/utilitarian perspective is impossible. In the early phases of a new technology, ethical deliberations become speculative because we lack the required knowledge (Grunwald, 2010). In the latest phases of a new technology, ethical deliberations often come too late, namely, when all of the relevant decisions have already been made, when it is too late to avoid harmful consequences of the technology. Collingridge’s own normative response to the dilemma is to maintain the ‘freedom to control technology’, because the essence of controlling technology is to retain ‘the ability to change a technology, even when it is fully developed and diffused, so that any unwanted social consequences it may prove to have can be eliminated or meliorated’ (Collingridge, 1980 20/21). He suggests developing organizational structures and scientific tools to deal with the resistance to such control (ibid. 19). Experts, decision makers, and end-users all are entangled in controlling the new technology.

However, Collingridge did not foresee that some experts were going to use a version of his control dilemma as a normative tool in their attempts to exclude prospective users from the innovation process. Experts sometimes stress that they are willing to include users in the early stages of the new technology (Gremmen, 2007), when there is still a lot of room to take the voice of prospective users into account in the design of the product, but the experts can offer little concrete information that would allow prospective users to imagine how they could integrate the end-product in their everyday life. This version of the Collingridge dilemma depicts the end-users in the emergence of new technologies as the end-point of a linear process. However, the world of the users and the world of technological innovation are by no means separate entities that only merge when a final product is delivered to the users; they are entangled from the start. Technology assessment, and, later, constructive technology assessment, recognized the importance of involving users in the innovation process to encourage the integration of new technologies in users' everyday lives (Rip et al., 1995; Oudshoorn and Pinch, 2003). The case has been made that technologists need to study responses to science in order to learn from them (Levitt, 2003) and to discover missing propositions in their own reasoning (Locke, 2002). Everyday life concerns that inform people's responses to emergent technologies may be at odds with scientific and technological standards but can and should be understood on their own terms. In this way, experts could benefit from the active involvement of prospective users (Veen et al., 2010).

It is difficult for innovators to deal with possible ethical issues. Not only do the results of an innovation trajectory have unknown consequences, but, more importantly, we do not know the results of innovation at the start of the innovation trajectory (Wathes et al., 2008). This means that, in moral reasoning about innovations in the making, the relevant moral facts and the appropriate principles are more or less still unknown, as are relevant moral consequences. Only by doing ethics in life sciences will the moral dilemmas in the trajectory of responsible innovation emerge.

## 3 Responsible research and innovation in agriculture

One of the strategies for addressing the criticism of society is stakeholder inclusion (Blok, 2019): academia, industry, citizens, and therefore the government collaborate in the innovation process to form robust, systemic solutions. Through stakeholder participation, the innovation process is predicted to become more inclusive and, as such, its results are expected to be more social-ethically accountable (Meissner and Carayannis, 2017). This 'democratization' of research and innovation is additionally called Responsible Research and Innovation (RRI) (Blok and Lemmens, 2015). For example, RRI is an emerging field within the European research and innovation (R&I) policy context that aims to balance economic, socio-cultural, and environmental aspects in innovation processes (European Commission, 2011). Because technological innovations can contribute significantly to answering societal challenges like temperature change or food security but can have negative societal consequences, it's assumed that social and ethical aspects should be considered during the R&I process. For this reason, the emerging concept of RRI concerns ethical reflection on the character, scope, and applicability of responsibility and innovation in innovation practices generally, and, therefore, the way social–ethical issues are often applied and addressed in agriculture. The concept of RRI expresses the ambition to deal with societal needs, next to the more traditional objectives like profit maximization, economic process, and competitive advantage (cf. Blok and Lemmens, 2015).

In the context of agriculture and food, RRI offers opportunities because it provides a new impulse to strengthen animal, agricultural, and food ethics. An example is the reflection on the killing of day-old male chicks (Bruijnis et al., 2015; Gremmen et al., 2018) (see Section 5). Compared to a 'classical' innovation trajectory, responsible innovation aims at some reasonable stakeholder involvement at an early stage (Blok and Lemmens, 2015; Blok, 2019). During this stage, stakeholders discuss normative values. An example of the method in agriculture is the reflexive interactive design method (Bos et al., 2009).

From a more general ethical point of view, one could argue that RRI is somewhat ambiguous. On the one hand, it promises a transparent ethical agenda (Schomberg et al., 2019; Van de Poel and Robaey, 2017)); on the other hand, it contains the danger that ethics (responsibility) is reduced to procedural categories like deliberation and responsiveness (Stilgoe et al., 2013). With living organisms, this reduction is counterproductive (Gremmen et al., 2019). To do justice to the particular assignment of RRI, ethics should, in these contexts, belong to the core of RRI (ibid). In the following section, we will elaborate on the ethically unique status of farming to enable the mainstream approach to RRI to be applied to agriculture and food. A list of four ethical issues will strengthen the moral agenda of RRI to enable the contextualization of RRI within agriculture.

## 4 Four ethical issues in developing new technologies in agriculture

Over the last few hundred years, there has been a plethora of innovations in farming techniques. From an ethical perspective, this is clearly very positive, but agriculture, compared to other technical practices, is special (Gremmen et al., 2019). Agriculture can be defined as the technical transformation of living material into plant and animal products, in which life processes play an essential role (ibid). Agricultural products enter our bodies, which is why farming is an interface, providing a sharp distinction between the (outside) world of nature and the (inside) world of humans. In this way, we are included in larger systems and part of many cycles. The products of farming are organic, while in all other technical practices, the products are inorganic. Without a doubt, agriculture is the most crucial human activity on the earth. Farmers don't just take care of plants and animals. They enable our survival on earth (ibid).

Without agriculture, we would be forced to collect the limited food that is available in nature. As a result, the number of people on the earth would decrease drastically. Agriculture is necessary for the survival of humanity. We can do without most other technical practices. In my view, this may explain the ethical debates about agriculture. Although we can survive without some agricultural products (e.g. meat), our culture is entirely focused on plant and meat consumption. In this way, the plants and animals 'take care' of us. Agriculture is the basis of our culture whereby, by intervening in the natural life of plants and animals, we gradually have domesticated nature. An important characteristic of this so-called incremental innovation is that it is reversible. We cannot just develop new technologies and immediately abandon agricultural processes and products in the way we can irreversibly abandon other technological processes and products. The *first ethical issue* is therefore that the development of radical technologies in agriculture is seen as disruptive by many stakeholders, citizens, and societal organizations. This means that the first ethical question for developers of new technology must be: how can we improve the current situation without irreversibly altering it?

In agricultural innovations, intrinsic normative standards seem to be provided and used, contrary to other innovations which provide no intrinsic normative standards at the start of the innovative process and call for extrinsic normative standards (e.g. in value-sensitive design). There is a symbiosis between people and domestic plants and animals in farming, as a result of which we can regard farming as a kind of 'second' nature. Animals in nature are, to a certain extent, autonomous: they do not need us to survive. We have made domestic plants and animals dependent on us by intervening in their life processes, especially their reproduction. The classic role of farmers is to take care of living things on the farm. They reproduced life by making a selection from everything that lives. Recent radical technologies in agriculture have led to the *second ethical issue*: farmers, aided by new high-tech processes, bypass the natural world and turn from reproducers of life into producers of life. The second ethical question for developers of new technology must be: are we going to change farmers into producers of life?

However, innovations leading to irreversible actions, such as the extinction of certain natural species by genetic modification, or the destruction of all the seeds of a cultivar, are very risky because interrelated cycles that continue to make the future of farming possible could be interrupted. This means that the artifacts resulting from non-agricultural innovations may have certain one-dimensional risks, while in agriculture often multi-dimensional risks may occur because of the interrelatedness of species in (agricultural) ecosystems. The need to deal with these multi-dimensional risks is the *third ethical issue*. For example, the invention of genetic modification in 1973 has been important for agriculture because it allows direct intervention in the genetic basis of the reproduction of plants and animals. This technology is transformational because it not only enables manipulation of life at the most fundamental, molecular level but also fundamentally changes the conditions of the possibility of transformation of life itself. The trial-and-error methods of the farmers are replaced by the targeted approach of scientists, therefore giving the concept of 'domestication' a completely new meaning. This means in general that the third ethical question for developers of new technology must be: can we deal with the multi-dimensional risks technologies generate?

In farming, plants and animals are not only a production goal but also a means of production. An important difference between the innovation of artifacts and animals and plants is that until now we have not designed the products in farming ourselves through a blueprint on the drawing board. There is talk of 'designing' via domestication and targeted breeding, but that is highly dependent on the biodiversity present and the natural path dependencies of the genetic material. But at this moment plants and animals in farming are not designed by us and they function relatively autonomously as means of production. In farming, the products produce themselves. They have, however, been transformed from natural organisms into domesticated organisms. This leads to the *fourth ethical issue*. Contrary to artifacts, organisms and agro-ecosystems have a double ethical status: they are both subjects and objects. In farming, there is no absolute distinction between the production process and the product. Through the process of growth, the products produce themselves, in contrast to practices in which people or machines make the products. For example, even in meat from the laboratory, the muscle cells produce the beefsteak by repetitiously dividing themselves. In farming, people only provide the preconditions and have to deal with an extra ethical status. This means that the fourth ethical question for developers of new technology must be: how must we deal with the double ethical status of the organisms?

In the following section, we'll use the four ethical issues, and their accompanying normative questions, to analyze the development of new genetic modification technologies. We'll focus on the case of the ethics of genetically modified chickens. Also, we'll use the ethical issues to find out if the technological toolbox of NPBTs, compared to genetic modification, has any specific ethical issues.

## 5 Ethics of genetic modification in agriculture

After the first half of the twentieth century, molecular biology developed ways to alter DNA in controlled ways. Genetic modification (GM) allowed the cutting and splicing of DNA molecules (Gremmen, 2017). Two methods were developed: the particle gun method and the agrobacteria method. These were used first in mono-cellular organisms and subsequently applied to multi-cellular organisms. The first GM-mammal, made in the mid-1970s, was a 'transgenic' mouse (a mouse containing DNA from another species). In 2015, the GM-salmon was the first GM-product to be approved for consumption in America (ibid).

The basic genetics in plants and animals is more or less the same, but the application of some methods and technologies differs (Barnes and Dupre, 2008).

For example, mutation breeding – increasing the mutation frequency through chemicals or radiation – is a common and legal method for plants but is not possible in animals, for ethical and economic reasons (Shu et al., 2011). In plant breeding, marker-assisted selection and GM have been used (Gremmen, 2005) for many years, but GM has not yet been applied to livestock on a large scale (Gremmen, 2009). The only approval given for a GM animal for food production is Canada's AquAdvantage salmon eggs, with a focus on growth enhancement (Goubau, 2011). Other examples of GM animals are pigs (i.e. increased growth rates and higher utilization of phosphate in their feed), dairy cows (enhanced resistance to mastitis, improved udder health, and improved milk quality), goats and sheep (improved wool production and disease resistance), and chickens (resistance to diseases and feed efficiency) (Thompson, 2007).

There are three different legal regimes for GM applications in the European Union (Gremmen, 2017). The industrial application of GM is the first. Industry transfers molds, viruses, and bacteria into genetically modified organisms (GMOs). This contained use is allowed because it is done in sealed containers. Agriculture is the second. The application of GM to plants is allowed. However, the application of GM to animals is not allowed, unless there are serious arguments to do it anyway. Currently, there are no GM animals allowed in the EU. The application of GM to humans is the third regime. This is the severest legal regime: GM of humans is not allowed.

Compared to the millions of hectares of soy, corn, canola, and cotton in South and North America, GM plants are almost non-existent in Europe. Although it is legal to develop and cultivate GM plants, the long and expansive regulatory road in the last decades has led to one crop in one country: about 60 000 hectares of Bt corn in Spain (ibid). The potential benefits of GMOs are higher quality, higher environmental value, lower price, and higher nutritional value. Potential societal values are higher food security, more affordable food, better food safety, higher societal health, more sustainability, and biodiversity. An important problem is that these benefits and values may clash. For example, higher food security or better price could result in lower health or lower food safety. It is all about setting the right priorities.

The results of the Eurobarometer showed in 2010 that people in the EU do not see the benefits of GM-food (Gaskell et al., 2011). Some people think GM is probably unsafe or harmful (ibid). People in the EU have a strong concern for safety and do not see the benefits of horizontal gene transfer. They have reservations about safety and the potential effects on the environment but accept the potential benefits of vertical gene transfer (ibid) (see the *third* ethical issue). Other people have strong reservations about other ethical issues, such as the use of human embryos, but think the science of regenerative medicine should be developed. Although strict laws are needed to alleviate concerns about ethical issues, they approve of stem cell research, transgenic animal research, and human gene therapy (ibid).

The ethical arguments about GMOs vary among societies (Gregorowius et al., 2012). On the critical side, some simply object to GM. It is claimed that GM technology amounts to a form of hubris concerning man's relationship to nature (are we allowed to 'play God'?) (Comstock, 2010) (see the *first* ethical issue). Criticism has also focused on other disruptive effects of GM, for example, the autonomy of farmers in deciding whether to use the technology (e.g. are patents allowed?) and the autonomy of consumers in deciding whether to put the products on the table (Comstock, 2010). An important argument against the use of GM is that it is unnatural and therefore morally problematic (Siipi, 2004; Haperen et al., 2012) (see the *second* ethical issue).

Many critics are not opposed to GM technology but to its different applications (Rollin, 2006). This means, from a consequentialist stance, that even people who do not have an objection in principle to the technology can still be critical of its use in agriculture in general, and in food production in particular (Sandoe and Christiansen, 2008). The risks and uncertainties of this new technology (see the third ethical issue) are also criticized. It is argued either that there are risks to the environment or human health, or that there might be such risks, and that for this reason some version of the precautionary principle should be applied (Gremmen, 2006).

From the viewpoint of justice, current applications of agricultural biotechnology have also been criticized, in particular with respect to the distribution of economic benefits from its use (Thompson, 2007). Also arguments about threatening the integrity and/or the intrinsic value of plants can be found (see the *fourth* ethical issue). Ethics may clarify and test such arguments and explain normative and epistemic assumptions. In livestock farming, GM may contribute to efficiency but, at the same time, may be used to circumvent ethical problems (Hanssen and Gremmen, 2013). The case about the ethics of genetically modified chickens illustrates (Bruijnis et al., 2015).

In response to the increasing demand for safe, cheap food in sufficient quantities, the intensification and mechanization of poultry farming began in the mid-twentieth century (Gremmen et al., 2018). The number of chickens kept by one farmer has increased considerably since then. Efficiency and specialization were enabled by developments in feeding, breeding, and housing of the animals and by increased knowledge of veterinary medicine, especially the availability of antibiotics for therapeutic and preventive reasons. Genetic selection enabled egg production by layer chickens and meat production by specialized meat chickens. Male chicks became less attractive for meat production (ibid). Available sexing techniques made it possible to distinguish males from females immediately after hatching, and it became common practice to kill these male day-old chicks.

In the Netherlands, over 50 million male chickens annually are killed in a gas chamber immediately after hatching. Societal opposition to this practice has prompted the development of innovations. Several alternatives to the killing of day-old chicks have been proposed (Leenstra et al., 2010); this leads to the question of whether these alternatives are morally superior. We have developed a framework to evaluate the technical and socio-ethical aspects of alternative more responsible innovations to solve this problem, selected on social desirability and technical potential compared to the current situation (Bruijnis et al., 2015). One alternative uses GM of breeding hens that permits the hatching eggs containing males to be identified with spectroscopy. This is a non-invasive technique compared to the technique of taking a sample from the egg to find the difference between male and female eggs. The GM alternative takes advantage of the genetics of birds to ensure GM-free laying hens, and also that their eggs are GM free.

This clear case of a morally inferior practice has potentially morally better alternatives. Besides the GM alternative, there are several others: raising the male chicks, dual use of chickens, taking a sample from the egg, etc. Each alternative has its advantages and disadvantages with respect to technical and socio-ethical aspects, and each has specific importance for various stakeholders. Solving one issue raised by the current situation raises new issues. For example, by acknowledging arguments against the killing of such young animals and starting to rear the males, issues arose about the effects on the environment and the marketing of the chicks. The issue of killing day-old chicks and its alternatives thus seems to be an example of choosing the least of several possible evils and can be explained by a special type of moral lock-in.

Technological lock-in has become since the mid-1980s an important subject of growing academic enquiry in the field of innovation studies, especially by economists working within an evolutionary tradition (David, 1985; Arthur, 1989). The general idea of lock-in is that technologies and technological systems follow specific paths that are difficult and costly to escape (Perkins, 2003). Even if potentially superior alternatives are available, these technologies and technological systems often survive for a very long time. An example is the triumph of the QWERTY keyboard layout over the Dvorak Simplified Keyboard layout (David, 1985). Another is the race between VHS and Betamax as a video cassette recorder standard (Arthur, 1989). Lock-in is explained by the increasing returns of an initial lead in the competition between technologies (David, 1985; Arthur, 1989). 'This arises because early adoption can generate a snowballing effect whereby the preferred technology benefits from greater improvement than its competitors, stimulating further adoption, improvement, and eventual leadership' (Perkins, 2003, 23).

There are many ways in which locked-in technologies may be inferior to their alternatives. We focus on moral lock-in: the way a production system can be locked-in to technology standards that are potentially morally inferior. In some cases, there is a consensus on the potential for moral improvement that could be achieved through the development of alternative technologies. The question then becomes: what is holding back the development of these morally better technologies? Many debates about the transition to these new technologies focus only on the costs involved (Carrillo-Hermosilla, 2013). Our hypothesis is a moral lock-in may explain the survival of morally inferior technologies. We suggest responsible innovation can be a concept for balancing economic, socio-cultural, and environmental aspects in innovation processes (EC, 2011), as an approach to morally 'unlock' alternative innovations. By involving stakeholders in the innovation process and by considering ethical and societal aspects during this process, the socio-ethical acceptability and the societal desirability of innovative products will increase significantly (Von Schomberg, 2013; Blok and Lemmens, 2015).

## 6 Ethics of the toolbox of new plant breeding technologies

The Court of Justice of the European Union (CJEU) decided on 25 July 2018 that all products made by the toolbox of NPBTs are GMOs. NPBTs are technologies to increase and accelerate the development of new traits in plant breeding, and gene editing, CRISPR-Cas9, is its main technology (Zhang et al., 2014). Two research institutes of the European Commission (Cf. JRC/IPTS, 2011) have described the content of the NPBTs toolbox. It contains intragenesis (technologies using transformation with genetic material restricted to the species' own gene pool), cisgenesis, emerging techniques to induce controlled mutagenesis or insertion (ODM, zinc finger nuclease technologies 1–3), and other applications such as or reverse breeding or grafting on GM-rootstocks.

In a short time, CRISPR/Cas9 has been used in plant breeding (Zhang et al., 2014). Compared to older techniques, these so-called genome editing techniques are cheaper, faster, more accurate, and more widely applicable because of their ability to cut and alter the DNA of any species at almost any genomic site with ease and precision (Jasanoff et al., 2015). They have been developed to overcome the problem of randomness that results from mutation breeding and the ability to determine the site of mutation or insertion of genes. Applications of animal gene editing techniques are many, varied, and rapidly evolving, including applications that promise benefits in welfare, disease resistance, and feed efficiency. Although gene editing technology promises significant benefits, this promise will not be realized unless the technology is firmly and fully embedded in ethical principles accepted by society. My aim is to adapt and broaden the existing ethical frameworks on biotechnology (Holland and Johnson, 1998; Rollin, 1995) to these new scientific methods and technologies. This will help scientists, stakeholders, and policymakers to understand, evaluate, and monitor the integration of the technical, social, and ethical aspects of the modern GM toolbox.

There has been a long debate in the European Union about the regulation and legal categorization of NPBTs. At the policy level, discussions have evolved around the question of whether products from NPBTs are or should be subject to special regulation (Sprink et al., 2016). Some people believe that they should also not be subject to special regulation (New Techniques Working Group, 2008) because most NPBTs could not be separated from conventional breeding techniques. Others, highlighting the requirements of the precautionary principle, call for regulation following the regulations for GMOs (Then, Bauer-Panskus, 2017). Most NPBTs are subject to regular GM regulation in the EU according to the CJEU judgment (CJEU 2018: Case C-528/16) on the mutagenesis exemption in Directive 2001/18/EC (European Parliament/Council of the European Union 2001 (hereafter Directive)). This ruling has created a regulatory system for NPBTs, which is unique in the world. If organisms obtained from NPBTs are put in the same basket as GMOs, this may carry a serious risk: transferring analogous ethical problems that GMOs encountered in the past, to organisms obtained from NPBTs, while they may not address similar risks (Poortvliet et al., 2019).

In plant breeding, several new genetic engineering techniques, also referred to as genome editing, have been developed. 'Genome editing' is 'the practice of making targeted interventions at the molecular level of DNA or RNA function, deliberately to alter the structural or functional characteristics of biological entities' (Nuffield Council on Bioethics, 2016, 4). Because of their ability to cut and alter the DNA of any species at almost any genomic site with ease and precision, these genome editing techniques are faster, more accurate, cheaper, and more widely applicable than older techniques (Jasanoff et al., 2015). They have been developed to determine the site of mutation or insertion of the genes and to overcome the problem of randomness that results from mutation breeding.

In plant breeding, the development of CRISPR-Cas9 enabled precisely targeted alterations to DNA sequences in living cells (Zhang et al., 2014). It is based on the 'virus library' of bacteria (a natural way of bacteria to defend against phage infection) and uses RNA to locate the exact spot in a genome. It is possible to insert a new piece of DNA (in the case of a cis- or transgene plant), and it cuts the unwanted piece of DNA (i.e. point mutations) (Jasanoff et al., 2015).

Applications of plant gene editing techniques are varied, many, and rapidly evolving, including applications that promise benefits in salt and drought tolerance, and disease resistance (Brandt and Barrangou, 2019). A new tomato variety that grows like a bush is one of the first cultivars. To realize the promised benefits of gene editing technology, the technology needs to be firmly and fully embedded in society. For example, plant geneticists from Tübingen have developed the 'Tomelo', a variety of tomato that is resistant to powdery mildew because it has a deletion in the SlMlo1 gene (Nekrasov et al., 2017). In less than 10 months, CRISPR-Cas9 enabled them to achieve this (ibid). The new tomato variety is also indistinguishable from naturally occurring deletion mutants and contains no foreign DNA (no natural species barrier was crossed) (Nekrasov et al., 2017).

Although there are all kinds of material on the Internet about the ethical discussion of GM, there are almost no journal papers about ethics and CRISPR-Cas9. The use of an adequate name in the societal debate is very important: is it gene editing or genetic manipulation CRISPR-Cas9 or GM? (Boersma and Gremmen, 2018). The public will link the name of a new technology to an element in the name if they lack knowledge of that new technology. For example, genomics has been linked to GM (ibid). Also, the aims and functions of the new technology are already described in different ways: tinkering with the genome; manipulation of DNA; repairing the genome; tools to create mutations; text processing of DNA. An inappropriate wording proves to be very hard to correct (Boersma et al., 2019).

How can we use CRISPR-Cas9 in the genomes of plants, animals, and humans? First, the technology can be used to *repair* the genome (i.e. heritable diseases), but in some cases, a natural alternative to repair a genome also is possible. *Prevention* is a second use (i.e. inheritable diseases), and *improving* the genome (existing traits or new traits) is a third. Improvement by adding new traits offers endless possibilities. The fourth way to use this technology is to *design* new genomes. In the case of humans, this could lead to the return of earlier ethical debates about eugenics.

What are the ethical issues of CRISPR-Cas9? Because it is possible to insert (a) gene(s) through gene editing, all the ethical issues of GM apply. There are two other ethical issues specific to CRISPR-Cas9, and I conclude by linking these main technological characteristics of CRISPR-Cas9 to the first and third ethical issues in developing new technologies in agriculture:

1. The *first* ethical issue is about the possible disruptive nature of a technology. CRISPR-Cas9 is not by definition a transgene technique (Nuffield Council on Bioethics, 2016). In the media, a denial of its transgenic possibilities is used to make it more likable. Also, a point mutation deletion caused by CRISPR-Cas9 (ibid) is impossible to detect. As a consequence, the difference between GM and non-GM becomes un-detectable, thereby blocking one of the cornerstones in the regulation of genetic modification. Therefore, it will be difficult to exercise societal regulation. Because CRISPR-Cas9 is relatively fast

(Nuffield Council on Bioethics, 2016), regulation could be slow and sometimes even implemented too late. It also means that it is difficult to label products developed by this technology. New transparent and responsible chains have to be developed to ensure the consumer's right to complete information.

2. The *third* ethical issue is about multi-dimensional risks. CRISPR-Cas9 is very accurate compared to GM (Nuffield Council on Bioethics, 2016). However, side effects, like off-target mutations and unexpected results, have also been reported after certain gene editing. Also, CRISPR-Cas9 is cheap compared to GM (ibid). This makes abuse by experts and companies more possible and economically attractive. CRISPR-Cas9 is relatively easy (ibid). This makes abuse by amateurs/terrorists more conceivable. How safe is CRISPR-Cas9?

## 7 Conclusion

Agriculture has been dominated by incremental innovation. Only recently radical innovation has become the standard way of introducing new technologies. We started this chapter by describing the role of ethics in the development of radical new technologies in general and concluded that innovators have to be able to deal with emergent ethical issues in the development of new technologies. What does this mean for applying the RRI initiative to agriculture? We concluded that RRI contains the danger that ethics (responsibility) is reduced to a procedural category similar to deliberation and responsiveness. Our view is that, in contexts with living organisms, like agriculture, this reduction is counterproductive. To do justice to the particular assignment of RRI, ethics should be fundamental to the core of RRI. We therefore elaborated on the ethically unique status of farming to enable the mainstream approach to RRI to be applied to agriculture and food. As a result, a list of four general, potential ethical issues will strengthen the moral agenda of RRI and enable contextualization of RRI within the domain of agriculture. These ethical issues signal the possibility of criticism from stakeholders, consumers, and policymakers and thus lead to specific normative questions innovators must answer. Finally, we analyzed two samples of developing new agricultural technologies that aim to change organisms: we found all four ethical issues in the debates about GM. Also, the debates about the toolbox of NPBTs contained, the issues we already found in GM and two other ethical issues. Innovators still have plenty of opportunities to deal with these issues because the development of NPBTs is still going on. We sincerely hope that innovators will try to discover in the early stage of the development of new agricultural technologies if the ethical issues apply. And if they do, deal with the emergent normative questions as soon as possible.

## 8 Where to look for further information

Some organizations involved with respect to ethical issues of developing new technologies in agriculture are as follows:

1 The European Union (EU) has a special website devoted to RRI tools: https://rri-tools.eu, and the RRI-Practice project is an example of a 3-year project under Horizon 2020. Its aim is to understand the barriers and drivers to the successful implementation of RRI in both European and global contexts, to promote reflection on organizational structures and cultures of research-conducting and research-funding organizations, and to identify and support best practices to facilitate the uptake of RRI in organizations and research programs. The project will review RRI-related work in 22 research-conducting and research-funding organizations and will develop RRI Outlooks outlining RRI objectives, targets, and indicators for each organization.

The RRI-Practice project seeks to

(a) harvest experiences on how research-conducting and research-funding/policy organizations work to strengthen RRI-related values;
(b) support the systematic development of such work in these organizations;
(c) generate scalable knowledge about good practices for the wider implementation of RRI.

2 The Food and Agriculture Organization (FAO) of the United Nations provides information on ethical issues in agriculture on its website: https://www.fao.org/3/X9601E/x9601e04.htm.
3 Unethical practices in agriculture have been described by the Union of International Association in their Encyclopedia of World Problems and Human Potential: http://encyclopedia.uia.org/en.
4 In the United Kingdom, the Nuffield Council for Bioethics doing research on the ethical issues of developing technologies in agriculture. For example, Farming Tomorrow: The Genetic Technology (Precision Breeding) Act 2023, https://www.nuffieldbioethics.org/blog/the-future-of-farmed-food-in-england-what-has-the-genetic-technology-precision-breeding-act-2023-changed.
5 Genome editing and its use as a tool to develop new plant species present ethical and political challenges that have been little discussed until now. A recent report of the INRA-CIRAD-IFREMER Ethics Advisory Committee turns a lens on the intricacies of these questions, analyzing the value systems and symbolic representations that underlie the wide-ranging issues it identifies. Its discussions focus on the example of the

CRISPR-Cas9 genome-editing system. https://www.inrae.fr/en/news/ethics-and-politics-plant-genome-editing-joint-committee-report-and-position.

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