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Ethical dimensions of livestock genomics

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This deliverable was completed and delivered late. The content of the deliverable conforms to the description of action in the BovReg project plan.

Dissemination and uptake

This deliverable concerns ethical aspects of (developments in) genomic selection in livestock breeding and should be available in the public domain. It will therefore be made available for consultation at the BovReg website.

Table of Content

1. Summary of results

This report discusses ethical dimensions of (developments in) genomic selection in livestock breeding, based on literature review. It discusses relevant ethical values behind EU agricultural policy; ethical questions that can be raised on the basis of public considerations with respect to new technologies more generally; ethical considerations based on the application of a mainstream ethical approach ('principlism') to genomic selection; and ethical questions based on the concepts of 'biopower' and 'geneticization'.

Ethical considerations identified in this report relate to potential human and environmental advantages of using genomic selection in animal breeding; to positive and negative impacts on animals and human-animal relations; to possible societal or interhuman impacts; and to the rationales and purposes underlying animal breeding in general.

These considerations are presented as concepts and questions in a preliminary heuristic framework that supports further ethical deliberations and evaluations of (developments in) genomic selection.

2. Introduction

The current report presents an ethical analysis of the application of genomic selection in animal breeding. It reviews literature addressing ethical aspects of genomic selection, including a report on the societal context of innovations in cattle genomics that has previously been published as a part of the BovReg project (Kramer & Meijboom 2020). It also draws on a selection of literature to discuss the strengths and limitations of the ethical analyses that have been published hitherto. The report results in a preliminary heuristic framework that is helpful for further ethical deliberation on and evaluation of (developments in) genomic selection in livestock breeding.

This report is part of a work package (WP8) from the 'BovReg' project on societal and ethical issues with respect to genomic selection in cattle breeding. It builds on a previous report from this work package on the societal context of innovations in cattle genomics (Kramer & Meijboom 2020) and will (together with this previous report and the outcomes of a 'democs' public engagement card game) be used to inform the development of an ethical framework that will facilitate stakeholders to address societal and ethical dimension of livestock genomics. The report published previously within this work package (Kramer & Meijboom 2020) also discussed the science behind genomic selection, including new developments within the 'omics' sciences that would allow basing breeding decisions on a wider range of biological parameters, and discussed (potential) applications of genomics in cattle breeding. These issues will not be covered in the current report.

In some places, this report considers the ethical implications of new developments in genomic selection, including its proposed application to pursue emerging breeding goals (such as reduced methane emission and improved disease resistance) and the use of additional biological parameters to predict the phenotypic results of breeding decisions ('biology-driven' genomic selection, see Kramer and Meijboom 2020). But except where noted otherwise, this report addresses the ethical aspects of breeding approaches informed by genomics more generally. A systematic assessment of the ethical differences between different approaches within genomic selection could be based on the ethical concepts and questions identified here, but is not within the scope of the current report.

Published analyses addressing ethical aspects of genomic selection are based on different views about what an ethical analysis entails. The current report distinguishes four types of ethical analysis, which vary along two axes (see figure 1 below). An ethical analysis can (as explained below) be either more heuristic or more evaluative, and can ask either what new ethical issues are raised by genomic selection or ask what ethical issues it raises that previous breeding approaches also raised.

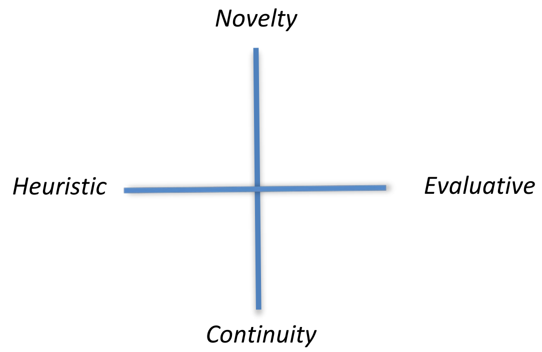

Figure 1: visualisation tool for characterizing types of ethical analyses of genomic selection. An ethical analysis can be placed along the horizontal axis based on the extent to which its purpose is either heuristic or evaluative, and along the vertical axis based on the extent to which its focus is on novel ethical issues raised by genomic selection or on ethical issues that apply to breeding more generally.

At the left end of the horizontal axis, a *heuristic* analysis aims primarily to *identify* a range of ethical considerations with respect to the adoption of genomic selection in animal breeding, without offering a final verdict on whether this change in breeding practices is ethically desirable. It must be assumed in such an analysis that the ethical considerations identified have some ethical weight or appeal, but it is not the point of such an analysis to reach an overall ethical evaluation of the issue.

At the right end of the horizontal axis, by contrast, an *evaluative* analysis does aim to offer such an overall evaluation. This can be informed by a wide range of ethical considerations revealed through a heuristic analysis, in which case reaching an ethical conclusion involves weighing all the considerations found. Views may differ on whether a thorough heuristic analysis is always required. From some ethical perspectives, overall ethical acceptability may be determined by a limited set of considerations. For example, some animal rights advocates argue that breeding and farming animals for meat production is necessarily wrong (e.g. Regan 1982), which means that an ethical evaluation of genomic selection in animal breeding need not consider possible benefits to humans, as these are from this perspective simply irrelevant.

At the top of the vertical axis, ethical analysis focuses on the *novelty* of genomic selection. The introduction of genomic selection in animal breeding could for example be analysed by comparing genomic selection to traditional selective breeding and considering whether the differences give rise to new ethical issues. This comparison may not always be explicit; traditional selective breeding may for example be taken as a baseline for comparison implicitly. There may also be an implicit assumption that the status quo is ethically acceptable, and that present issues do not need to be re-examined in the light of the new developments.

At the bottom of the vertical axis, analysis focuses on the *continuity* of genomic selection with previous techniques and existing practices. This type of analysis involves asking how the adoption of genomic selection relates to existing ethical issues with respect to the breeding and farming of animals; whether it solves these, perpetuates them, or even aggravates some issues. For example, some analyses have situated genomic selection within ongoing processes of 'rationalization' and 'geneticization' in animal breeding and farming, and have addressed the ethical dimensions of those wider processes.

An ethical analysis can be both heuristic and evaluative. As mentioned above, an analysis offering an overall evaluation of genomic selection can be based on a careful identification of relevant ethical considerations. In addition, a heuristic analysis is always to some extent evaluative: such an analysis must assume that the considerations identified have at least *some* ethical appeal, even if it does not aim to reach an overall ethical judgment about genomic selection. An ethical analysis can also address both the novelty of genomic selection and its continuity with previous breeding approaches.

Distinguishing these axes nevertheless helps to assess the few ethical analyses of genomic selection that have been published so far. As discussed later in this report, Coles et al. (2015) offer an ethical analysis that is mainly heuristic and focused at the novelty of genomic selection. By contrast, Holloway and colleagues and Twine (2010) discuss at length in what sense genomic selection is continuous with previous breeding approaches, which leads to a more clearly evaluative analysis in Twine (2010) than in the works of Holloway and colleagues. We will see that these approaches have strengths and limitations that correspond to the type of analysis pursued, which underscores the need to critically assess the aims of any ethical analysis of genomic selection.

Distinguishing these axes also helps to clarify the aim and scope of this report itself. Its aim is primarily heuristic: it presents a range of ethical considerations with respect to genomic selection (and related techniques) that seem to have at least some ethical appeal, but it does not strive to offer an overall ethical judgment of the use of genomic selection in animal breeding. It discusses not only novel ethical issues associated with genomic selection, but also ethical issues in animal breeding that are applicable to both genomic selection and earlier breeding approaches.

In sections A and B of the core report (see chapter 3), we consider two approaches that mainly have heuristic aims. Section A seeks to draw ethical considerations from policy documents and from expert and lay deliberations on genomic selection. In the absence of a sufficiently developed base of literature on the subject, we build on the analysis of policy aims and societal concerns that was offered in a previous report on the societal context of innovations in livestock genomics (Kramer & Meijboom 2020). Section B uses a second heuristic approach, which is to consider a range of mainstream ethical theories to see what ethical perspectives these may open up on genomic selection. The focus will be on Coles et al. (2015), which applies an approach called ‘principlism’ to genomic selection. Section C then considers the approaches of Lewis Holloway and colleagues (Holloway & Morris 2008, Holloway & Morris 2012, Holloway et al. 2011, Morris & Holloway 2014) and Richard Twine (2010). The authors place genomic selection in a wider development of ‘geneticization’ and the application of what they term ‘biopower’ to animals, but this leads to a more pronounced evaluative stance in Twine’s work than in the works of Holloway and colleagues. The ethical considerations and with respect to genomic selection that are identified in sections A through C are summarized and integrated in the conclusion (see chapter 4) of this report.

3. Core report

A. Views of stakeholders, policy-makers and lay publics

A first heuristic approach would be to identify views of stakeholders, policy-makers and lay publics with respect to genomic selection in livestock breeding, and to consider whether these are ethically relevant. The current section presents some views that seem to have at least some ethical appeal. Their ethical relevance is confirmed in section B by showing that these views can be connected to concepts from mainstream ethics.

Empirical research

Research into the views of stakeholders, policy-makers and lay publics with regard to genomic selection in cattle breeding is very limited. The lack of research in this area possibly mirrors a lack of public concern about genomic selection (compared for example to genetic modification or genome editing). One of the few studies into perceptions on genomic selection in livestock breeding used a survey to determine lay views on using genomics to reduce emission reductions in beef cattle (Kessler et al. 2013). This study found that half of the respondents (51%) were in doubt, that roughly half of the respondents (27% of all respondents) who did offer an evaluation were in favour of this use of genomics, and that the other half of those respondents (21% of all respondents) were against it. This study also showed that support for this application of genomic selection depended on a range of variables, including the degree of acceptance and knowledge of environmental problems, biodiversity familiarity, attitudes towards animals, trust in government, food processors, and food researchers, having heard of genomics, and education. As this survey used a closed answer format, this study only quantified participant's views with respect to issues that the researchers identified as relevant beforehand – it could not reveal unanticipated ethical perspectives on genomic selection.

Van den Heuvel et al. (2008) did explore laypeople's views with respect to genomic selection using a qualitative research format, but their research addressed genomic selection in tomatoes rather than animals. The perceived 'naturalness' of genomic selection proved to be important for the attitudes of their focus group participants, with genomic selection being considered more natural than genetic modification but somewhat less natural than traditional selection. Furthermore, efficiency in tomato breeding was valued, as was the sensory appeal of its products. It is difficult to use these results for an ethical analysis of animal breeding, though, as the application of breeding technologies in animal breeding may raise different public concerns than their application in plant breeding. Efficiency and naturalness do seem to be relevant concepts for an ethical analysis of genomic selection in livestock breeding, but why and to what extent these concepts are considered ethically relevant may well be different in this context.

Stakeholder views based on literature review

Ethical values of stakeholders and other parties can also be inferred, somewhat indirectly, from other sources. Our previous report on the societal context of innovations in cattle genomics (Kramer & Meijboom 2020) identified the values underpinning EU agricultural policy and considered how these related to genomic selection. The EU's Common Agricultural Policy (CAP) is meant to be a broad framework for agricultural policy that is not competent to offer guidance on specific issues such as genomic selection. Still, CAP aims to promote a range of values in relation to agriculture: according to the European Parliament, CAP should "enable the EU farming and forestry sector to respond to justified citizens' demands regarding not only food security, safety, quality and sustainability, but also environmental care, biodiversity and natural resources protection, climate change action, rural development, health and high animal welfare standards, and employment" (European Parliament 2018). Behind these aims lie important ethical values. As discussed in Kramer and Meijboom (2020), ethical values are interrelated with economic, environmental and societal factors in complex ways. For example, pursuing environmental values can be framed as a way of ensuring the wellbeing of future generations and improving rural development as a way of ensuring justice between residents of rural versus urban areas. We will revisit these values (which are summarized in table 1) in section B and confirm their ethical relevance by showing how they can be connected to mainstream ethical theory.

Table 1: values behind EU agricultural policy, potentially relevant for genomic selection
Food security
Food safety
Food quality
Food sustainability
Employment
Rural development
Animal health
Animal welfare
Environmental care
Biodiversity
Natural resources protection
Climate change action

Public concerns from literature review

Our previous report (Kramer and Meijboom 2020) also anticipated public responses to genomic selection. Drawing general lessons from reviews of focus group studies on emerging technologies (Sykes & Macnaghten 2013, Macnaghten & Chilvers 2014), the report speculated on how lay publics might perceive genomic selection and considered potential societal concerns. As lay views on emerging technologies are according to these reviews to a significant extent shaped by ethical perspectives, such views are a possible point of entry for ethical analysis.

The potential public considerations with respect to genomic selection identified previously (Kramer & Meijboom 2020) can be translated into a number of questions (see table 2):

Table 2: ethically relevant questions based on anticipated public considerations with regard to genomic selection (Kramer & Meijboom 2020)
To what extent does genomic selection address 'big challenges' or significant societal problems?
Are there alternative ways to address these challenges or problems?
Whose interests are served by addressing these challenges or problems by means of genomic selection (rather than an alternative approach)?
Can it be ensured that commercial interests will not trump societal and ethical considerations in practice?
Who will benefit and who will be affected negatively?
Are there pressures to innovate too rapidly, that is without a full consideration of possible (social and ethical) impacts, in livestock genomics?
To what extent does genomic selection interfere in natural processes (in a problematic way)?
Are people sufficiently engaged in and able to influence directions in innovations in livestock genomics?

It should be recognized that it is not clear whether lay publics, when engaged in deliberation about genomic selection, would raise these questions. Genomic selection seems less controversial than some emerging technologies with respect to which lay publics raised such questions critically, for example genetic modification. Ethical analysis could nevertheless proceed from these questions. They have at least some ethical appeal, as confirmed in the next section, and so it would be relevant for an overall evaluation of genomic selection (which is outside of the scope of this report) to answer them. The conclusion of such an evaluation might be that these questions should be answered more favourably for genomic selection than for some other emerging technologies. In any case, it would be relevant for an ethical evaluation of genomic selection to answer these questions explicitly (or to show why these questions, upon closer consideration, should not carry much weight in an overall evaluation of genomic selection).

Conclusion

The views of stakeholders, policy-makers, and lay publics could be used as input for an ethical analysis of genomic selection in livestock breeding, but views specifically on genomic selection have barely been researched empirically. Inferring such views –

indirectly and speculatively – from other sources suggests a set of values and questions that are relevant for an ethical evaluation of genomic selection.

The values and questions identified in this section have been summarized in tables 1 and 2. Note that the ethical relevance of these values has not been established in this section. We will connect them to a mainstream ethical approach in the next section, as one way in which their ethical relevance could be defended.

B. Principlism and the ethical matrix

An ethical analysis of genomic selection could also start from a general normative ethical theory (such as utilitarianism, Kantianism, contractualism, or virtue ethics) and consider the implications of this theory for the use of genomic selection in livestock breeding. Such an analysis can be evaluative: it can aim to offer an overall ethical evaluation of genomic selection. A limitation of such an approach is that there is no agreement among ethicists on which of these theories should prevail when they offer conflicting ethical evaluations (Rachels 2009, Arras 2010). Neither can it be presumed in the (European) context of the current project that any one of these ethical theories is superior to the others. This does not mean, however, that these theories have no value at all for an ethical analysis of genomic selection. They can be applied as heuristics to identify ethically relevant dimensions of an issue or case, even if this does not settle how the issue should be evaluated overall. Applying several theories then helps to identify relevant dimensions from a variety of ethical perspectives (Rachels 2009, Arras 2010).

Such an ethical analysis which draws on mainstream ethical theories to discuss ethically relevant impacts of genomic selection in livestock breeding has been offered by Coles and colleagues (2015). These authors apply an approach known as 'principlism', which combines key elements of major ethical theories and is a well-established approach in applied ethics. This approach includes a number of ethical principles which can be applied to identify ethically relevant dimensions of an issue. These principles are *respect for autonomy*, *nonmaleficence*, *beneficence* and *justice*.

Principlism has been developed primarily within biomedical ethics (cf. Beauchamp & Childress (2001 [1979]) but has also been applied to examine the ethical dimensions of novel foods and agri-food biotechnologies (Mepham 2000, Kaiser et al. 2007). The principles of nonmaleficence and beneficence have in this context sometimes been combined into a single principle: *respect for wellbeing*. Moreover, principlism has in this context informed the development of an 'ethical matrix' (Mepham 2000, Kaiser et al. 2007), a tool for the identification of ethically relevant impacts of the introduction of novel foods and agri-food biotechnologies on both human and non-human stakeholders. Relevant stakeholders and ethical principles are represented as rows and columns in a matrix, with the cells at their intersections describing ethically relevant impacts on types of stakeholders. (See figure 3 for a sample ethical matrix from Mepham 2000.)

Table 3: sample ethical matrix (Mepham 2000)

Respect for:	Wellbeing	Autonomy	Justice
Treated organism	e.g., Animal welfare	e.g., Behavioral freedom	Telos
Producers (e.g., farmers)	Adequate income and working conditions	Freedom to adopt or not adopt	Fair treatment in trade and law
Consumers	Availability of safe food; acceptability	Respect for consumer choice (e.g., labelling)	Universal affordability of food
Biota	Protection of the biota	Maintenance of biodiversity	Sustainability of biotic populations

This ethical matrix approach has been widely used for a range of issues and in many contexts to structure ethical deliberations with policy makers, scientists and the general public. It is however a flexible framework that can also be applied for other purposes, and has for example been applied by Coles et al. (2015) to categorize ethical aspects of the application of genomic selection in livestock breeding. Following a systematic search for literature on ethical aspects of genomic selection, Coles and colleagues constructed an ethical matrix to capture ethically relevant impacts on scientists, primary producers (farmers), industry (manufacturers and distributors), agricultural workers, consumers, animals, and the biotic environment.

In this ethical matrix developed by Coles and colleagues (2015), the principle of beneficence covers a range of ethically relevant benefits that could result from the application of genomic selection to animal breeding, including:

- Offering financial benefits to scientists, farmers, industry, agricultural workers, and consumers
- Advancing science and farming practices
- Improvement the health, disease resistance, and welfare of animals
- Enhancing the environmental sustainability of animal agriculture
- Increasing food security and quality.

The principle of non-malfeasance (i.e. nonmaleficence) is mainly used by Coles et al. (2015) to identify measures that should be taken to limit negative impacts on the wellbeing or welfare of the stakeholders involved. This includes:

- Assessing possible risks to any type of stakeholder
- Testing new products and process to avoid harms to consumer health and the environment
- Identifying adverse animal welfare effects of new genotypes and not using animal varieties with suboptimal welfare
- Preserving the gene pool
- Avoiding market exploitation
- Providing adequate labelling of food products derived from animal bred through genomic selection.

The principle of respect for autonomy requires respecting existing ecosystems and the balance of nature as well as respecting a range of freedoms of stakeholders:

- The freedom of scientists to develop new varieties of animals
- The freedom of farmers to make informed and uncoerced breeding choices
- The freedom of industry to choose whether or not to use genomic animals
- The freedom of consumers to make informed and uncoerced consumption choices
- The freedom of animals to express their *telos* (i.e. their species-specific nature)

Finally, according to Coles et al. (2015), the principle of justice requires:

- Setting clear and consistent regulatory guidelines, risk assessment processes, and labelling requirements
- Setting clear regulation to safeguard animal health, animal welfare, and environmental sustainability.
- Protecting of intellectual property rights
- Assessing the impact of the introduction of new strains of animals on their species and the environment
- Allowing farmers to change supplier
- Improving the welfare of animals and allowing them to express their *telos*
- Enhancing the environmental sustainability of animal agriculture
- Providing adequate information and labelling to fully inform consumers

Principlism and the ethical matrix approach could also be used for a preliminary ethical analysis of the values behind EU agricultural policy presented in the previous section (see table 1 at page 9). Connecting these values to principlism's main principles (or their underlying concepts) is one way to confirm that they are at least to some extent ethically relevant. For example, food security, food safety, and food quality can be related to the wellbeing of consumers, employment to the wellbeing of producers, animal health and welfare to the wellbeing of animals, and environmental care and biodiversity to the 'wellbeing' of the environment. Furthermore, food sustainability, natural resources protection, and climate change action might be explained as requirements of justice towards future consumers, and rural development as a requirement of justice towards rural populations (who often face economic and other disadvantages relative to urban populations in urbanized societies). An ethical matrix could then be constructed to visualize how these values relate to the ethical principles on the one hand, and to the interests of particular stakeholders on the other. Such a matrix might look, for example, as follows (see table 4):

Table 4: example of how the values behind EU agricultural policy could be plotted in an ethical matrix

	Wellbeing	Autonomy	Justice
Consumers/citizens	Food security Food safety Food quality		Food sustainability Natural resources protection Climate change action
Producers	Employment		Rural development
Animals	Animal health Animal welfare		
Environment	Environmental care Biodiversity		

The relation between these values, ethical principles, and stakeholders is more complex than this simple ethical matrix suggests. There can be disagreement on which value connects to which principle – for example whether protecting biodiversity should be seen respecting a type of autonomy of the environment, as suggested by Mepham (2000). Moreover, one value may speak to the interests of several stakeholders, as care for the environment is for example not only in the interest of the environment itself, but arguably also in the interest of consumers, producers, and animals. A much more extensive analysis would be required to account for this complexity and to justify the connections made between values and principles here. But this simple ethical matrix suffices to show that the values identified in the previous section can be connected to mainstream ethical theories quite easily.

The questions which were based on anticipated public considerations with respect to genomic selection (see table 2 on page 10) can also be connected to the ethical principles recognized in principlism and the ethical matrix. It can be argued, for example, that the question whether research and innovation address significant societal problems (such as global warming, serious diseases, and food security) implicitly expresses the ethical view that technologies should genuinely benefit (or at least not harm) society and its members.

Most of the further considerations identified in table 2 can then be interpreted as more specific ways of assessing this societal benefit. Whether genomic selection is socially beneficial can be considered, for example, by asking whose interests are served by its use in animal breeding, how the benefits and disadvantages of its use are distributed across society, whether commercial interests might trump societal and ethical considerations in genomic selection programmes, and whether innovations in livestock genomics do not progress too quickly or interfere in natural processes too much. The question whether there are alternative ways to address the relevant societal issues could furthermore be interpreted as a plea to consider whether more beneficial (or less harmful) answers to these issues are available, while the question whether regular citizens are able to influence directions in research and innovations implicitly states that citizens should have some autonomy in matters that could have significant impacts on them. Again, the point is not to offer a full and satisfactory ethical analysis of the questions presented in table 2. The point is to show that they can easily be connected to mainstream ethical principles and concepts, which means that they have at least some ethical appeal.

Strengths and limitations

The ethical analysis of genomic selection offered by Coles et al. (2015), based on principlism and the ethical matrix, has a number of strengths and limitations. On the positive side, it has explicitly taken the interests of a broad set of stakeholders into account, including scientists, primary producers (farmers), industry (manufacturers and distributors), agricultural workers, consumers, animals, and the biotic environment. Moreover, a variety of ethically relevant impacts on those stakeholders have been identified and connected to the important ethical principles, including (among others) economic and health-related benefits and risks to various human stakeholders, benefits and risks to farmed animals, and impacts on the freedom of human and animal stakeholders to pursue activities that are important to them. An additional strength here is that the analysis connects these impacts to mainstream ethical concepts that are relatively easy to understand and appreciate for non-ethicists, thus supporting ethical deliberations across disciplinary boundaries (Kaiser et al. 2007). This helped Coles et al. (2015) to bring diverse considerations such as economic benefits and concern for animal welfare and the environment together under common ethical concepts that seem relatively simple for stakeholders to understand, recognize, and discuss.

One limitation that Coles et al. (2015) acknowledge is that some ethical considerations that surfaced in their literature review do not fit the four principles discussed. The first of these considerations relates to the ‘naturalness’ or ‘unnaturalness’ of animals bred through genomic selection. Coles and colleagues note that the prospect of genetically modifying animals used for food production had raised various objections related to the perceived unnaturalness of GM, including objections based on emotions such as unease and disgust, objections based on religious beliefs or cultural norms and identities, objections based on perceptions of consumer health and environmental risks, and objections based on animal welfare or other animal ethical concepts. The authors suggest that the application of genomics may not be considered unnatural, but leave this as an open question. The second consideration that according to Coles et al. does not fit the four principles relates to the permissibility of enhancing or 'disenhancing' animals to improve their welfare. The idea of enhancing animals by increasing their resistance to disease or 'disenhancing' animals by reducing their ability to suffer under prevailing farming conditions might fit the concern for animal welfare captured under the principles of beneficence and nonmaleficence, but raises ethical questions of its own. Coles and colleagues note that these approaches to improving animal welfare may be motivated from an economic perspective that does not assign farmed animals any rights, dignity, or moral status. This according to these authors raises the question whether commodifying animals is appropriate at all.

A second limitation is that the ethical matrix does not offer an approach for weighing the interests of different stakeholders (Mepham 2000). Although the ethical matrix can be used to identify impacts of genomic selection on various stakeholders, further ethical deliberation is required to determine and compare the weights of particular ethically relevant impacts, for example how positive impacts on agricultural producers should be balanced against negative impacts on farmed animals. The application of the ethical matrix to genomic selection offered by Coles et al. (2015) accordingly reveals (potential) ethically relevant impacts of genomic selection but does not translate into an overall evaluation.

A third limitation is that the consideration of ethically relevant impacts on stakeholders threatens to be constrained by which ethical principles are included in the framework. This limits the framework's value as a heuristic tool. Although the principles of beneficence, nonmaleficence, autonomy, and justice are quite broad (Mepham 2000), they may still fail to capture a range of ethical concerns. As Coles et al. (2015) acknowledge, ethical concerns around the 'naturalness' and 'unnaturalness' of animals bred using advanced biotechnologies and around the 'enhancement' and 'disenhancement' of animals to improve animal welfare do not fit the framework easily. But there may also be ethically relevant concerns with respect to genomic selection that Coles and colleagues do not acknowledge, for example concerns around the concepts of 'biopower' and 'geneticization' discussed in the next section of the current report. These concerns have apparently not come up in their literature search, but the ethical matrix does not seem to have facilitated becoming aware of them either.

Finally, as Mepham (2000) notes, "the impacts recorded [in the cells of the ethical matrix] are *relative* to a pre-existing condition, which itself might be far from ethically acceptable." In other words, the ethical matrix has not been developed as a tool for critically questioning that pre-existing condition. Coles et al. (2015) touch upon this limitation as they discuss the ethics of enhancing and disenhancing animals and raise the question whether continuing to commodify animals is appropriate at all. Although the ethical concepts and principles on which the ethical is based can be applied to analyse ethical aspects of animal breeding that antedate genomic selection, some of the concepts that fall outside of the ethical matrix (including the concepts of biopower and geneticization discussed in the next section) have been invoked specifically to think through the more fundamental issues regarding our treatment of animals to which genomic selection connects.

Conclusions

Principlism and the ethical matrix offer a set of ethical concepts and considerations that can be applied to genomic selection. Coles et al. (2015) also identify a number of further relevant concepts. These latter concepts may be less mainstream than the concepts that derive from principlism, but may still have some ethical appeal. The concepts mentioned by Coles and colleagues are presented in table 5, which also gives examples of related ethical considerations:

Table 5: ethical concepts offered by Coles et al. (2015) and examples of considerations that connect to those ethical concepts	
Concept	*Examples of related considerations*
Wellbeing	Human health Food security Food quality Human economic wellbeing Animal welfare Environmental care
Autonomy	Freedom of humans to research, produce and consume as desired Freedom of animals to express their *telos*
Justice	Consistent regulation Food sustainability Natural resources protection Climate change action Rural development
Telos	Typical behaviours of animals of some species
Naturalness	Extent to which animals bred can be considered natural Extent to which breeding procedures can be considered natural
Acceptability of (dis)enhancing animals	Commodification of animals Animal rights Dignity of animals Moral status of animals

C. Biopower and geneticization

Holloway and colleagues (e.g. Holloway & Morris 2008, Holloway & Morris 2012, Holloway et al. 2011, Morris & Holloway 2014) and Twine (2010) have offered ethical analyses of genomic selection that draw mainly on the notions of 'biopower' and the 'geneticization' of life.

Biopower and animal breeding

Foucault (2018 [1976]) introduced the concept of biopower to analyse how the bodies of humans as well as human populations are in modern times being optimized to meet the needs of capitalism and the state. This idea has been worked out in more detail by Rabinow and Rose (2006), who propose that the exercise of biopower includes at least the following elements. First, biopower operates through a range of discourses in which knowledge claims about health and vitality are made, and in which certain authority as considered competent to make such knowledge claims. Second, biopower is exercised by a variety of actors intervening in collective life, with a variety of interventions that are performed in the name of the population's life and health. Third, individuals are disciplined to optimize their own life and health according to authoritative knowledge claims about human health and vitality.

The concept of biopower has been extended to livestock breeding by Lewis Holloway and colleagues (e.g. Holloway & Morris 2008, Holloway & Morris 2012, Holloway et al. 2011, Morris & Holloway 2014) and by Richard Twine (e.g. 2010). These authors consider this concept a useful resource for describing and assessing contemporary relationships between humans and farmed animals and, in connection to that, power relations between humans involved in animal breeding. They argue that the characteristics of biopower proposed by Rabinow & Rose (2006) can be recognized in animal breeding as follows. First, selective breeding is associated with discourses in which knowledge claims about animal bodies and populations are made, where a range of authorities (e.g. animal scientists or breeders) are deemed competent to make such knowledge claims (Holloway et al. 2011). Second, selective breeding includes approaches aiming to optimize populations by intervening in the collective life of animals, in particular by intervening with their reproductive processes. According to Holloway and colleagues (Holloway et al. 2011, Holloway & Morris 2008), the optimization of animal populations in animal breeding involves ranking animals relative to certain norms for 'performance' and making selection decisions based on estimates of the level of performance of the next generation. Third, those involved in animal breeding are shaped by its knowledge claims in certain ways (Holloway & Morris 2012, Twine 2010). Although animals do not discipline themselves to conform to human ideas about what makes a good breeding animal, breeding practices do have the potential to shape animals' bodies and behaviours according to such ideas. Animals can be and have been bred for temperament and ease of handling, for example, to improve how they fit into agricultural production systems (Twine 2010). In addition, breeders and farmers may come to discipline themselves to practice their vocation according to certain authoritative ideas about what good breeding is (Holloway et al. 2011, Twine 2010). Some may choose to resist such claims about (Holloway & Morris 2012, cf. Lonkila & Kaljonen 2018), but they will understand themselves and each other in relation to such claims. For example, farmers might be considered 'progressive' or 'old fashioned' based on their attitudes to new breeding approaches.

According to these authors, the exercise of biopower is in certain respects more thorough in animals than in humans. This is because shaping animal populations in some desired direction is far less controversial than trying to shape human populations in a similar way. Whereas the idea of optimizing human populations meets heavy ethical resistance, the optimization of animal populations through selective breeding is widely practiced almost without question (Twine 2010). When animals are concerned, the exercise of biopower is intertwined with the 'sovereign' power to kill individuals. A decision to continue breeding with some animals invariably implies a decision not to breed with others, and those animals may be killed outright, as stated by some breeders interviewed by Holloway and colleagues (2011).

The concept of biopower, as invoked by Holloway and colleagues and by Twine, is apparently meant both to describe a central aspect of animal breeding and to raise critical questions about animal breeding (even though such questions are not always spelled out explicitly). A first question is what justifies trying to optimize animal bodies and populations to the extent that contemporary breeding practices do. Twine (2010) observes that the optimization of human populations through interventions in reproduction is highly controversial – even though reproductive techniques are being deployed to reduce certain genetic diseases and disabilities among humans (Twine 2010) – and ask why it would be acceptable to change animal populations in a similar way. Twine concludes that the supposed right to optimize animal populations by genetic interventions is yet another result of the low moral status assigned to animals.

A second ethical issue relates to the purposes for which animals and animal populations are being optimized. Both Holloway and colleagues (e.g. Holloway & Morris 2012) and Twine (2010) see economic conditions and motivations as main drivers in animal breeding. Breeding decisions are in their view steered significantly by economic considerations, which shows for example in attempts to optimize production traits and in the large extent to which breeding values are meant to translate into economic value. Twine is overtly critical of the predominantly economic rationality behind animal breeding and farming, which he thinks leads to the commodification of animals that threatens their interests and is difficult to square with the growing awareness that farmed animals have rich emotional and social lives.

Of course, contemporary breeding programs also include breeding goals that speak to non-economic values (cf. Kramer & Meijboom 2020). Such breeding goals are not discussed by Holloway and colleagues, but Twine does discuss the use of genomic selection (and other breeding technologies) to make animal agriculture more sustainable and to improve animal health. The development of breeding goals relating to sustainability and animal health should, according to Twine, still be understood as motivated by economic considerations to an important extent. It is a response to problems in animal agriculture that have (at least partially) delegitimated the production and consumption of animal products and that thus threaten the sector's economic interests. It is in Twine's view at the same time a strategy to protect vested economic interests. While the environmental impact of animal agriculture should according to Twine be reduced by reducing the consumption of animal products, addressing this environmental impact through breeding is aimed at avoiding such a reduction in animal product consumption. Similarly, trying to improve animal health through breeding is according to Twine a narrow approach to improving the welfare of farmed animals, and aims to avoid overhauling husbandry systems that compromise animals' interests in a range of ways.

Whether these analyses of the economic motivations behind animal breeding are accurate or not, an ethically relevant question is for what purposes breeding aims to optimize animals, and whether optimizing animals to meet those purposes is ethically preferable to alternative approaches.

Genomics and the 'geneticization' of life

Another wide development in which genomic selection is embedded, according to Twine (2010) and Holloway and colleagues, is the 'geneticization' of life. 'Geneticization' refers to a focus on understanding and intervening in living organisms on the basis of genetics, which has increasingly replaced other ways of understanding and changing life (Holloway & Morris 2008, 2012). Geneticization marks a paradigm shift in biological sciences and biotechnology that has been going on for decades and that motivated, for instance, cataloguing genes associated with human pathologies and mapping genomes of various animal species. This geneticization also suggested applications in animal breeding: if associations could be found between the genetic features of animals and traits of interest in animal agriculture, then animals' genetic profiles could be used to inform selection decisions. A range of approaches have been developed to make this idea applicable in animal breeding. An approach that does not involve screening an animal's DNA for genetic variations of interest is to calculate 'estimated breeding values' (EBVs) by measuring relevant traits in the animal and its relatives and statistically calculating the probability that its (further) offspring will inherit these traits. Although this approach does not involve mapping the animal's genetic features directly, it is premised on the idea that phenotypic traits of interest are determined by genetic factors and passed along according to the laws of genetics (Holloway & Morris 2008). Newer approaches do involve mapping the animal's genetic features directly, either by identifying 'snips' of DNA that are associated with traits of interest or by mapping the full genomes of large groups of animals and making breeding predictions by drawing on known correlations between genotypic and phenotypic features (Lowe & Bruce 2019, cf. Kramer & Meijboom 2020). The term 'genomic selection' is in what follows intended to capture the latter approaches.

A first point of concern that Holloway and colleagues and Twine raise about this geneticization of life of which genomic selection is one of the more recent expressions is its reductionist understanding of animals. The implicit assumption of genomic selection is that an animal can be sufficiently understood by understanding its genetic features. DNA is perceived as 'information' that can understood and manipulated without paying much attention to the rest of the animal's body (Twine 2010). This may result in a failure to anticipate possible adverse effects of selection decisions, if these have a more complex biological cause. This problem is recently being addressed, and recognized implicitly, by attempts to incorporate insights from other 'omics' sciences into animal breeding. These omics sciences (e.g. transcriptomics and metabolomics) investigate further biological factors that regulate how an animal's genotype is expressed phenotypically (cf. Kramer & Meijboom 2020). Yet these omics sciences still aim to understand animals in terms of microscopic biological processes, and it remains to be seen whether these sciences are able to adequately integrate the different levels of animal biology that they distinguish.

A second point is that the geneticization of animal breeding has changed how animals are evaluated and which animals are valued. Although producing hierarchies of animals based on valued characteristics was also part of previous breeding approaches, genetic selection has changed which parameters are taken into breeding decisions (Holloway et al. 2011). The genetic evaluation of animals takes place at a distance from the animals themselves, behind computers running statistical software, rather than by visual inspection of and physical interaction with the animal. Although this genetic evaluation may in practice often complement rather than replace more traditional ways of evaluating animals (Holloway et al. 2011, cf. Lonkila & Kaljonen 2018), changing evaluation practices have led to different rankings of animals and to different breeding decisions. Some breeders interviewed by Holloway and colleagues (2011) use genetic evaluation as a preselection for visual inspection. Animals that would perform poorly as breeding animals according to genetic evaluation are rejected and may be killed, and the same applies to animals that pass genetic evaluation but fail the subsequent sensory inspection. Holloway and colleagues conclude that genetic evaluation through EBVs or genomics makes certain animals more 'killable'. Animals are compared relative to certain norms for genetic quality, and animals that do not meet this norm are presented and perceived as flawed (Holloway et al. 2011). Moreover, if selection decisions are not made in the proximity from animals, without seeing and feeling them, it is easier not to see them as morally considerable beings, and thus easier to consider them killable (Holloway et al. 2011). On the other hand, Holloway and colleagues also present quotes from animal breeders suggesting that animals are also considered quite killable when they are inspected 'by the eye'. Depending on how it is used to inform breeding decisions, genetic evaluation may make certain animals less killable: some animals that would be rejected on the basis of traditional selection criteria (e.g. conformity to the breed's characteristic physical traits) may now be valued on the basis of their genetic characteristics. It is thus somewhat unclear whether *more*, *different,* or *fewer* animals have become killable to breeders because of the changed selection process. How techniques for the evaluation of animals affect breeders' view of animals as either 'valued' or 'killable' is nevertheless a relevant ethical question.

The geneticization of animals has according to Holloway and colleagues and Twine (2010) also changed relationships among humans involved in animal breeding. More particularly, and this is a third concern which they raise, the application of genetics to animal breeding is associated with a shift in authority. The practice of evaluating an animal's merit for breeding on the basis of genetic information has challenged existing ways of knowing and evaluating animals, in particular the 'traditional' approach in which animals were assessed on the basis of their ancestry records and by sensory inspection (Holloway & Morris 2008, 2012). This more traditional approach assigned authority on matters regarding animal breeding to breeders and farmers working directly with animals, who evaluated animals' breeding qualities by sensory inspection and tacit knowledge. The rise of genetic science in animal breeding, on the other hand, meant that the authority of these breeders and farmers was implicitly or explicitly questioned and that authority was assigned to scientists and breeders evaluating animals with genetics-based approaches. Because of the specialized nature of this knowledge, this claimed authority befalls a relatively small groups of scientists and breeding corporations or cooperatives, who work at a distance from the variety of farms at which their knowledge is to be applied.

However, this shift in authority is neither absolute nor uncontested (cf. Lonkila & Kaljonen 2018). The new ways of knowing and evaluating animals sometimes clash with the approach which assesses animals' qualities based on sensory inspection and ancestry records. Advocates of the latter approach may consider breeding directions based on genetic evaluation too abstract and simplified to capture the complexity of breeding with actual animals, or may object to its inherent reductionism (Holloway & Morris 2008, 2012). The pre-existence of other ways of knowing and evaluating breeding animals means that breed societies and breeding companies working with genetic types of evaluation need to enrol breeders and farmers into seeing and evaluating animals from a different perspective: breeders and farmers must come to see and evaluate animals through the lens of (quantitative) genetics (Holloway & Morris 2008). This is pursued by presenting evidence of the efficacy of the new breeding techniques and by framing the adoption of these techniques as an economic necessity: arguments referring to 'commercial realities', 'international competitiveness', the possibility of being 'left behind', and 'consumer demand' aim to establish that applying genetic techniques to optimize animals is imperative for breeders and farmers

(Holloway & Morris 2008). This seems to put some pressure on breeders and farmers to practice their vocation according to a genetic perspective, even though this pressure can be resisted.

The shifts in authority that occurred with the geneticization of animal breeding are also associated with shifts in power between different parties engaged in animal breeding. Genomic selection requires large databases of genotypic and phenotypic data and specialist knowledge to work with those databases (cf. Kramer & Meijboom 2020). Furthermore, genomic selection programmes draw on a wider range of technologies than only genetic sequencing technologies: technologies for phenotypic measurement and advanced reproductive technologies may be used to further improve 'genetic gain' (Kramer & Meijboom 2020, Twine 2010). Acquiring and supporting these databases, specialist knowledge, and technologies requires significant financial investments (compared, for example, to breeding programs based on visual inspection, heritage assessment, and artificial insemination). This may have been an important factor in the horizontal integration of the breeding sector, i.e. in the consolidation of a small number of large and economically powerful breeding companies and cooperatives through acquisitions and mergers (Twine 2010). While this process has been quicker and more decisive in pig and poultry breeding, some fear that there will be similar shifts in economic power in beef and dairy cattle breeding (cf. Kramer & Meijboom 2020). The specialized nature of genomic knowledge may also mean that farmers become dependent on breeding companies and cooperatives for guidance on breeding decisions, especially if farmers feel that they must yield authority on breeding decisions to more knowledgeable parties. In addition, in breeding sectors where only a few large and economically powerful companies or cooperatives remain, individual farmers may have a limited choice between suppliers and little power to influence them, for example to influence priorities in breeding programmes. Services may be offered to facilitate farmers to shape their herds according to their own views or values, such as breeding consultation services, but these will not remove farmers' dependency on authorities with respect to breeding and genetics.

Strengths and limitations

The analyses discussed in this section situate genomic selection in wider developments within and outside animal breeding. The concept of biopower has been applied to analyse how breeding approaches, including genomic selection, aim to optimize animal bodies and populations according to certain external goals and according to certain knowledge claims and techniques. The concept of geneticization has been mobilized to show that genomic selection is embedded in a wider development of understanding and intervening in living organisms on the basis of genetics. Both concepts give rise to some ethical questions regarding genomic selection. A strength of this approach is that it can identify both questions related to the novelty of genetic approaches in breeding (through the concept of geneticization) and questions related to the continuity of genomic selection with previous breeding approaches (through the concept of biopower).

A limitation of the analyses discussed here is that the ethical relevance of the concepts of biopower and geneticization is more difficult to grasp, compared to a mainstream ethical approach such as principlism (see section B). These concepts are used descriptively to indicate how genomic selection fits into wider developments in breeding, but at the same time, they are used as a basis for ethical critique. It is not always clear when these concepts are used merely descriptively and when they are used critically, nor what the underlying (meta)ethical perspectives are that give these concepts ethical significance.

A further limitation is that these analyses engage with positive arguments for (genomic or traditional) selective breeding only to a limited extent. The concept of biopower is mobilized to formulate a fundamental critique of animal breeding, without giving a full overview of its ethical dimensions. This limits the heuristic value of these analyses: they offer unique perspectives on animal breeding, but should in a balanced heuristic analysis be complemented by further perspectives (such as those discussed in section B).

A final limitation is that it is difficult to draw actionable conclusions from ethical analyses based on these concepts. Because they raise ethical questions with respect to wider developments in which genomic selection is according to these authors embedded, a critical analysis of genomic selection based on these concepts naturally leads to a critique of animal breeding more generally. But it will be more difficult in practice to steer these wider developments than to change directions in genomic selection only. Thus, even if one were to conclude that these developments are indeed ethically problematic, it may be unclear how a transition to a more ethical situation could be achieved.

Conclusions

Ethical analyses of genomic selection based on the ideas of ‘biopower’ and ‘geneticization’ lead to different considerations than those discussed in earlier sections. These analyses embed genomic selection in wider developments within and outside animal breeding, and raises questions that relate both to the novelty of genetic selection approaches and to their continuity with previous breeding approaches. Although the ethical significance of these concepts is more difficult to articulate and appreciate than that of the concepts discussed in the previous section, and although it may be relatively difficult to identify actionable implications of those concepts, they do open up additional ethical perspectives on genomic selection.

The questions identified in the current section are presented in table 6.

Table 6: ethically relevant questions associated with the concepts of biopower and geneticization	
Biopower	What justifies aiming to optimize animal bodies and populations?
	What justifies aiming to optimize animal bodies and populations according to particular (e.g. economic) motivations?
Geneticization	Can animals be represented adequately by basic biological (genomic and other omics) data?
	Are more, different, or fewer animals 'killable' to breeders in genomic selection programmes?
	How have authority and power shifted because of genomics, and how are the interests of people involved in breeding affected?

4. Conclusions

This report presented ethical dimensions of genomics by reviewing some published ethical analyses on this topic. Some of the analyses reviewed had a mainly heuristic purpose (aiming to identify ethically relevant aspects genomic selection), others had a more evaluative purpose (aiming to reach an overall conclusion on the ethical desirability of genomic selection). Furthermore, some focused on the dimensions in which genomic selection is novel, others considered its continuity with previous breeding approaches.

The purpose of this report itself has been heuristic. It aimed to give an overview of considerations with respect to genomic selection that have at least some (*prima facie*) ethical appeal and therefore deserve consideration in any more evaluative ethical analysis of genomic selection. This included both considerations related to the novelty of genomic selection and concepts and questions related to its continuity with other breeding approaches. The purpose has not been to provide final assessments of the considerations identified, let alone to provide an overall ethical evaluation of the use of genomic selection.

The considerations that were identified throughout the report have been presented as concepts and questions in a number of tables (table 1, 2, 5, and 6). These tables are integrated and summarized in the following figure (figure 2). This integrated set of concepts and questions, we propose, provides an initial heuristic framework for ethical evaluations of (developments in) genomic selection. It can serve to avoid ethical evaluations that focus on a limited range of ethical considerations and leave out others – for example evaluations that focus only on benefits for humans or impacts on animals, or evaluations that consider only whether genomic selection raises new ethical issues and do not address how genomic selection relates to existing ethical issues in animal breeding.

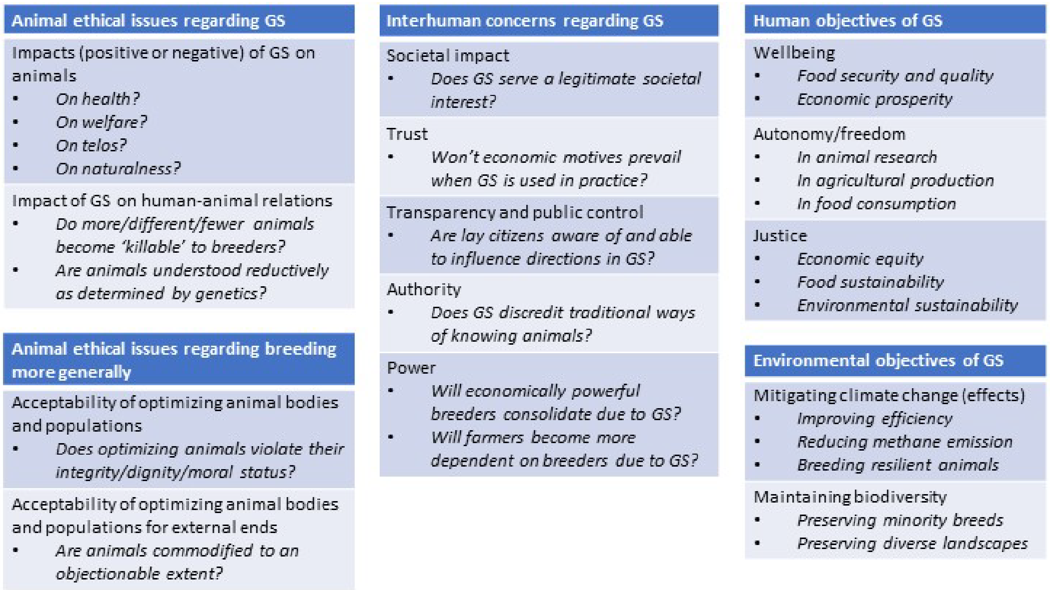

Figure 2: ethically relevant concepts and questions with respect to genomic selection, as identified in this report

5. References

Arras, J., 2010 Theory and Bioethics. In E. N. Zalta (Ed.) The Stanford Encyclopedia of Philosophy. Available at https://plato.stanford.edu/archives/win2016/entries/theory-bioethics/ (Date visited 22-JAN-2021)

Beauchamp, T.L. and J.F. Childress, 2001 Principles of biomedical ethics. Fifth edition. Oxford: Oxford University Press

Coles, D., L.J. Frewer and E. Goddard, 2015 Ethical Issues and Potential Stakeholder Priorities Associated with the Application of Genomic Technologies Applied to Animal Production Systems. J Agric Environ Ethics 28:231–253

European Parliament, 2018 Report on the future of food and farming. Available at: https://www.europarl.europa.eu/doceo/document/A-8-2018-0178_EN.html (Date accessed 20-NOV-2020)

Foucault, M. 2018 [1976] Geschiedenis van de seksualiteit. Translated by J. Holierhoek. Amsterdam: Boom

Holloway, L., and C. Morris, 2008 Boosted bodies: Genetic techniques, domestic livestock bodies and complex representations of life. Geoforum 39:1709–1720

Holloway, L., and C. Morris, 2012 Contesting genetic knowledge-practices in livestock breeding: biopower, biosocial collectivities, and heterogeneous resistances. Environ Plan D 30: 60-77

Holloway, L., C. Morris, B. Gilna, D. Gibbs, 2011 Choosing and rejecting cattle and sheep: changing discourses and practices of (de)selection in pedigree livestock breeding Agric Hum Values 28:533–547

Kaiser, M., K. Millar, E. Thorstensen and S. Tomkins, 2007 Developing the ethical matrix as a decision support framework: GM fish as a case study. J Agric Environ Ethics 20:65–80

Kessler, A., E. Goddard and J. Parkins, 2013 Exploring factors that influence perceptions of using genomics for emission reduction in beef cattle. Conference paper presented at the 2013 annual meeting of the Agricultural and Applied Economics Association (AAEA). Doi: 10.22004/ag.econ.150419

Kramer, K. and F.L.B. Meijboom, 2020 The societal context of innovations in cattle genomics. Available at https://www.bovreg.eu/wp-content/uploads/2020/12/BovReg-deliverable-8-1-v20201215-FINAL-PDF.pdf

Lonkila, A. and M. Kaljonen, 2018 Animal bodies multiple: Practising genomic knowledge on dairy farms. Geoforum 96:198–206

Lowe, J.W.E. and A. Bruce, 2019 Genetics without genes? The centrality of genetic markers in livestock genetics and genomics. HPLS 41:50 https://doi.org/10.1007/s40656-019-0290-x

Macnaghten, P. and J. Chilvers, 2014 The future of science governance: Publics, policies, practices. Government and Policy 32: 530–548

Mepham, B., 2000 A framework for the ethical analysis of novel foods: the ethical matrix. J Agric Environ Ethics 12: 165–176

Morris, C. and L. Holloway, 2014 Genetics and livestock breeding in the UK: Co-constructing technologies and heterogeneous biosocial collectivities. J Rural Stud 33:150-160

Rachels, J., 2009 Ethical Theory and Bioethics. In: H. Kuhse and P. Singer (eds.)A Companion to Bioethics: Second Edition. Malden: Blackwell, pp. 14-21

Sykes, K. and P. Macnaghten, 2013 Responsible innovation – Opening up dialog and debate. In: Ri. Owen and J. Bessant (eds.) Responsible Innovation. New Yersey: John Wiley & Sons, pp. 85–108

Van den Heuvel, T., R. J. Renes, B. Gremmen, C. van Woerkum and H. van Trijp, 2008 Consumers' images regarding genomics as a tomato breeding technology: ''maybe it can provide a more tasty tomato''. Euphytica 159: 207–216

Twine, R., 2010 Animals as biotechnology: ethics, sustainability and critical animal studies. London: Earthscan