

Do We Care About Synbiodiversity? Questions Arising from an Investigation into Whether There are GM Crops in the Svalbard Global Seed Vault

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Abstract The Svalbard Global Seed Vault provides a backup of seed collections from genebanks around the world. It's unique character has made it iconic in the public imagination as a 'Noah's Ark' for crop plants. Its remote location and strict controls on access have, however, also lent it an air of mystery, swirling with conspiracy theories. In this paper, I first clarify the aims of the Vault, the history of its development and the policies and practices of its current operation. Given concerns around its potential links to the biotechnology industry, I go on to ask whether GM crops are currently stored in the Vault. Presenting several reasons for why GM crops are formally excluded, while indicating the potential for both change and unintentional contamination, I am compelled to question whether GM crops *should* be excluded. Answering this requires an interrogation of their potential conservation value as modern contributors to crop biodiversity. In exploring this issue, I suggest that there has been surprisingly little discussion of the moral status and conservation value of bio-technological crop plants and indeed, of how we care for all the techno-lifeforms we are currently engaged in co-creating. I suggest that these are becoming important issues as biotechnological techniques and applications begin to rapidly evolve and diversify (e.g. through genome editing and synthetic biology). Emphasizing the scope for a refreshed interdisciplinary research agenda exploring the interface between biotechnology and biodiversity conservation, I conclude the article by proposing new concepts of synbiodiversity and symbiodiversity to encourage further debate.

Keywords Biotechnology · Biodiversity · Conservation value · GMO · Seed vault · New plant breeding techniques

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I stood at the base of a frozen mountain on an island high up in the arctic archipelago. The wind tore through me in icy shards as snowdrift whipped around my ankles. Nestling my hands deeper inside my pockets I scanned the landscape. An airport. A port. A stain of abandoned coal mines. A scattering of colored houses against a backdrop of steeply rising white mountains and deeply plunging blue seas. Ocean and Ice. Snow and Stone. Raw rugged nature and doggedly hardy humanity. I had come to the place where polar bears outnumber people and it is dark for months at a time. Here I stood before a locked metal door, leading deep into the heart of the mountain. “In there” he said, “is the most biodiverse room in the world”.

Introduction

Conserving the diversity of our important crop plants is crucial for the resilience of agricultural systems in the face of change. Currently, there are two main approaches to the conservation of crop biodiversity—in situ approaches that seek to conserve (and generate) biodiversity on farms through ongoing cultivation, management and use in evolving socio-ecological systems, and ex situ approaches in which germplasm (typically in the form of seeds but also possibly as cuttings, tissue samples, DNA samples etc.) are frozen and stored in ‘genebanks’ for future use and development by researchers and plant breeders. This paper stems from a project interested in both of these models of crop biodiversity conservation. The work presented here, however, results from a specific investigation into the operation of the Svalbard Global Seed Vault (hereafter the Vault) as the international apex of ex situ models of crop biodiversity conservation. The Vault contains backup collections of diverse crop seeds from genebanks all around the world and is meant to offer them safe keeping in the face of any potential disaster.

The initial question framing the research reported here was simply one of how the Svalbard Global Seed Vault functioned—its operational policies, procedures and practices. While conducting this research, however, I posed a question that inadvertently led me deep into a swamp of interdisciplinary entanglements. The deceptively simple question I posed was “Are there any genetically modified (GM) seeds in the Vault?” This paper documents my attempt to answer that question and therefore describes not only what I learned about the Vault and its operations, but also the diverse answers received as to whether GM crops can be found in its icy interior. Furthermore, it goes on to present and reflect upon the important philosophical and socio-political questions that arose as a result of this investigation, namely those around the moral status and conservation value of biotechnological organisms and whether and how we care for the rising cacophony of ‘synbiodiversity’ we are engaged in co-creating.

Biotechnological interventions into agriculture continue to amplify and diversify, both beyond transgenic crops to include agricultural insects and fish, and through the introduction of new techniques for gene silencing, genome editing (such as the much-touted CRISPR/Cas9), and epigenetic DNA methylation. Much of the current debate around this diversification is focused on the extent to which the new

techniques and organisms are covered by existing regulatory regimes (Kuzma and Kokotovich 2011; Lusser and Davies 2013), or how they may be developed ‘responsibly’ to minimize risks and take social and ethical concerns about their impacts into account (National Academy of Sciences 2015). While these are important issues, through this paper I demonstrate that there are also a host of unaddressed issues relating to the moral status and conservation value of biotechnological organisms that urgently require more sustained attention as the techniques of manipulation continue to diversify. Furthermore, I propose that for discussions on these issues to advance, it is crucial that we seek out new concepts to help capture, conceptualise and consider what is going on within a broader perspective. To this end, the paper proposes the notions of synbiodiversity and symbiodiversity as heuristic concepts to encapsulate the burgeoning diversity of techniques and organisms and help us consider how to approach our entangled inter-being. Finally, through the introduction of these new terms, the paper encourages us to consider whether and how we care for the synbiodiversity of techno-life forms we are currently engaged in co-creating. The aim of the paper is thereby not only to clarify the operations of the Svalbard Global Seed Vault but also to reinvigorate critical scholarship on agricultural biotechnologies and to stimulate further research on important underlying and as yet unresolved philosophical and socio-political issues in the GMO debate. These issues include: the legitimacy of the basis for legal, socio-economic and moral distinctions between traditional breeding and modern biotechnologies; the moral status, conservation value and responsibility we have for bio-technological hybrids; the role a concept of naturalness plays in ordering our thinking; and finally, how we might not only advance responsible purposes and processes for research and innovation (Stilgoe et al. 2013) but also take responsibility for all the mutants and monsters we are co-creating through our practices (Latour 2012; Haraway 1991).

Method

The research described in this paper was conducted using mixed qualitative methods. This included: (a) review of academic and popular literature (first on the functioning of the Vault and extending out into interdisciplinary areas of conservation biology, environmental philosophy, international law and regulatory politics as this became appropriate); (b) a week long site visit to the Vault in Svalbard (conducted during the arrival of a new shipment of seeds) and associated ethnographic observations; (c) interviews with all key institutional partners involved in the management of the Vault and; (d) philosophical reflection around questions of conservation value, techno-biological relations and matters of care. This mixed methods approach is reflected in the presentation of the research results, which includes a collection of factual descriptions, ethnographic field notes and photos, interview quotes, analytical discussion and philosophical reflection. The weaving of these various elements into the telling of this story has been necessary to try and capture not just the facts of the case, but also the feelings of the place and the interdisciplinary questions that they both raise.

The Svalbard Global Seed Vault

The Svalbard Global Seed Vault is the global figurehead of *ex situ* approaches to agricultural crop biodiversity conservation (or conservation of *genetic resources for food and agriculture* as it is increasingly referred to). The Vault provides a location for genebanks¹ around the world to store duplicate, back-up, copies of their collections. The aim of the Vault is therefore to offer safe-keeping and some insurance for the *ex situ* collections of crop biodiversity held in genebanks in the face of the various potential threats they are vulnerable to. These threats include technical failures (e.g. power outages and freezer facility failures), natural disasters (e.g. fire and floods) and socio-political unrest (e.g. conflict and war). The Vault opened for operation in 2008 and now houses over 860,000 different samples of more than 5000 species originating from more than 230 countries and deposited by over 60 institutes from around the world (Svalbard Global Seed Vault 2016). In October 2015, the first withdrawal was made from the Vault when ICARDA, the International Center for Agricultural Research in the Dry Areas based in war-torn Aleppo, requested that some of the seeds it had previously deposited in the Vault be sent to Morocco and Lebanon so that Syrian researchers could continue their work (Sifferlin 2015).

The Vault is located on the arctic archipelago of Svalbard (also formerly known as Spitsbergen), not far from the township of Longyearbyen. The only externally visible component of the Vault is the huge concrete housing surrounding the entrance door, and the striking light installation (“perpetual repercussion” by Dyveke Sanne) on the façade and roof of the entrance portal commissioned to make the Vault visible from a distance in both darkness and daylight (see Fig. 1). Behind this entrance door, is a 120 m long tunnel that descends into Platåfjell mountain, leading to three large storage caverns excavated in the permafrost (although only one of these caverns is currently required and in use). Each of these caverns or storage halls is around 27 m long by 9.5 m wide. Although the permafrost of the mountain keeps them below freezing temperature all year round, the cavern currently in use lies behind huge ice covered double doors and is actively refrigerated to -18° (the current international standard for long-term storage in gene banks) (see Fig. 2). The storage hall is fitted with five long corridors of metal shelving and these hold the sealed boxes of seeds deposited by genebanks from around the world (see Figs. 3, 4). The Vault also contains a small insulated office space off the main tunnel.

Svalbard was chosen as a location for the Global Seed Vault for several reasons. In the first instance, the Nordic Genetic Resource Center had a history of using an old mine shaft on Svalbard to store its safety duplicates and this served as an early model for the Vault (Qvenild 2008). The location was also supported for practical reasons, such as the way in which it is uniquely both remote and accessible, i.e. it is situated on an island close to the North Pole but still serviced by an airport and close

¹ The terms ‘seedbank’ and ‘genebank’ are often used interchangeably although it can certainly be argued that the difference between a focus on conserving seeds and conserving genes is highly significant and worthy of another paper (van Dooren 2009).



Fig. 1 The entrance to the Svalbard Global Seed Vault

Fig. 2 Ice covered doors at the entrance to the storage hall



to a village. Importantly, the permafrost of Svalbard could also provide a backup should the refrigeration system within the Vault fail. Furthermore, Norway was seen to be a politically stable country with a significant level of support and trust from both industrialised and non-industrialised countries for its international work and



Fig. 3 Storage hall within the Vault



Fig. 4 Black boxed seed deposits from genebanks around the world

commitment to agricultural biodiversity conservation (Statsbygg 2008). Svalbard has also had a history of international collaboration through the Spitsbergen Treaty (Spitsbergen Treaty 1920), which was ratified in the 1920s and effectively made Svalbard a part of Norway's sovereign territory but subject to unique rules allowing citizens and companies from other nations the right to fish, hunt and conduct industrial commercial activities there.

Norway originally offered to create a repository for the world's genebanks in 1989. However, the international community did not accept the offer at the time due to ongoing debates about access to and control of plant genetic resources and the lack of an international legal framework governing the matter (Qvenild 2008). After years of tough negotiations, in 2004 the International Treaty on Plant Genetic

Resources for Food and Agriculture (ITPGRFA) (Treaty 2004) entered into force, establishing a multilateral system of access and benefit sharing for the genetic resources of 64 of the most important crop plants.² While the Treaty was a keystone legal agreement enabling the Vault to receive international support, a range of other international agreements have also arguably been crucial. These include: (1) the agreement in 1994 to place the genebank collections of the Consultative Group on International Agricultural Research (CGIAR) under the auspices of the FAO (FAO and CGIAR 1994); (2) an agreement on international standards for genebanks (originally published in 1994 by the FAO and the International Plant Genetic Resources Institute (now Bioversity) and revised in 2014) (FAO 2014); and (3) the development of a standard material transfer agreement (SMTA) with rules for the exchange of genetic resources among parties to the Treaty (including requirements such as that access for research and breeding is provided free of charge, intellectual property rights limiting access to the material as received cannot be claimed, and where commercial products develop as a result of research on the material, payment should be made into a benefit sharing fund) (ITPGRFA 2006).

While the Norwegian government covered the costs associated with building the Vault, its operation is currently managed through a collaborative agreement between the Norwegian government, the international organization The Crop Trust (formerly the Global Crop Biodiversity Trust) and the Nordic Genetic Resource Center (NordGen). In general terms, the Norwegian Ministry of Agriculture and Food has the overarching responsibility for the Vault, NordGen provides practical management and coordinates activities with the international depositors, and The Crop Trust is central in raising and dispersing supporting funding for the Vault's ongoing operation. Since no employees of these organisations actually work full time on site at the Vault in Svalbard, responsibility for its daily oversight is also performed by Statsbygg (a Norwegian public sector enterprise dealing with construction and property issues), although their role is limited to ensuring that things like the lights and freezers continue to function. The Vault is not open to members of the public and remains locked at all times except when management staff arrive to receive and store new deposits of seeds.

While genebanks actively distribute the material from their collections to researchers and plant breeders, and regenerate their material regularly so as to retain high quality collections of viable seed, the Vault does none of these things. It simply serves as a backup location for accessions that are already held by other genebanks. As such, it does not take seeds from actors other than genebanks, it does not perform any analysis or research on the seeds deposited, nor does it distribute or regenerate the seeds it receives. In fact, the Vault operates as a 'black box system', meaning that no one responsible for the Vault or its management is allowed to open the boxes of seeds they receive, or do anything with the material they contain (except under express permission and instruction from the depositor). The Vault is only allowed to transfer the material back to the depositor upon request and cannot distribute it to

² Some of the important exemptions from the crops covered by the Treaty include soya, sugar cane, and oil palm. These crops were excluded to appease challenges made during the negotiations by nations where these crops have their centres of origin and/or diversity.

any other actors or entities. Furthermore, no property rights are transferred with the deposit and neither Norway nor the Vault's managers have any claim to ownership over the material deposited there.

This means that although there has been some degree of concern that the Vault enables certain actors to gain access to the world's genetic resources for food and agriculture, in fact, significant work has been done to establish the Vault as a system in which depositors retain full rights and sole access to the materials sent there for safekeeping. Indeed, this has been a crucial feature allowing it to gain international support and use. It is also worth noting that although the media has dubbed it the 'Doomsday Vault', the management views this name as a misrepresentation of the Vault's role, which they describe as not to provide a safety net for the world's agricultural systems, but rather, more simply to provide a backup of the genetic resources held in genebank collections.

The door is locked. The boxes are sealed. Nobody gets in. Nobody works here. Sealed shipments are collected at the airport and transferred to the shelves. There they can sit for all eternity. Frozen. There is no testing, no checking, no real work being done. There is no hum of workers, no practice to observe. The hallway is empty and still, bound by concrete and ice. There is no smell of the soil, touch of the sun or sound of the rain. Sealed boxes of seeds sitting on shelves in a freezer. That's it. The cavern echos in silence. Can this really be the most biodiverse room in the world?

Are There GM Crops in the Svalbard Global Seed Vault?

During the course of my research to understand the operation of the Vault, I asked the question of whether it contained any GM crops, and if not, might they be stored there in the future. In other words, whether the Vault provided backup for the conservation of biotechnological forms of agricultural crop biodiversity. Initially, I received diverging answers to this question from the different institutes engaged in the collaborative management of the Vault, from a firm 'no', to an uncertain 'not that I know of', to a cautious 'perhaps', and even an open 'sure, why not?' This initial diversity encouraged me to investigate the matter further and as I pressed on, the answers began to converge around no, there were no GM crops in the Vault. However, several different reasons were given for why GM crops were excluded.

The Vault is Not a GM Certified Facility

The official response provided by the Norwegian Ministry for Agriculture and Food is that there are no GM crops in the Vault because it is not a certified facility for the storage of GM seeds. Under European law (which also applies in Norway), work with GM crops can only take place in certified facilities and receiving this certification necessitates meeting particular requirements in regards to building specifications, materials and infrastructure. This can include things such as having sealed joins and netted windows to avoid insect intrusions, use of non-porous

building materials, having appropriate waste facilities and the possibility to decontaminate the area via gassing (Ministry of Health and Care Services 2001). While the specific requirements vary with the extent to which the plants in use have an ability to be easily spread, all the requirements across the different levels are effectively tailored towards containing the GM material within the facility.

Given the unique nature and location of the Vault's construction, the current facility may not meet all of the requirements across the various containment levels for different types of GMOs. However, when interviewed, a Senior Advisor at the Norwegian Ministry of Agriculture and Food stated that although she did not think the Vault could pass all the certification requirements to be a GM storage facility, it could be possible to receive a waiver and gain certification because of the way in which the Vault's operations are already oriented towards strict containment of the deposited materials and there are facilities for seed destruction on site within the Vault. So although GM crops are currently excluded from the Vault by a lack of formal legal certification to store them, this could be changed in the future if the motivation was there. When asked about the possibility of a future waiver, the Ministry representative stated "There might be possibilities to find a way if that was something Norway wanted to do, but so far we have not really looked into that question because we have not got any requests yet and politically there has been some reluctance to do so." This leads us to the second reason that GM crops are excluded from the Vault.

There is No Political Will to Include GMOs

While the lack of legal certification is given as the official reason for GM exclusion from the Vault, lack of political will is why no change in this certification status has ever been sought. While unable to find any clear policy statement on the Vault's position regarding GMOs, a former coordinator for its operation and management stated during an interview "I remember when we looked at this in 2007, before the Vault opened, everyone knew that if GM seeds were stored there, this would be a point of criticism...there was a concern with public communication. Everyone knows that this is so contentious that it is probably good not to work with them." Lack of political will to include GM crops in the Vault from its very inception was also confirmed by the ministry representative. As the former Vault manger elaborated, "So instead of going into all those difficult considerations of whether one should out of scientific interest store GM seeds, it was decided that simply on the grounds of this Norwegian certification policy and law, we are not going to have GM seeds up there." This means that when the Vault was established in 2008, there was no desire by either the advisory board or the management to become (any further) entangled in the socio-political controversy surrounding GMOs and the lack of legal certification for the Vault as a storage facility served as a convenient way to avoid the issue.

I say any further entangled in the GM controversy because the profit oriented industry of biotechnology and its claims to strong intellectual property rights over plant genetic resources have been a source of significant tension with the field of crop biodiversity conservation for years, including in the negotiations leading up to the ITPGRFA and during the establishment of the Vault. Given the Vault's reliance

on the ITPGRFA and its multilateral system for access and benefit sharing to establish international trust and support, lack of political will to include GM crops during its establishment is perhaps understandable.

Even today though, one of the most common and persistent misunderstandings and sources of criticism that the managers of the Vault say they face is the perception that Monsanto (one of the major players in the agricultural biotechnology controversy) either funds the Vault or has access to its materials. The well-established black box system gives no reason to believe that any organization has access to material placed in the Vault by other depositors. However, large organisations with a history of positive engagement with biotechnology development, such as the Rockefeller foundation, the Bill and Melinda Gates foundation, DuPont/Pioneer Hi-bred, CropLife International and Syngenta, have all made donations to The Crop Trust, which finances the functioning of the Vault (Crop Trust 2016). Since conspiracies continue to swirl around what influence such donations allow (Engdahl 2016; Anderson 2015), a political desire to minimize misunderstandings and possible public outcries by specifically excluding GM crops from the Vault on the (neither scientific nor emotional) basis of a lack of legal certification may persist for some time to come. However, political will can change, not only with the party in power, but also through shifts in popular opinion or the desires of the depositing institutes, and should such a shift occur, GM certification for the Vault remains a possibility.

GM Crops Do Not Meet the Requirements for Multilateral Access

Even if there was political will to gain certification status so the Vault could store GM seeds in the future, they would arguably still be unwelcome if they did not meet the requirements for multilateral access. Although intellectual property law varies between nations, in most countries, crop plants developed through traditional breeding practices are typically protected by plant breeders' rights (or plant variety rights), which give the creator of a new variety exclusive marketing rights. However, under the scheme of plant breeders rights (PBRs) farmers are still permitted to save and plant the seeds of that variety in following seasons, and a research exemption means that other breeders can freely experiment with the material to develop new varieties of their own (UPOV Convention 1978). GM crops, however, are commonly awarded intellectual property protection in the more broadly applicable and restrictive form of utility patents rather than PBRs (or indeed plant patents).³ This effectively gives them a different ontological status and represents a significant reordering of human-nature relations (Hettinger 1995). No longer simply a new plant variety for which limited rights can be claimed, GM

³ It is worth noting that the US is somewhat unique in that it has a Plant Patent Act (in addition to a Plant Variety Protection Act) that allows for traditionally bred varieties of asexually reproduced plants to be patented. These plant patents are restricted though in that they allow for experimental research and licensees can sexually reproduce the plants indefinitely as long as the seeds are not given or sold to others for planting. The ability to achieve the broader type of utility patents for biotechnologies advanced significantly after the landmark case of *Diamond vs Chakrabarty* in which the US Supreme court (in a contested decision) ultimately ruled that living organisms could be patented as inventions (Rimmer 2008).

plants have been legally sanctioned as human inventions, as devices that we have created and that can be legitimately subject to monopoly ownership and control. As patented inventions, GM crops are not freely available to other researchers and plant breeders and cannot be saved and replanted by farmers.

As mentioned above, when the Vault was first proposed, tensions and concerns around trends towards bioprospecting, biopiracy, and the privatization of genetic resources through intellectual property rights meant that it was not widely accepted internationally. The Convention on Biological Diversity (CBD) (CBD 1992) established national sovereignty over biodiversity (and protocols for bilateral benefit sharing), although the US refused to sign due to its perceived inadequacies in recognizing biotechnology patents and royalties (Hettinger 1995) and remains one of only four nations not a party to the treaty. Questions also still existed at the time concerning the materials held in international genebanks, and especially those collected prior to the implementation of the CBD. When the CGIAR agreed to place their genebank collections under the auspices of the FAO in 1994, the crop biodiversity they contained was effectively placed in trust for the world community as part of *humankind's common heritage*. This sense of the common heritage of crop biodiversity (or genetic resources for food and agriculture) was further supported when the ITPGRFA established its multilateral system of access and benefit sharing (although the narrow interpretation of 'benefit' in the economic terms of industrial agriculture has been a point of critique). The common practice of granting of patents to GM crops, however, effectively removes their genetic resources from the common heritage of humanity and makes them the private property of the patent holder.

Patented GM crops do not fulfill the requirements of the multilateral scheme for access and benefit sharing established under the ITPGRFA. They neither allow for free and open access to the genetic material, nor are their commercial sales currently contributing to the Treaty's benefit sharing fund. There is a clear expectation that all organisations making deposits to the Vault follow the ITPGRFA, and therefore it may be assumed that GM crops would be firmly excluded on that basis. While no one involved in the management of the Vault directly raised this issue during my interviews, all confirmed the lack of mutual access and benefit sharing for GM crops as a limiting factor when I brought the issue forward. However, it is important to note that the language of the standard deposit agreement (Svalbard Global Seed Vault 2013) does allow for exceptions. Section 3.1 1c of the depositor agreement states that depositors shall only deposit materials that "Are available to other natural or legal persons in a manner that facilitates access for conservation and sustainable use in compliance with national laws and applicable international treaties". However, Section 3.1 2 states that any or all of the requirements "may be waived". Both the ministry and former and current operations managers of the Vault are not aware of any waivers made on the basis of access requirements and therefore GM crops as patented inventions are also arguably excluded from the Vault on this ground. However, just as for the other reasons for their current exclusion, this has the potential to change in the future—either by patented GM crops being granted specific waivers for inclusion (perhaps unlikely) or through a request for storage of

unpatented GM crops developed by public research institutes (such as the famous ‘Golden Rice’ being developed by the International Rice Research Institute).

Having described three good reasons for why GM crops are not currently found in the Vault, it would be remiss of me not to reveal why, despite these good reasons and the assurances of the Vault’s management, GM crops may in fact be housed within its walls. Due to the black box system, there are no scientific facilities and no one has the right to check the genetic make up of the material received by the Vault. There are also no requirements from the Vault for depositors to test for GM contamination in their collections and document any results before submission. There is therefore the possibility that some of the seeds have been unintentionally contaminated with GM material through either seed mixtures or, more likely, gene flow.

The possibility for unintentional presence of transgenes in genebank accessions has been recognized by the CGIAR and principles for the development of policies on the matter are available (Genetic Resources Policy Committee 2005). Building on these principles, some CGIAR centres have developed more concrete procedures for avoiding GM contamination and even carried out some monitoring (Mezzalama et al. 2010). However, such guidelines and practices do not seem widespread and it is certainly unlikely that all deposits within the Vault have been thoroughly screened for potential GM contamination. Furthermore, even the CGIAR centres recognize that no level of testing could provide an absolute guarantee (CGIAR 2005):

It is recognized that available technical means do not permit the complete exclusion of unintentional presence of exotic genes, including transgenes, in genebank accessions. It is also recognized that available testing techniques do not provide an absolute guarantee, without testing every single seed or plant that any given accession is free of transgenes.

While the significance of having unintentional GM contamination within the Vault may be considered marginal, unmonitored GM contamination in genebank accessions has the potential to spread—either through gene flow during regeneration or contaminated collections in areas with commercial or experimental GM cultivation. To minimize such contamination requires dedicated detection work, monitoring systems and systemic vigilance. The costs associated with a vigilant monitoring program and the challenges associated with accurately detecting the presence of transgenes in landraces and wild relatives should not, however, be underestimated (Cleveland et al. 2005).

Should There be GM Crops in the Vault? Do GMOs Have Conservation Value?

Until now, the focus of this paper has been on nature of the Vault and the question of whether it contains GMOs. What is arguably a more interesting question though, is whether the Vault should contain GMOs. If we are committed to conserving agricultural biodiversity as a safety net for dealing with an uncertain future, on what

grounds should GM crops be excluded from that? Biotechnology is regularly claimed to have a crucial role to play in securing future food security and agricultural adaptability and resilience in the face of change. Biotechnological organisms also already dominate a number of important cropping systems (such as the maize, soya, cotton and canola) in several countries (including the US, Argentina, Brazil, India, Canada, and Australia) and promise to be only more widespread in the future. Even the CGIAR publicly endorses modern biotechnology as a crucial part of its investment in the future of agricultural research (Okusu 2009). So if biotechnology has such an apparently valuable role in our agricultural future, why should GM crops not be valued as an important part of agricultural biodiversity and included in our global conservation safety net? What are the arguments for and against the conservation value of GMOs? Answers to these questions entangle science, philosophy and politics and have received limited attention to date. Since these issues promise to only become more complex and pressing as biotechnological techniques and organisms continue to diversify, in what follows I outline several lines of discussion that these questions lead into and point to areas where further research would be highly beneficial.

GM Crops Have Conservation Value in Principle, but are Conserved Differently in Practice

For people concerned with crop biodiversity conservation, there is a general consensus that all crop biodiversity has conservation value because we do not know what may be useful in the future. There is, however, a recognized limit to what can be conserved *ex situ* in genebanks due to resource constraints. With thousands of different breeding lines in motion, it is simply not possible to conserve examples of each and every one *ex situ*. Therefore, choices are often made to try and conserve the broadest genetic base possible. As a former Vault manager states: “In principle, all plant genetic resources have conservation value, but it is obvious that modern varieties have less conservation value than a land race or wild relative with a broader genetic base...the aim is to conserve as much as possible of the gene pool of these crops.” When the focus is on conserving genes rather than on whole seeds or varieties, protecting the older breeding lines from which modern cultivars and hybrids have emerged is seen to protect the diversity of available genes, which then substitutes the need to conserve all the varieties possible from different combinations of these genes. Under this line of thinking, GM crops may be seen to have conservation value, but this is limited to the genes that constitute their component parts and these may be conserved through the protection of older varieties from which they have been derived.

The way we currently approach the conservation of GM crops is, however, arguably not actually primarily through *ex situ* gene banking. Genebanks have historically had a focus on giving plant breeders and researchers improved access to a diverse range of genetic resources, something that the patent protection awarded GM crops specifically seeks to minimize. What we see then, is that the conservation of GM crops is actually being performed through an encouragement of their *in situ* uptake across ever more farming systems. While *in situ* conservation has typically

been perceived and emphasised as important for maintaining native crop diversity and local landraces, and imagined as taking place through traditional small scale farming (Brush 2000; Altieri and Merrick 1987), in industrialized economies it is actually GM crops that are increasingly coming to dominate in situ settings. Unlike traditional varieties though, GM crops cannot be managed by farmers in a way that continues to not just conserve but also to actively generate biodiversity through ongoing selection, cross-breeding and evolution. As patented inventions, the generation of GM crop diversity is therefore restricted to scientific actors in distanced laboratories and cannot occur through ongoing interrelations with the immediate socio-ecological system of the farm. This means that the legal and socio-economic conditions surrounding GM crops effectively remove the possibility for farmers to pursue their adaptation and co-evolution with in situ conditions.

Indeed, we are arguably entering a significant period of shift in which native and traditional varieties are increasingly disappearing from cultivation and therefore being prioritized for ex situ conservation in genebanks, while modern varieties are emerging from ex situ settings to dominate in situ landscapes. This has the potential to significantly affect agricultural biodiversity as a creative commons. Both the slide towards seeing genes as the ultimate unit of biodiversity conservation value rather than the historic focus on species and ecosystems (Martin et al. 2016) and the shift towards freezing our dynamic common heritage of crop biodiversity ex situ while increasing the use of privately owned patented inventions that cannot be adapted by farmers in situ, call for enhanced philosophical reflection and socio-political analysis and action.

GM Crops Add to Biodiversity, but Their Conservation Value May No Longer be as Plant Genetic Resources

As described above, one response to the question of whether GM crops have conservation value will be that as modern cultivars they have a narrow genetic base and therefore less conservation value than wild relatives, land races or traditional varieties. However, a reply to this claim could well be that GM crops resulting from recombinant DNA technology (the majority of GM crops under commercial cultivation today) contain transgenes that could not have been acquired by traditional breeding and therefore represent a radical new form of crop biodiversity. In this case, GM crops may be seen as adding biodiversity to our pool of important crop plants and may be conservation worthy on this ground. Interestingly though, while many people want to recognize, honour the value of, and actively conserve the crop biodiversity created through the human-nature inter-actions of farmers over thousands of generations, the same people often hesitate to extend this embrace to GMOs and the modern human-nature inter-actions of scientists. Justifications for why traditionally bred forms of crop biodiversity are embraced as valuable while radical new forms of diversity offered by GM crops is not, is neither widely debated nor well elaborated and would benefit from more sustained attention from environmental philosophy, conservation biology and social psychology.

Given the transgenic nature of commercial GM crops, one glib reason for their exclusion from the Vault could be that they are no longer “plant genetic resources”

and therefore fall outside the scope of its mandate. Since they contain unique combinations of bacterial, viral and plant DNA, it could be argued that transgenic crops are no longer plants in a traditional sense. Any such argument would need to address horizontal gene flow more generally though and the way viral DNA, for example, can be found integrated into the genomes of many different organisms (including ourselves) that we maintain have conservation value. If there is something about the transgenic identity or the commodification culture from which they emerge that leads to a loss of their value as a plant genetic resource, more work across genetics, philosophy and law would arguably be necessary to establish legitimate grounds for how a human-directed crossing of species boundaries or a private property status, can alter an organism's conservation value. Furthermore, any such argument would need to specifically address why such transgenic inventions fall outside biodiversity as an otherwise all embracing environmental value.

GM Crops Have Conservation Value for Instrumental Purposes but Their Intrinsic or Integrity Value is Questionable

To argue that certain species, or even genes, are not worthy of conservation runs against both beliefs in the intrinsic value of biodiversity today for its own sake and the instrumental view that it may be potentially useful for us tomorrow. Despite this, the conservation value of GMOs is rarely proclaimed and the question of the moral status of bio-technological organisms (especially in relation to crop plants), has received surprisingly little detailed discussion (Baertschi 2012). Critics of GM crops may counter that conservation value is granted to those things that we cherish and want to protect, and that this simply does not extend to GMOs. However the justification for such an exclusion can be muddled.

As indicated above, agricultural biodiversity is typically conserved for its instrumental value, or in other words, its value for human purposes either now or in the future. Critics may challenge the instrumental value of the GM crops available today, believing they do more harm than good. However questions could be raised about whether this would necessarily or categorically hold for all GM crops of the future. Certainly proponents advocate GMOs as holding enormous instrumental value both today (demonstrated by their widespread and increasing use) and for the ability of agricultural systems to adapt and persist in the future. This assertion of their current or potential use value need not rely on them being completely necessary or the only solution for agricultural challenges. If GM crops are accepted to have instrumental value though, then they should certainly be seen as protection worthy by adherents of the 'new conservation science' (Doak et al. 2014), and the question of *how* we conserve and care for them (e.g. as part of our common heritage vs as privately owned patented inventions) would then stand central as requiring further attention.

It could of course also be contended that GMOs lack conservation value because they somehow lack the type of intrinsic value awarded to other living organisms and systems. However, what would be the basis for this? Since a GM crop is distinguished from other plant varieties on the basis of the technique used to create it, arguments are

required for how the use of a particular technique creates a morally relevant difference (Baertschi 2012). Or indeed, how different biotechnological techniques may create organisms with different degrees of moral significance (Attfield 2012). Again, significant work remains to be done by philosophers and willing interdisciplinary scholars if legitimate grounds are to be established for why GMOs may lack or have varying degrees of intrinsic value. One argument could be that a loss of intrinsic value stems from the way in which GM crops are (legally) perceived as human inventions rather than living organisms. While living organisms may have natural value and be granted intrinsic or inherent worth on the basis of having their own ends/telos (Taylor 1986; Sandler 2012), human inventions, machines and bio-artefacts may not (Nicholson 2013). Furthermore, if the telos of an organism is seen to be encoded in its genes as some have suggested (Rolston III 1991), then the moral status of a GMO could also be brought into question (Attfield 2012). Indeed the question of the impact different forms of genetic modification have on the telos of a GMO and its potential place in an environmental ethic, seem to be areas ripe for further philosophical exploration, especially since the work on this to date has largely been limited to transgenic animals (Verhoog 1992; Thompson 1997) or the extreme case of synthetic biology (Sandler 2012; Preston 2008).

It has been argued that synthetic biology represents a clear “line in the sand” for intrinsic value because the loss of a causal connection to historical evolutionary processes has ontological and moral significance (Preston 2008). This claim has been contested by those proposing that even artefactual organisms can have inherent worth and intrinsic value, with the process of their creation having no moral significance (Sandler 2012; Baertschi 2012). If a line in conservation value is to be justified on the basis of the technique used to create an organism, it is crucial to consider not just the extreme case of synthetic biology but also existing transgenic crops and the range of new gene editing techniques coming into play. More work is arguably required to articulate exactly what makes for a morally relevant difference here and specifically, how the use of certain techniques (but not others) may create an entity lacking intrinsic and/or conservation value. This argument will need to be developed by those with knowledge of environmental philosophy, molecular biology, and with plant breeding more broadly.

While the moral status and conservation value of GMOs might be rarely explicitly discussed and debated within conservation biology, the concept of ‘genetic integrity’ and the rights and duties it implies is more common (e.g. see Rohwer and Marris 2016; Timmerman 2016; Welchman 2016). While the use of a concept of genetic integrity in environmental ethics typically focuses on wild animal populations and implications for their conservation, the notion of genetic integrity is also given significant weight within genebanking and the conservation of crop varieties. For example, in the available guiding principles and policies to minimize transgene flow into seed collections, specific emphasis is placed on the importance of preserving a crop’s genetic ‘identity’, ‘integrity’ and ‘structure’ (CIMMYT 2005; Mezzalama et al. 2010; CGIAR 2005). The value given to maintaining genetic integrity in this setting and how it specifically relates to the ethics of GMO creation and conservation (in which genetic integrity is arguably intentionally violated) are also areas relevant for further investigation. Although the

significance and validity of the concept of genetic integrity for questions concerning both the intrinsic and conservation value of GMOs seems ripe for further research, any work in this area is bound to hit up against the challenge of drawing clear boundaries of distinction within the history of crop breeding.

It is Not Clear How or Where to Draw the Boundaries of Distinction for Crop Conservation Value

A typical approach to conserving wild biodiversity has been to barrier off certain places as protected areas and to restrict human impact and interaction. When it comes to agricultural biodiversity, however, this idea makes little sense because what has value cannot be decided on the basis of a concept of ‘naturalness’ as something free from human influence. All agricultural biodiversity has a fluid character and is a direct result of human interaction with the natural world; it is our common co-creation and we value it as such. Since we value agricultural biodiversity, which has always clearly been a human-nature co-creation, it cannot be the fact of human intervention alone that would cause a GMO to lose its intrinsic or conservation value. All current crop plants are the result of human inter-being with nature, with a sliding scale on forms and scope of genomic interaction, and therefore no clear line can be drawn between a ‘natural’ diversity developed through traditional breeding and ‘unnatural’ diversity developed through the application of biotechnological techniques.

Interestingly, when we look at the Vault, it is not only GM crops that are excluded. The Crop Trust, which plays a key role in funding the Vault’s operations and deposits, also explicitly excludes another category of organisms from its support. In its financial strategy and work plans for funding, The Crop Trust makes it clear that the International Mutant Germplasm Repository is not included in its work and mission. Indeed it is given as the “singular exception” for collections under Article 15 of the ITPGRFA whose work is “not of interest” and will not be supported by The Crop Trust (Global Crop Diversity Trust 2014). The Crop Trust’s mission is stated as being “to ensure conservation and availability of crop diversity for food security worldwide” so why should mutant varieties (varieties arrived at through the use of radiation to generate genetic mutations) be explicitly excluded as the singular exception?

Neither the current nor former managers of the Vault, or the ministry representative I interviewed, were actually aware of The Crop Trust’s decision to explicitly exclude materials from the mutant germplasm repository nor did they have reasons for why it was so. When asked about the explicit and singular exclusion of the mutant germplasm repository, a representative from The Crop Trust replied that “It is not a priority for the Crop Trust at the moment because it seems to be pretty safe already”. This position, however, was not echoed by the International Atomic Energy Agency, which manages the mutant repository. Although initially unaware of the repository’s exclusion, upon further investigation a representative of the IAEA suggested that it was perhaps because the implementation of the repository had been discontinued. This means that rather than being “pretty safe” as the Crop Trust indicated, it is in fact, no longer receiving any form of support.

This raises the question of whether irradiated mutant crop varieties also fall through the cracks of an otherwise all embracing biodiversity value. Similar to GMOs, it seems mutant varieties are not perceived as having the same kind of conservation value as the rest of agricultural biodiversity. This is despite mutants, unlike GMOs, being subject to the same type of intellectual property protection as traditionally bred varieties and the exchange of mutant germplasm being regulated by the same kind of standard material transfer agreements. Why then should the value of irradiated mutants be seen as any different to conventionally bred crops? Here there seems to be an implicit concept of naturalness in play. This is despite the fact that the use of a concept of naturalness for understanding the conservation value of agricultural crop biodiversity (in which human intervention and interbeing is always present) has little academic justification. Indeed most of the work on ‘naturalness’ within both environmental philosophy (see Noer Lie 2016) and conservation biology, has remained focused on it in specific contrast to ideas of the wild and the pristine, rather than to directly interrogating its use in the clearly socio-ecological context of agriculture where nature/culture, organism/artifact boundaries have always been porous.

The history of human-nature interbeing and co-creation of agricultural biodiversity makes it near impossible to border control the value of different organisms/systems on the basis of a naturalness framed by the classic criterion of the degree of human interference/interaction. Despite this, an implicit concept of naturalness seems to often be performing important ordering work in this field. While drawing any clear boundary in the history of crop breeding is difficult, with biotechnology a clear demarcation was in fact made, enacted and enforced by law on the basis of technique. This includes laws awarding GM crops property rights in the form of utility patents as already discussed, but also laws recognizing GMOs as unique kinds of organisms for the purposes of regulation. This legal demarcation of GMOs as a different kind of entity, granted them a different ontological status and this has had flow on implications not only in the demand for new border control practices (Lezaun 2006) but also apparently for their perceived moral status.

One of the most pressing questions within agricultural biotechnology now though, is the explosion of a new range of techniques and the matter of whether or not these techniques also generate what is labeled and regulated as a GMO (Caplan et al. 2015) (especially if methods for their detection remain lacking and no foreign DNA is present in the final product). The rapid development of genome editing techniques is giving rise to what has been referred to as the “CRISPR zoo” (Reardon 2016), with the promise of a wide array of manipulated organisms coming into being. Because ‘GMO’ is a category term used to separate on the basis of technique (modern biotechnology is as modern biotechnology does), the uptake of a range of new biotechnological techniques raises serious questions about the identity, moral and regulatory status, and conservation value, of all the organisms that will be generated through them. While it could be said that if organisms resulting from emerging techniques are deemed to be GMOs for intellectual property purposes, then they should also be considered GMOs for regulatory purposes, questions of their moral status and conservation value remain wide open for debate. The explosive development of new biotechnological techniques (re)emphasises the

importance of questions around the moral and conservation value of GM crops and really calls for new concepts to help us understand, categorise and consider the cacophony of techno-life forms now on the horizon.

Synbiodiversity and Symbiodiversity

While different definitions exist (Husby 2007), it is common that a GMO is defined by the use of certain biotechnological techniques. Within international law, the Cartagena protocol on biosafety uses the term living modified organism⁴ and defines it as: *any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology*; in which modern biotechnology is defined as the application of:

1. In vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or
2. Fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection;

However, since biotechnological techniques are evolving and emerging all the time, both our legal definitions and our popular understandings need to try and keep pace. For example, while the majority of what we refer to as GM crops today stem from recombinant DNA transgenesis, the advance of other approaches such as cisgenics (Schouten et al. 2006), gene editing (Doudna and Charpentier 2014) and synthetic biology (Khalil and Collins 2010) mean that this is likely to change. Indeed, biotechnology is already a very diverse field of practice, utilizing a host of different molecular tools and methods. As techniques continue to develop and diversify, we therefore need to ask not only whether and on what grounds the use of biotechnology as a whole creates (significantly) different types of organisms and what implications this has for their moral status and conservation value, but also whether different techniques create different types of organisms and whether all types of techno-lifeforms are equal in the eyes of the law, risk assessment, ethics and public opinion. For this, we arguably require (in scientific, policy and public discourse), new terms able to hold the full range of bio/technological hybrids that are emerging without being bound to the preexisting ideas and practices currently linked to the term GMO. The debate needs a new category term that captures the diversity of biotechnological organisms being created while at the same time allowing for and encouraging more nuanced recognition of differences across techniques.

⁴ The use of the term 'living modified organism' rather than the more common 'genetically modified organism' in the Cartagena Protocol is a result of a compromise made to deal with restrictions US delegates had for working with the issue of GMOs. It is also worth noting that work is ongoing within the scope of the protocol to consider the place and impact of new plant breeding techniques and synthetic biology.

If synthetic biology is a term used to refer to the adoption of an engineering approach to biology and the design and construction of biological parts and systems for useful purposes, then perhaps what we are talking about here is a kind of synthetic biodiversity: *synbiodiversity*. Although it would no doubt benefit from further debate, *synbiodiversity* might be defined as biological diversity arising from purposeful human attempts to engineer organisms to express desirable traits through directed manipulations of genetic code. The transgenic GM crops that we are familiar with now would then become just one example of this *synbiodiversity* more broadly conceived.

However, one problem with both the term synthetic biology and *synbiodiversity* is the emphasis placed on the role of the human and the ‘synthetic’, overshadowing the role of the biological and failing to open for a normative discussion about the relationship between the two. We may therefore also want to consider a concept of *symbiodiversity*. *Symbiodiversity* would draw on the concept of symbiosis in which organisms are engaged in a mutually beneficial relationship. *Symbiodiversity* would then refer to all the diverse forms of life that are intimately woven together with human beings in their emergence and ongoing existence, and for which there is a mutually beneficial relationship involved. *Symbiodiversity* as a term could then potentially cover not only certain biotechnological forms of life but also arguably existing crop plants, including both traditionally bred and irradiated mutants. In doing so, it would offer a category term in which these different types of crop biodiversity could be captured and coexist. It would also compel us to consider and evaluate the nature of the relationship at stake, and particularly the extent to which it was mutually beneficial and supportive of common flourishing. Playing with these two heuristic concepts of *synbiodiversity* and *symbiodiversity* would allow us to reimagine certain established boundaries of distinction and open up for new questions in the space between biotechnology development and biodiversity conservation.

Since our social, legal and economic systems have already categorized GMOs as a distinct class of organisms requiring special treatment, reframing GMOs as part of a broader category of *synbiodiversity* opens for discussing them directly in relation to various other forms of bio-technological lifeforms emerging through the use of new techniques. Collecting them within a broader category of *symbiodiversity* also opens for discussing them directly in relation to traditionally bred crop varieties. In redrawing the lines of distinction in the discussion, both terms can arguably encourage us to further explore the question of the moral status and conservation value of the bio-technological lifeforms we are engaged in co-creating. Since it is clear that we value biodiversity intrinsically and/or instrumentally, as the life technosciences continue to expand, we urgently need enhanced academic, policy and public attention on the question of whether and how we value *synbiodiversity* and the extent to which it represents a genuine form of mutually beneficial *symbiodiversity*.

How we relate to *syn-* and *symbiodiversity* is particularly important in this burgeoning era of the bioeconomy and ecomodernism. Recent movements in (post) environmental thinking (Nordhaus and Shellenberger 2007; Shellenberger and Nordhaus 2011) have come out in strong support of the use of emerging

technologies, such as GMOs in agricultural production, as important tools to advance environmental objectives. To date though, they have said very little about the moral status or conservation value of new forms of life created through biotechnosciences. While the conservation of biodiversity is the closest thing we have to a universally acknowledged environmental value, what exactly we are seeking to conserve, for what reason, how, and why are all deeply contested issues in need of further attention. As ever more diverse forms of life are being created through diversifying technological applications, environmental philosophers, legal scholars, political scientists and conservation biologists (as well as governmental authorities, international bodies and environmental NGOs) arguably all need to begin seriously interrogating questions of their moral value and how we intend to care for them.

From Synbiodiversity Conservation to Care

Technologies (or techno-organisms) that blur the cultural boundaries and categories we use to understand and orient ourselves in the world have been referred to as ‘monsters’ (Smits 2006) and Bruno Latour has recently called for us to love our monsters and care for them as our own children (Latour 2012). While love may be a particularly strong request, we clearly need to take responsibility for our creations (Attfield 2012; Baertschi 2012). Caring for synbiodiversity as symbiodiversity will require us to marry reason with emotion and be particularly attentive to relationships, dependencies, and vulnerabilities, as well as to context, specificity and story (Preston and Wickson 2016). To advance this agenda, this article effectively serves as a plea for engaging in a deeper interrogation of how we conceptualise and consider the moral status and conservation value of all the mutants and monsters we are engaged in producing, as well as how we take responsibility and care for them as our co-creations in practice.

For the range of new biotechnological techniques now emerging, significant noise is being made in academic and policy discourse about the need for “responsible research and innovation” (RRI) (Stilgoe et al. 2013; Owen et al. 2012). This is usefully placing attention on responsibility in the processes and purposes of research and innovation, however it has said little to date on how to care for the products of innovation as living organisms. The notion of responsibility as care is receiving some discussion within RRI (Groves 2015; Davies and Horst 2015) and indeed, within Science and Technology Studies generally there has also been a call to direct our attention towards ‘matters of care’ (de la Bellacasa 2011) and an increasing exploration of the potential value and challenges associated with employing care ethics and politics in technoscience governance (Martin et al. 2015; Viseu 2015; Bellacasa 2015; Mol et al. 2010). However, this recent work has not yet specifically focused on biotechnologies and very little attention has been directed towards the question of how we care for the organisms and ecologies we are creating and what our moral responsibilities towards them are. It is therefore my assertion that we need to dedicate further effort to interrogating not only the moral status and conservation value of our monsters and mutants but also whether and how we engage in practices of care for them. This represents a research agenda that must

be coupled to the current explosive growth of new biotechnological techniques if we are to have truly responsible research and innovation.

Conclusion

In this article, I began by explaining the operation and management of the Svalbard Global Seed Vault and answered the question of whether GM seeds can be found there—arguing that although there are good reasons to believe GM crops are explicitly excluded (on legal and political grounds), unintentional contamination remains a possibility. Understanding whether GM crops have a place in the Svalbard Global Seed Vault inadvertently led me into questions around the moral status and conservation value of GMOs, which I have argued require more sustained academic attention. Suggesting that this issue is becoming increasingly pressing as biotechnological techniques and lifeforms continue to diversify and challenge our existing legal and conceptual categorisations, I used the final part of the paper to propose the notions of synbiodiversity and symbiodiversity as conceptual heuristics to help (re)arrange our thinking, debate and further work in this interdisciplinary swamp. Finally, I conclude that not only is further work needed on the questions of how we conceptualise and categorise bio-technological forms of biodiversity, and how we argue for their moral status and conservation value, but also that exploring how we care about and for them is also an important new area for research. Since I am unfortunately unable to follow all the interesting questions and lines of investigation raised during my research here, it is my hope that this paper may at least serve to stimulate new areas of conversation and debate regarding the interface between biotechnology development and biodiversity conservation, and ultimately lead to more thoughtful practices of care for all the mutants and monsters we are engaged in co-creating and with whom we now share a future on this earth with.

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References

- Altieri, M. A., & Merrick, L. C. (1987). In situ conservation of crop genetic resources through maintenance of traditional farming system. *Economic Botany*, *41*(1), 86–96.
- Anderson, J. (2015). Why are Bill Gates and Monsanto funding a “Doomsday” seed vault? *Activist post*, June 23.

- Attfield, R. (2012). Biocentrism and artificial life. *Environmental Values*, 21(1), 83–94.
- Baertschi, B. (2012). The moral status of artificial life. *Environmental Values*, 21(1), 5–18.
- Brush, S. B. (Ed.). (2000). *Genes in the field: on-farm conservation of crop diversity*. Boca Raton: Lewis Publishers.
- Caplan, A. L., Parent, B., Shen, M., & Plunkett, C. (2015). No time to waste—the ethical challenges created by CRISPR. *EMBO Reports*, 16, 1421–1426.
- CBD. (1992). Convention on biological diversity. <https://www.cbd.int>.
- CGIAR. (2005). Guiding principles for the development of future harvest centres' policies to address the possibility of unintentional presence of transgenes in ex situ collections. <http://library.cgiar.org/handle/10947/3881>.
- CIMMYT. (2005). Practices and procedures to avoid the unintentional presence of transgenes in maize germplasm accessions at the Wellhausen-Anderson Plant Genetic Resources Center. http://cropgenebank.sgrp.cgiar.org/images/file/management/transgenes/cimmyt_maize.pdf. Accessed 30 July 2015.
- Cleveland, D. A., Soleri, D., Aragon Cuevas, F., Crossa, J., & Gepts, P. (2005). Detecting (trans)gene flow to landraces in centers of crop origin: Lessons from the case of maize in Mexico. *Environmental Biosafety Research*, 4, 197–208.
- Davies, S. R., & Horst, M. (2015). Crafting the group: Care in research management. *Social Studies of Science*, 45(3), 371–393.
- de la Bellacasa, M. P. (2011). Matters of care in technoscience: Assembling neglected things. *Social Studies of Science*, 41(1), 85–106.
- de la Bellacasa, M. P. (2015). Making time for soil: Technoscientific futurity and the pace of care. *Social Studies of Science*, 45(5), 691–716.
- Doak, D. F., Bakker, V. J., Goldstein, B. E., & Hale, B. (2014). What is the future of conservation? *Trends in Ecology & Evolution*, 29(2), 77–81.
- Doudna, J. A., & Charpentier, E. (2014). The new frontier of genome engineering with CRISPR-Cas9. *Science*, 346(6213), 1258096.
- Engdahl, F. W. (2016). 'Doomsday Seed Vault' in the Arctic. *Global Research*, January 28. <http://www.globalresearch.ca/doomsday-seed-vault-in-the-arctic-2/23503>.
- FAO. (2014). Genbank standards for plant genetic resources for food and agriculture. <http://www.fao.org/3/a-i3704e.pdf>. Accessed 23 Mar 2016.
- FAO, & CGIAR. (1994). Joint statement of FAO and the CGIAR centers on the agreement placing CGIAR germplasm collections under the auspices of the FAO. <https://library.cgiar.org/handle/10947/697>. Accessed 23 Mar 2016.
- Genetic Resources Policy Committee. (2005). Guiding principles for the development of Future Harvest Centre's policies to address the possibility of unintentional presence of transgenes in ex situ collections. <https://www.seedquest.com/News/releases/2005/april/11989.htm>. Accessed 23 Mar 2016.
- Global Crop Diversity Trust. (2014). *Fundraising Strategy 2014–2018*. Bonn: Global Crop Biodiversity Trust.
- Groves, C. R. (2015). Logic of choice or logic of care? Uncertainty, technological mediation and responsible innovation. *NanoEthics*, 9(3), 321–333.
- Haraway, D. (1991). *Simians, cyborgs and women: The reinvention of nature*. New York: Routledge.
- Hettinger, N. (1995). Patenting life: Biotechnology, intellectual property, and environmental ethics. *BC Environmental Affairs Law Review*, 22, 267–305.
- Husby, J. (2007). Definitions of GMO/LMO and modern biotechnology. In T. Traavik & L. C. Lim (Eds.), *Biosafety first*. Trondheim: Tapir Academic Publishers.
- ITPGRFA. (2006). Standard material transfer agreement. <ftp://ftp.fao.org/ag/agg/planttreaty/agreements/smta/SMTAe.pdf>. Accessed 23 Mar 2016. <http://www.planttreaty.org/content/what-standard-material-transfer-agreement-smta>.
- Khalil, A. S., & Collins, J. J. (2010). Synthetic biology: Applications come of age. *Nature Reviews Genetics*, 11, 367–379.
- Kuzma, J., & Kokotovich, A. (2011). Renegotiating GM crop regulation: Targeted gene-modification technology raises new issues for the oversight of genetically modified crops. *EMBO Reports*, 12, 883–888.
- Latour, B. (2012). *Love you Monsters: Why we must care for our technologies as we do our children*. Winter: Breakthrough Journal.

- Lezaun, J. (2006). Creating a new object of government: Making genetically modified organisms traceable. *Social Studies of Science*, 36(4), 499–531.
- Lusser, M., & Davies, H. V. (2013). Comparative regulatory approaches for groups of new plant breeding techniques. *New Biotechnology*, 30(5), 437–446. doi:10.1016/j.nbt.2013.02.004.
- Martin, J. -L., Maris, V., & Simerloff, D. S. (2016). The need to respect nature and its limits challenges society and conservation science. *Proceedings of the National Academy of Sciences, Early edition*, 113(22), 6105–6112.
- Martin, A., Myers, N., & Viseu, A. (2015). The politics of care in technoscience. *Social Studies of Science*, 45(5), 625–641.
- Mezzalama, M., Crouch, J. H., & Ortiz, R. (2010). Monitoring the threat of unintentional transgene flow into maize gene banks and breeding materials. *Plant Biotechnology*, 13(2), 1–6.
- Ministry of Health and Care Services. (2001). Forskrift om innesluttet bruk av genmodifiserte planter. <https://lovdata.no/dokument/SF/forskrift/2001-12-21-1603>.
- Mol, A., Moser, I., & Pols, J. (2010). *Care in practice: On tinkering in clinics, homes and farms (perspectives from empirical science studies)*. Bielefeld: Transcript Verlag.
- National Academy of Sciences. (2015). Gene drive research in non-human organisms: Recommendations for Responsible Conduct. <https://www8.nationalacademies.org/cp/projectview.aspx?key=49717>. Accessed 23 Mar 2016.
- Nicholson, D. J. (2013). Organisms ≠ Machines. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, 44(4), 669–678.
- Noer Lie, S. A. (2016). *Philosophy of nature: rethinking naturalness (Routledge explorations in environmental studies)*. Oxon: Routledge.
- Nordhaus, T., & Shellenberger, M. (2007). *Break through: From the death of environmentalism to the politics of possibility*. New York: Houghton Mifflin Company.
- Okusu, H. (2009). Biotechnology research in the CGIAR: An overview. *AgBioForum*, 12(1), 70–77.
- Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy*, 39(6), 751–760.
- Preston, C. J. (2008). Synthetic biology: Drawing a line in Darwin's sand. *Environmental Values*, 17(1), 23–39.
- Preston, C. J., & Wickson, F. (2016). Broadening the lens for the governance of emerging technologies: Care ethics and agricultural biotechnology. *Technology in Society*, 45, 48–57.
- Qvenild, M. (2008). Svalbard global seed vault: A 'Noah's Ark' for the world's seeds. *Development in Practice*, 18(1), 110–116.
- Reardon, S. (2016). Welcome to the CRISPR zoo. *Nature*, 531, 160–163.
- Rimmer, M. (2008). *Intellectual property and biotechnology: Biological inventions*. Cheltenham, UK: Edward Elgar.
- Rohwer, Y., & Marris, E. (2016). Is there a prima facie duty to preserve genetic integrity in conservation biology. *Ethics, Policy and Environment*, 18(3), 233–247.
- Rolston, H., III. (1991). Environmental ethics: Values in and duties to the natural world. In F. H. Bormann & S. R. Kellert (Eds.), *Ecology, economics and ethics: The broken circle* (pp. 73–96). New Haven: Yale University Press.
- Sandler, R. L. (2012). The value of artefactual organisms. *Environmental Values*, 21(1), 43–61.
- Schouten, H. J., Krens, F. A., & Jacobsen, E. (2006). Cisgenic plants are similar to traditionally bred plants. *EMBO Reports*, 7, 750–753.
- Shellenberger, M., & Nordhaus, T. (Eds.). (2011). *Love your monsters: Postenvironmentalism and the Anthropocene*. Oakland: The Breakthrough Institute.
- Sifferlin, A. (2015). Syrian seeds first to be withdrawn from Arctic 'Doomsday Vault'. *TIME*. <http://time.com/4078310/seeds-doomsday-vault/>.
- Smits, M. (2006). Taming monsters: The cultural domestication of new technology. *Technology in Society*, 28, 489–504.
- Spitsbergen Treaty. (1920). Treaty Concerning the Archipeligo of Spitsbergen. <http://www.jus.uio.no/english/services/library/treaties/01/1-11/svalbard-treaty.xml>.
- Statsbygg. (2008). Svalbard global seed vault: New Construction. (Vol. Project number 11098). Oslo: Statsbygg.
- Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, 42(9), 1568–1580.
- Svalbard Global Seed Vault. (2013). Standard deposit agreement. http://www.nordgen.org/sgsv/scope/sgsv/files/SGSV_Deposit_Agreement_until150101.pdf. Accessed 23 Mar 2016.

- Svalbard Global Seed Vault. (2016). Seed Portal. <http://www.nordgen.org/sgsv/>. Accessed 22 Mar 2016.
- Taylor, P. W. (1986). *Respect for nature: A theory of environmental ethics*. Princeton: Princeton University Press.
- Thompson, P. B. (1997). *Food biotechnology in ethical perspective*. London: Blackie Academic & Professional.
- Timmerman, C. (2016). Addressing a duty to preserve biodiversity, not genetic integrity. *Ethics, Policy and Environment*, 18(3), 262–264.
- Treaty. (2004). International Treaty on plant genetic resources for food and agriculture. <http://www.planttreaty.org/content/texts-treaty-official-versions>.
- Trust, T. C. (2016). Donors. <https://www.croptrust.org/about-crop-trust/donors/>. Accessed March 22nd 2016.
- UPOV Convention. (1978). International convention for the protection of new varieties of plants. http://www.upov.int/upovlex/en/upov_convention.html.
- van Dooren, T. (2009). Banking seed: Use and value in the conservation of agricultural diversity. *Science as Culture*, 18(4), 373–395.
- Verhoog, H. (1992). The concept of intrinsic value and transgenic animals. *Journal of Agricultural and Environmental Ethics*, 5(2), 147–160.
- Viseu, A. (2015). Caring for nanotechnology? Being an integrated social scientist. *Social Studies of Science*, 45(5), 642–664.
- Welchman, J. (2016). Attack of the hybrid Swarm? *Ethics, Policy and Environment*, 18(3), 252–255.