

Agrobiodiversity under different property regimes

Cristian Timmermann¹ and Zoë Robaey²

¹Instituto de Investigaciones Filosóficas, Universidad Nacional Autónoma de México

²Department of Values, Technology and Innovation, Faculty of Technology, Policy and Management, TU Delft

cristian.timmermann@gmail.com

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Abstract: Having an adequate and extensively recognized resource governance system is essential for the conservation and sustainable use of crop genetic resources in a highly populated planet. Despite the widely accepted importance of agrobiodiversity for future plant breeding and thus food security, there is still pervasive disagreement at the individual level on who should own genetic resources. The aim of the article is to provide conceptual clarification on the following concepts and their relation to agrobiodiversity stewardship: open access, commons, private property, state property and common heritage of humankind. After presenting each property regime, we will examine whether and how these incentivize the conservation, improvement and sharing of crop genetic resources, and conclude by defending a mixed property regime.

Keywords: crop genetic resources; state sovereignty; common heritage of humankind; temporary exclusivity; sustainable agriculture; seeds

Introduction

We are currently facing a massive impoverishment in agrobiodiversity. It is estimated that of the over 7000 species of food crops under cultivation, only 103 species are used to secure over 90% of the global food production (Tomich et al. 2011). Despite the widely acknowledged role for future food security there is still no universal consensus at the individual level on the property regime(s) the varieties making up agrobiodiversity should fall

under (Louwaars 2007; Kloppenburg 2014), leaving rights and responsibilities in regard to agricultural genetic resources and their subjects insufficiently addressed.

The aim of this article is to provide a conceptual clarification of the four most prominently discussed property regimes in regard to agrobiodiversity along with the incentives these raise for propagation, conservation and further development of crop genetic resources. Under property regimes we discuss the set of rights and duties recognized in relation to crop genetic resources stewardship, concentrating on four regimes: commons, private ownership, state sovereignty and common heritage of humankind. We proceed by first discussing what agrobiodiversity is and the complexity involved in its stewardship, second examining why it has been so difficult to order this good under a single regime, third introducing the four different regimes with the incentives they raise, and fourth, concluding with a short discussion on why conserving a plurality of regimes is something to welcome.

What is agrobiodiversity?

The object we are examining is difficult to define as well as to confine. First, there is the so-called lower-limit problem of biodiversity: it is unclear at what stage organisms start to count as alive (Malaterre 2013). Second, it is also difficult to separate the organisms relevant for food production and those that are not (Gliessman 2007). Third, the boundaries between wild, semi-wild and domesticated varieties are far from sharp (cf. Khoury et al. 2013).

For the purposes of this writing, we settle for a working definition of agrobiodiversity that should guide us through the central issue being agricultural genetic resource governance. We understand agrobiodiversity as the whole spectrum of crop and animal varieties that have been consciously selected and bred targeting a particular set of desirable traits. In addition, agrobiodiversity is also conserved and augmented by creating wild or semi-wild refuge areas. It is important to keep in mind that crop genetic resources have a dynamic nature and their

survival and performance depends on their adaptation (on their own or through human efforts) to new environmental and evolutionary pressures, including climate change, pathogens and pollution, as well as demands raised by consumers. Therefore the economic and social importance of a crop variety changes over time.

The biological entities that make up biodiversity are useful for humankind directly as a resource, either now or potentially in the future, or indirectly by helping to sustain other species that are or could be of direct utility (cf. Wood 1997). Wild relatives of currently used crop varieties have much more genetic diversity and thus, as a group, have greater chances in surviving biotic and abiotic stresses. Plant breeders borrow genetic materials from these wild and semi-wild relatives and interbreed them with high-yielding varieties to merge the benefits (high yields and specific stress resistance) into a single breed (Kloppenburg 2005). Due to the opportunities it grants, the worldwide pool of crop genetic resources can be considered as a global public good.

Since we cannot predict which varieties will be useful in the future, humanity needs to conserve a wide genetic pool to draw from for future needs. Further, many species act as supporting organisms within the wider ecosystem (Deliège and Neuteleers 2015). The loss of some species that appear to be useless from an anthropocentric perspective may have catastrophic effects on an ecosystem (Herrera Vásquez and Rodríguez Yunta 2004), ultimately affecting future food security and in extreme cases human survival.

To confine this examination we focus in the remainder of the article solely on agrobiodiversity in crop varieties. However, much of the upcoming arguments also apply for domesticated animal species and agriculturally relevant bacteria. In addition, by referring to seeds we also consider other types of propagating material. We will not distinguish between genetically modified varieties and conventional varieties, as whether the first can be an equivalent replacement for the latter is an issue that requires a separate investigation.

The public good dimension of agrobiodiversity and the problem of ownership

Since property rights are inherently of instrumental nature, we should not fail to discuss the public interest dimension within any type of regime that seeks to exclude a resource, either temporarily or permanently, from the public domain. The resources making up agrobiodiversity are claimed as goods meant to enhance private interests, i.e. as an exploitable commodity, and as goods that should benefit society as whole, i.e. falling under a particular understanding of public good. Let us briefly state who is claiming ownership over agrobiodiversity and on what grounds.

Since farmers can collect seeds from previous harvests, seeds are by their nature not suitable as a tradable commodity (cf. Vatn 2000). Legal and scientific innovations were made to be able to exclude others from crop genetic resources, by developing intellectual property rights and hybrid seeds (Kloppenburg 2005). Nowadays these resources can be owned in a variety of ways. Ownership can up to a certain extent be claimed on information carried in crops' genes and also on seeds themselves. The latter can be done by either owning all *tokens* of a specific genetic resource, e.g. by having property rights (or sovereign rights) over a landrace, seed bank or botanic garden, or, in legally defined cases, one can also apply for exclusive rights over a certain *type* of genetic resource (cf. Wilson 2009; Robaey 2015) – depending on jurisdiction through some version of plant breeders' rights or patents. Lastly, we can also observe a difference between what people can claim as their own on legal grounds and what people could claim as their own on moral grounds.

Crops make up a huge pool of in large part self-replicating varieties that continuously evolve and are subject to breeding efforts. The dynamic state of agrobiodiversity allows people to only claim exclusive rights with a certain backlog and with some degree of uncertainty. Parties seeking to control access over crop genetic resources are mostly pursuing

economic interest directly, by being able to sell seeds above production costs – facilitating investment in research and development – or indirectly by blocking the entry of specific crop genetic resources in order to market other varieties more lucratively.

Let us briefly examine why it is so difficult to use economic reasoning to assess the problem of ownership and crop genetic resource stewardship by focussing on two economic theorists who have a huge legacy in the study of environmental resources conservation. Coase (1960) famously demonstrated that people with different interests will bargain to come to optimal results even in the absence of state interference. Ostrom (1990) shows with a number of case studies that groups can develop conflict resolution mechanisms on their own. There are a number of limitations applying Coase's and Ostrom's findings to our subject. Both emphasize the need for clearly defined property rights, something that is difficult or impossible to achieve with crop varieties due to their dynamic and often heterogenic nature. Also, both authors rely on case studies in which a sovereign actor threatens to impose a binding regulation that would be suboptimal for the actors involved, encouraging them to come up with a better solution beforehand. As is widely known, our strongest global institutions (WTO, World Bank, United Nations) do not have enough power or legitimacy to impose their will to address environmental issues. Another challenge is coming to an agreement on the economic value of crop genetic resources. Biodiversity in general is not only a mere resource, but holds for many cultures and worldviews, intrinsic values which are not compatible with monetary valuation (O'Neill 1997; Campbell et al. 2014). When large groups of people hold such perspective, predictions that assume that people are profit-maximizing agents poorly reflect reality. Bargaining among people who have such different ways of valuing the disputed goods becomes much more complex and time-consuming (De Jonge 2011). There are well over two billion smallholders in the world using and benefiting from crop genetic resources (Holt-Giménez and Altieri 2013). Moreover, farmers can collect

seeds from most varieties after the harvest. Due to the complex interaction between crops and the environment the true potential of a variety is first seen once exposed to the natural and socio-economic environment it is meant for (Timmermann and Félix 2015). People will avoid allowing others to test the performance of a crop variety if they are unable to control what happens to it afterwards (e.g. stay in the public domain or be treated as someone's property). This makes it very difficult to know what each other's assets are worth.

Now it does not come as a surprise that there are a variety of stakeholders advocating various forms of property regimes, as these incentivize different forms of stewardship. Let us sketch three representative standpoints.

Agrobiodiversity as a universal good. Many civil society groups, public breeders and international organizations see crop genetic resources as a public good over which nobody ought to be excluded (cf. O'Neill 2001). Some of these groups reject property rights on biological organism altogether due to the intrinsic value (Cahill 2001; Kloppenburg 2014). These resources should be made available for poor and rich alike as well as conserved for future generations. In line with this idea is the demand that these resources should be made public – in the sense of visible and accessible – to empower farmers and breeders so they can further developed varieties to improve global social welfare.

Agrobiodiversity and reciprocity. Especially agrobiodiversity-rich countries emphasize the effort done over several decades and centuries by their farmers to develop and conserve the varieties within their jurisdictions. Starting from this position, parties tend to argue that this effort should be (i) compensated in cases new varieties are not made available on similar terms, or (ii) remunerated like any other new variety.

Enhancing agrobiodiversity through market models. Following a neoliberal economic reasoning, many industry advocates and states argue that crop genetic resources are not

necessarily a public good and therefore private parties, and not the state, being more suitable to provide that good.

To exacerbate this already problematic situation, agrobiodiversity raises the so-called “jointness of production” problem of public goods (cf. Waldron 1987), since both erosion and improvement of agrobiodiversity are caused by the sum of individual actions. To paraphrase Elizabeth Kahn (2014), while genetic erosion is an essentially aggregative harm, agrobiodiversity is an essentially aggregative good. We therefore face three major problems for the maintenance of agrobiodiversity. First, individual contributions to the common pool are difficult or impossible to trace, for a large number of communities often spread through different countries contributed over centuries to the existence of current varieties (Kloppenburg 2005; Engels et al. 2011). Second, analogously, individual farmers opting for monoculture have caused genetic erosion in agriculture as a collective (Lacy 1994; Peres 2015). Third, commercial plant breeders who have borrowed genetic resources from the public domain can seek for exclusive rights (Batur and Dedeurwaerdere 2014). Therefore, the number of crop varieties available in the public domain shrinks when people are inadequately incentivized to contribute to the common pool or have the possibility to unilaterally withhold potential contributions. These factors contribute to the deterioration of the global public good agrobiodiversity.

Taking these findings with us, we examine the effects of exclusive rights on crop genetic resources in regard to conservation, improvement and sustainable use.

Agrobiodiversity as a resource

The possibility to guarantee food security in the future is strongly dependent on the genetic resources available for plant breeding (Peres 2015). This complicates the liberty to dispose of the varieties making up agrobiodiversity as exploitable resources, that is, by solely following

private interests. However, when assessing responsibilities, the nature of the causal relationship between agrobiodiversity and food security is difficult to establish. As far as individual responsibility is concerned, the causal link between exclusive rights on a single crop variety and food security is blurry. Excluding single varieties from the public domain generally has no effect on food security. Resistance to specific pathogens are often present in more than one variety. We thus face a standard moral conflict: the actions or omissions of single individuals are not enough to cause harm, but if a collective follows suit, it brings negative consequences for society at large (A. E. Kahn 1966). As an essentially aggregative harm, the conservation of agrobiodiversity calls for regulation. Profit-maximizing individuals are acting in a way that leads to genetic erosion, endangering future generations' ability to secure their food needs. Until now, global society has relied on the poor farmers' inability to purchase commercial seed varieties to slow down genetic erosion. The large-scale acquisition of land by multinational corporations and foreign governments (i.e. land-grabbing) will reduce the land available for indigenous landraces that host a large amount of agrobiodiversity (cf. De Schutter 2011). Unlike crop improvement efforts, which can largely be made by a series of independently working breeders and farmers, the difficulties involved in conservation and sustainable use raise the need for worldwide top-down regulation since market incentives disproportionally reflect the wants of financially strong groups.

A further threat to the environment and long-term food security is what is considered from an economic perspective an ideal product. A profit-maximizing agent envisions selling a single product that took little effort to develop to the largest number of people. When this reasoning is adopted by the seed industry, we face ecologically disastrous incentives (Altieri 2003). Large-scale monocultures indicate genetic erosion and are much more vulnerable to pathogens, requiring higher doses of pesticides. Agrobiodiversity is best maintained when no varieties become dominant. When an individual tries to maximize her short-term private

interests by selling (or making freely available) a particular seed variety at a massive scale, we face genetic erosion. A variety, even if leading to higher yields, should not become so dominant that it disincentivizes the seeding of other varieties.

Solving this misplaced incentive problem is difficult, as a reformulation of Hardin's (1968) classic version of the tragedy of commons illustrates. Let us imagine arable land hosting agrobiodiversity as a global commons. Rational, profit-maximizing plant breeders have the interest to increase the number of their proprietary seeds in the global commons (i.e. increase their market share). The benefits of additional revenues go to the profit-maximizing plant breeder; while the price of expanding the market share – genetic erosion – is paid by society at large. While we admit that there is a certain irony in using the very same line of argument used to justify privatization to show the negative effects of market incentives, the argument is not far-fetched. Extensive monocultures are already a major socio-ecological problem, especially taking the wide dominance of genetically-modified soy in South America (e.g. for Argentina, see Arancibia 2013; Leguizamón 2014). The private interest of profit-maximizing individuals is here incompatible with the public interest of conserving agrobiodiversity.

Further, market incentives and the maintenance of ecological balances have little causal relation. Competitive markets require a modularization of products. Yet, as Keulartz rightly notes “[e]nvironmental goods and services are not by their nature fit to be itemized” (2013). Species are dependent on other species; markets may provide incentives to conserve one, but not the other.

Having mentioned some of the main issues regarding the sustainable use of agrobiodiversity as a resource, we should ask ourselves what we need to incentivize to safeguard the genetic resources required to secure the human right to adequate food and to

maintain ecological balances. We have identified four specific goals in regard to maintaining (or even increasing) agrobiodiversity in the long run. Future food security demands:

- (1) incentives to conserve varieties,
- (2) incentives to further improve varieties, and
- (3) incentives to share and make available existing and future varieties.

In addition, sustainability needs:

- (4) a strong incentive to not waste genetic resources and the opportunities such resources offer.

These four goals are to guide us in judging the different property regimes that could govern agricultural genetic resources. Before proceeding we first need to examine how moral responsibilities in regard to conservation, improvement and sustainable use could be linked to property rights.

Ownership, rights and responsibilities

Throughout the last centuries and recent decades, we have witnessed strong variations between what property rights entitle to and what these rights demand from holders. At one end of the spectrum, we have traditions that seek absolute rights without having to assume any obligations, and at the other end, we encounter those who only are willing to grant exclusive rights for instrumental reasons conditional to the fulfilment of certain obligations towards society. Without aspiring to identify which tradition has globally historical precedence, we will settle by exposing the central arguments justifying the societal responsibilities property holders may have.

We have to find out first, what property rights entitle to. Subject to a variety of provisos, property rights are rights to exclude others from unlicensed use of an object. As far as further rights and liberties concern, even hard-line libertarians set limits on what property

rights allow their holders to do (cf. Reitan 2004). The simplest case: ownership of a resource (e.g. a plant pathogen) does not entitle to harm others. Somewhat more controversial is to say that ownership does not necessarily mean that the rights holder can commercialize (or in some cases even use) the object over which she has titles. The rights holder may have the right to exclude others from using the resource without having the right to use the resource commercially herself, e.g. by not having obtained market approval from corresponding biosafety regulation agencies. Depending on the object, there are some limits in how far property owners are allowed to alienate (sell or lease) the object. Likewise, there might be some limitations in how far right holders are allowed to *actively* modify or destroy the object (cf. Strahilevitz 2005), even though substantial liberties on how the object is to be managed are generally acknowledged. The non-uniformity of liberties granted to property rights holders over the use of their resources has led to the idea that property titles consist in a “bundle of rights” (Honoré 1961).

The idea of attaching duties to property has a considerable tradition in political thought. Already Locke (1689/1960) made property rights conditional to non-wastage of the good. People should not enclose more land than they could work on without allowing fruits to spoil. Modern interpreters wonder if rampant underuse of opportunities could count as wastage of resources as well (Sterckx 2005; Attas 2008). While Locke justifies property rights by arguing that these will benefit society as a whole by incentivizing improvement of estates (Strauss 1952), less prominent are traditions that assign more direct duties to manage one’s holding for the benefit of the general public. In the protestant tradition, particularly in the Lutheran school, the true property owner is God and earthly property owners are merely stewards of land having the task to manage their assets for the benefit of society (Kübler 1960). This idea resonates in the German *Grundgesetz* under article 14.2, with the principle “*Eigentum verpflichtet*”, loosely translated as ownership comes with obligations. A strict

mandate to manage one's property according to public interest is extremely demanding. Any resources exchanged for luxury goods, from limousines to cigarettes, could have found better use when spent on something of public interest. In practice, German jurisprudence has taken a rather narrow interpretation of the sub-article arguing that property holders have a general duty of considerateness and attentiveness in regard to how their property affect others (Kübler 1960). Secular versions of these arguments have had to wait to gain prominence until recently with the emergence of scholarship on sustainable development.

In relation to sustainability, we should ask ourselves if property rights holders should not only actively abstain from destroying or damaging their objects, especially when these are irreplaceable and unique, but even protect the object from deterioration and hostility, as well as engage in conservation efforts. In the realm of agrobiodiversity, impeding destruction through conservation responsibilities has substantial implications. First, there is the cost factor and the limited availability of resources. Unfortunately resources destined for conservation efforts are likely to originate from the same land that harbours agrobiodiversity, leading to further competition for land, making it even more difficult to conserve habitats. Second, evolutionary pressures make it impossible not to lose varieties. And third, there is a substantial human involvement in agrobiodiversity. Many varieties came to existence due to human efforts and therefore arguably could count as creations of individuals or communities.

The way property rights holders exercise their rights will affect the future survival of a resource (Goodin 1990). Property rights allow a certain amount of control over resources and here it becomes important to discuss eventual responsibilities attached with the use of this capacity. If we want to analyse the responsibilities each party has to conserve a variety under their control, we are helped by discussing four major scenarios: (1) if x owns exclusive rights over a variety and forbids its use by others, is x responsible for conserving the variety? (2) Is x also responsible to conserve the variety, if x 's exclusive rights reduce the incentives others

have to conserve the variety in question? (3) Does it make a difference if x created the variety (in the sense that the crop variety would never have come to existence naturally)? And (4), what responsibilities does a mere co-owner of a crop variety have? Let us examine these four cases.

In the first scenario, x employs her exclusive rights to block others from using the resource. Conservation requires access to the resource and since x is unwilling to grant access, conservation by others is impeded. x may have private incentives to allow the resource to vanish, e.g. as a major corn seeds seller, she might have an interest in the extinction of certain perennial teosintes species, whose genetic material could be used to develop varieties that jeopardize her market. Given that crop varieties came into existence through the work of a large number of generations of farmers, and are very difficult or impossible to replace (cf. Goodin 1983), property rights can be made conditional to assuming conservation responsibilities.

The second scenario involves another likely case, the one in which x is willing to allow others to conserve the resource, but wants to reserve the right to commercially exploit the crop or makes conservation efforts subject to unacceptable or unfair conditions. Owners of all known or accessible tokens of a crop variety could use contracts (e.g. material transfer agreements) to make sure that they retain all rights on commercial use, or to secure a disproportionately high share on eventual profits over any improvements on the variety. Such exercise of rights may create a disincentive for others to conserve the variety. In the case that outside conservation efforts add value to a resource owned privately, we could say that the owner is entitled to a share in the benefits that has to have some proportionality with the size of the contribution she made to the conservation effort. Any benefits coming from a joint undertaking should be divided fairly among those who have cooperated in the joint venture (on cooperative justice, see Van Parijs 2011). Being indispensable does not entitle to veto all

distributional arrangements that do not lead to a maximization of one's profits. We could therefore argue that genetic resource owners' conservation responsibilities should be proportional to the share in eventual revenues they are seeking.

In the case of newly created varieties, the third scenario, x changes the moral background conditions by bringing into existence a new variety. A world where a technological solution exists, e.g. a crop variety resistant to a higher level of salinity, is in a specific way, essentially different to one where such technological solution does not exist. If planting such a variety in an affected river delta reduces famine, hunger in that region moves from being an inevitable harm towards being an avoidable harm. The hungry and their sympathisers raise a strong normative claim due to the urgent need and want that the resource (i.e. the created crop variety) should not be wasted. Therefore, we can say that conservation responsibilities also apply for newly created varieties.

In the fourth case, which discusses the responsibilities of owners of one of the many tokens of a crop variety, we can follow a line of argument that can be developed from Kahn (2014). As mentioned earlier, arable land hosting agrobiodiversity can be considered as a global commons. Those who do not establish and follow regulation on the sustainable use of the commons contribute to essentially aggregative harm: genetic erosion. Seed producers and land owners thereby acquire the responsibility that the seed types they sell or plant do not become so dominant that they contribute to genetic erosion and thereby harm others. A responsibility to prevent harm also requires direct and indirect users of arable land both to establish a regulatory framework that combats genetic erosion and compliance with the rules such a framework will set.

Let us now examine how these responsibilities are addressed by the different incentives raised by the four property regimes here examined. Afterwards, we analyse if these parallel incentive schemes are offering the necessary stimulation for sustainable stewardship.

Governance of agricultural genetic resources

The prospect of asserting property rights depends on the social recognition of these rights and an authoritative figure reinforcing these rights (Bromley 1992). Policing is necessary for an entity to effectively exclude others and regulate the use of a resource; a complete lack of social recognition of property rights, however, will make policing extremely or even prohibitively expensive. We start by examining the effect of absence of widely recognized property rights over crop genetic resources. Thereafter, we discuss scenarios in which genetic resources are owned by a group of people, individuals, a state, and humankind, and examine how these property regimes affect sustainable stewardship.

Non-proprietary goods

The elimination of property rights is supported by a variety of civil society groups from all over the world who oppose ownership on living organisms (Kloppenburg 2014). The absence of property rights allows unregulated exploitation, as non-proprietary goods are essentially unmanaged (Ossorio 2007). A classic example is Hardin's (1968) pasture, an open access regime that allows cattle holders unrestricted use with the likely negative effect of deterioration of the resource held in common. In order to counter deterioration a number of resources are subject to usage restriction, changing access restriction from openness to specific community membership (Aguilera Klink 1991), as we will discuss in the next section under commons.

People seeking to exploit self-replicating innovations in an open access regime are obliged to rely on secrecy to maintain their market share. It is much more difficult to control these type of innovations, because after the initial acquisition, farmers will be able to recover seeds from the first harvest for subsequent use. If recognized and enforced, plant breeders

may ensure a continuous flow of royalties through material transfer agreements; otherwise they have to rely on donations or voluntary purchases. The absence of control mechanisms over who is making additional copies also insufficiently incentivizes the marketing of seed varieties. If distributors do not get enough income for distributing seeds, or are otherwise insufficiently motivated, this will lead to undersupply.

In cases plant breeders have alternative funding sources to recover research and development costs, e.g. as public institutions, an open access regime greatly facilitates the inclusion of a wide genetic makeup in varieties. When this is not the case, open access regimes tend to provide insufficient incentives to spend resources for the conservation, propagation and further development of new varieties, as costs cannot be individually recouped. Absence of alternative funding schemes leads therefore to an underuse of resources at a global level even when these are freely available.

Commons

Resources falling under a commons regime are subject to group regulation. Indeed, commons governance concentrates not so much on ascertaining property rights but on regulating behaviour (Vogler 2012). These regimes can be designed in many different ways, e.g. by limiting group membership to residence in a geographic region, ancestry, or the willingness to adhere to a specific cause. Membership can also be conditional to the acceptance of certain usage restrictions. Modern examples are creative commons licenses, which often subject the use of resources held in common to willingness to freely share derivative products (i.e. share-alike). A variety of groups who recognize the problems involved in unrestrained access recognize commons licenses as a second best option to defend a wider availability of crop genetic resources. Among the supporters we find public breeders, NGOs, international organizations, farmers, and also some commercial breeders (Kloppenburg 2014).

The design of innovation incentive systems was strongly influenced by industry interests groups (Drahos and Braithwaite 2003). We have therefore more incentives to develop and sell homogeneous seed varieties than seeds coming from landraces, which generally show larger agrobiodiversity. This leads to a situation where those governing landraces rarely have exclusive rights over seed types. Farmers will have to form a commons with all other farmers who have access to a certain type of crop variety in order to make sure they can effectively control the crop as a group, otherwise individual farmers may sell single tokens of the propagating material for their own advantage. This can be a major organization challenge if the variety is widely dispersed.

The present-day re-emergence of commons has goals that go beyond seeking group advantage. A central aim is to (re-)establish an environment that makes reciprocity mandatory or at least hinders parasitism. The parasitic behaviour that is primarily fought is not so much the free-riding of the poor who are unable to reciprocate, but the one from entities that take from the commons without contributing back improvements or making alternative donations. Nonetheless, we could easily imagine commons regimes that do not distinguish between those who are unwilling and those who are unable to contribute.

Generally the survival of commons regimes is highly dependent on sanctioning possibilities (Ostrom 1990). In this regard, the recently developed creative commons licenses have inspired a new generation of farmers and public institutions to develop licenses that facilitate the sharing of seed varieties with much lower risk of these ending up as private property (Deibel 2013). Committed farmers and breeders can use these licenses to maintain a certain threshold of quality seeds available for free, thus pushing private industry to market varieties that perform better in a cost-benefit ratio, similarly as we have witnessed with software (for a comparison between plant breeding and the software industry, see Lemmens 2013). Farmers as a community, are campaigning for this movement by calling for the need to

repossess varieties as a demand for sovereignty and as (re-)empowerment (Kloppenborg 2010).

Nonetheless, commons regimes demand from their users a great deal of commitment to share, improve and maintain varieties. People working with commons licenses have to set their differences aside and build a large community that is able to incorporate a significant pool of resources. Fragmentation of commons regimes increases transaction costs. It will be difficult to keep this ideal alive to ensure sufficient and consistent collective action to conserve varieties that presently show no use, but might be valuable in the future. While modern communication technologies can greatly help to disperse such efforts, idealism remains as the central incentive source.

Private goods

The seed industry and countries where such companies are headquartered have been from early on strong supporters of private property rights for novel varieties (Louwaars et al. 2013). Generally privatization starts to make sense once the gains of careful resource management outweigh the costs of establishing and running a private property system (Rose 1986). The self-propagating nature of plants and the necessity of maintaining biodiversity complicate this classic economic assertion. Commercial exploitation of genetic resources raises the transaction costs involved in developing new varieties that include a diverse genetic makeup. Further, current intellectual property regimes only incentivize the breeding of plant varieties that are stable and uniform¹ or have genetic material covered by patents, offering only indirect incentives to conserve traditional varieties.

Private ownership is compatible with the idea of trusteeship, the sustainable use of resources for the benefit of society, as long as the owner(s) behave in public interest (Sand

¹ see International Convention for the Protection of New Varieties of Plant (1991), art. 5.1

2004), e.g. provide a good service without usurious fees. Behaving in public interest is however a difficult task for individual seed owners as it requires coordination with other users. Social responsibility may come at the cost of long-term survival if competitors do not follow trend.

Another problem is that market incentives reflect ability and willingness to pay and only very indirectly ecological needs and social demands for food security. Only 6% of privately funded agricultural research focuses on the needs of developing countries' agriculture (De Schutter 2009). When markets start to reflect ecological damages, it is usually extremely late and costly to reverse the harm. Market forces create an incentive to overexploit a variety when it is profitable and underexploit varieties that do not attract enough paying customers. A balance has to be struck between maintaining agrobiodiversity and making sure that high-yielding varieties are used up to an ecologically safe threshold.

In how far sanctioning possibilities go, private property regimes raise a problematic issue. Usually, the owner of the seed variety will have far greater knowledge on the full potential of the variety, leaving her in a position of advantage over the sanctioning institution.

Lastly, private property rights come with no obligation to distribute a variety. Economically rational agents will only make a variety available if incentivized to do so. Private property regimes waste thereby a large number of opportunities, by allowing dead-weights that may not represent a large monetary loss, but in a highly unequal world still affect an unjustifiable number of people.

State property

The ownership of crop genetic resources by states bring along many of the same problems as private ownership. However, there are some additional difficulties. We start by enlisting the

demands specified in the preamble of the Convention on Biological Diversity (1992), which expresses the widest support for state sovereignty:

- (1) States are responsible for conservation
- (2) States are responsible for sustainable use

Further, there is the issue of compliance with the human rights law:

- (3) If States acknowledge the right to food and health, sharing of genetic resources becomes essential

The idea of state sovereignty implies that individual governments become the contact partner for eventual negotiations over the use of genetic resources. However a large number of countries in the Global South have inadequate infrastructure to determine ownership titles over landraces (Soto 2000), and some states also demand the consent of land owners before genetic resources can be exploited (Safrin 2004). In countries where owning land is restricted to males, we also face an issue of gender justice. It is important to underline that women steward approximately 90% of the genetic resources contained in landraces within South Asia and Sub-Saharan Africa (De Schutter 2009). Furthermore, different ministries within single countries may claim rights on genetic resources, making negotiation costly and time-consuming (Louwaars 2007). Government interests may also vary from the interests of single communities within the state, especially from the interests of the indigenous communities who developed the crop varieties (cf. Safrin 2004; De Jonge 2011; Haugen 2015). This conflict of interests may create disharmony and unwillingness to cooperate.

As far as conservation efforts go, we can expect a variety of outcomes. Government policies will vary depending on how profitable it is for political parties in power to pursue long-term conservation efforts rather than focus on short-term projects with immediate pay-outs. The possibility of obtaining returns from benefit-sharing agreements usually emerges some years after a democratic government in power leaves office due to slow process of plant

breeding. It is likely that competing political parties will be harvesting eventual benefits. An additional problem is that some countries demand that citizens as well as foreigners seek government permits when using traditional varieties, limiting the liberty to dispose of these resources (Safrin 2004).

Moreover, conservation is costly and, as the Nagoya Protocol (2010) specifies, its implementation requires international transfers. However, the better off among the agrobiodiversity-rich countries are better equipped to assess the value of the resources they have sovereign rights over and to provide evidence on the need for international assistance. Unfortunately, the worst off countries are so financially poor, that they lack the infrastructure to survey what they own (Lira-Noriega and Soberón 2015). This may lead to incentives to overstate what countries own when benefits can be expected (or serve as excuse to avoid helping others) as well as understate what is owned to avoid responsibilities that could jeopardize the liberty to exploit other natural resources (Coolsaet and Pitseys 2015).

To summarize, we can affirm that state sovereignty on its own, provides insufficient incentives for the long-term stewardship of agrobiodiversity, as governing parties will rarely grasp the fruits of their investments.

Common heritage of humankind

The principle of common heritage of humankind is a modern legal construct that acquired certain popularity in the 1960s (Mgbeoji 2003). During the early 1980s the FAO promoted the view that crop genetic resources should be seen as common heritage of humankind (Brody 2010). The concept was promptly abandoned, since biodiversity-rich countries in the Global South did not want to contribute to a regime that did not also allow access to the commercial varieties developed in the Global North, especially when these were developed using genetic materials originating in their jurisdictions (de Goede 2014). In addition, some developing

countries saw the enclosure of genetic resources as an opportunity to gather wealth (Sell 2010). Despite the early rejection, the idea of common heritage has regained popularity during the last decade (Taylor 2013), therefore we will take a closer look at the concept.

The concept of common heritage of humankind involves five principles (Wolfrum 1983; Shackelford 2008): (1) common management, (2) no unilateral appropriation without worldwide sharing of benefits, (3) swift sharing of knowledge gathered by scientific research, (4) prohibition of harmful uses, and (5) preservation for future generations.

This idea represents in many perspectives a radical shift. First, it goes strongly at odds with current ways of doing science, as rapid sharing of knowledge and benefits is incompatible with proprietary science models. Second, the different parties will only share possible benefits to the best of their abilities when they consider the whole system as fair. There is evidence that many people will often avoid cooperating in a system that they consider unjust, even if this comes at a personal cost (Dodds 2005). Third, the biotechnological revolution has made research and development in the plant sector cost-intensive. It will be difficult to come to a global agreement on which of these expenses can be deducted before sharing benefits after using resources held in common. Fourth, the idea of common management requires some basic agreement on what common priorities are. As mentioned, agricultural needs differ vastly between the Global South and the Global North. The system runs the risks of being too slow in making decisions due to the large number of stakeholders with differing interests. Fifth, in a highly divided world, a common management regime for agricultural genetic resources faces the danger of being utilized to advance agendas that have nothing to do with environmental and food security needs (as we can currently observe in official development aid politics (Singer 2004)). Sixth, the conservation burden among the different countries varies significantly and if everyone is to benefit from common ownership, justice demands a fair division of costs. Essential for the successful

working of a common management system will be to have an effective sanctioning system (Kiss 1985). However, in a world with such vast inequality in political power, effective and fair sanctioning will be very difficult to realize.

Due to these difficulties, it is hard to defend the common heritage of humankind principle as something more than a strong ideal. Nonetheless, the principle has an easy to familiarize strong normative call that underlines the importance of having something to bequest future generations and humanity in general. Adhering to weaker versions of the principle still provides a significant incentive to not waste resources regardless of the property regime people rely on as practitioners.

	Incentives to conserve varieties	Incentives to further develop varieties	Incentives to share varieties	Incentives not to waste varieties
No property	adequate if the variety is used and does not require large investments		no impediments for propagation, but also no special incentives to make varieties widely available	
Commons	strong if the variety is used by members and does not require large investments (appropriateness dependent on size of commons)		licenses favour sharing if recipients reciprocate	
Private property	strong if lucrative in the near future (subject to future-discounting)	strong if varieties attract sufficient paying customers	private industry is bound to fulfil shareholder interests	there is a private interest in the disappearance of some varieties and a strong incentive to sell other varieties
State sovereignty	subject to the long- vs. short-term agenda of the sovereign state and benefit-sharing agreements in place	depends on whether the country has adequate infrastructure and international collaborations	strong motivation to capitalize on resources instead of free sharing	weak incentive for long-term conservation of varieties of uncertain value
Common heritage	strong commitment to bequest a large pool of resources to future generations		strong commitment to make resources available for human welfare	strong commitment to bequest a large pool of resources to future generations

Discussion and conclusion

In what concerns the optimal mix between private and common property, Richard Epstein emphasized the complexity involved in following the simple maxim “minimize the sum of the costs of exclusion and coordination” (Epstein 1994). As we saw, finding out where exactly this balance between the different types of property regimes could be, is a very complex task in relation to crop genetic resources.

We have to establish for crop genetic resources an incentive system that adequately stimulates conservation, sustainable use and further development. At the same time, such a system has to find support from its main users, groups who see genetic resources as (1) an universal good that should be accessible to all, (2) a pool of resources where everyone should contribute materials and know-how according to their capacities, and (3) an opportunity for entrepreneurship. Further, food security and environmental sustainability demands that property regimes: (1) reduce uncertainty in regard to rights and duties, (2) preserve the freedom to develop new varieties, (3) create incentives to share non-marketable varieties, (4) do not pose a threat to ecological balances, and (5) integrate environmental externalities. As all these different interests and needs are impossible to accommodate under a single property regime a mix of property regimes should be favoured.

However, additional top-down regulation is still necessary. We live in a world of extreme inequality, in terms of scientific capacity, availability of suitable crop genetic resources, agrobiodiversity conservation burdens, and purchasing capacity. In order to conserve agrobiodiversity, regulations on land-use have to be implemented at a global scale and the costs thereof shared. *In situ* conservation requires the protection of landraces and the creation of zones dedicated to the maintenance of agrobiodiversity. Depending on dietary needs and ecological constraints, areas of arable land could be zoned for specific crop varieties, farming methods and type of seed governance. In addition, coordinated efforts to

provide improved varieties to areas in need have to be made. Worldwide cooperation cannot be ensured if crop genetic resource exchange is perceived as unfair – something hard to realize in a world highly interdependent on agrobiodiversity where people with hunger and luxurious eating habits live side by side. These drawbacks, representing additional transaction cost, can be mitigated by strengthening the democratic nature of such regulations through a common management regime. Social experiments have shown that compliance with regulations on common-pool resources can be considerably improved by giving users a vote (Hauser et al. 2014). Increasing democratic legitimacy is a long-term effort, but it is a call that is widely demanded in regard to environmental resources management (Villarroel 2013). Such regulated efforts can thrive along a competitive seed industry characterized by polycentric decision-making. However, we have largely lost this institutional diversity due to enormous concentration within the seed industry and food retailers (McIntyre et al. 2009)

Fortunately, some organizations are already recognizing the potential of stimulating agrobiodiversity stewardship through a diversity of property regimes. Here we can welcome the new raise of commons regimes that stimulate innovation and conservation through licenses in a system that emphasis reciprocity instead of exclusiveness (cf. Halewood 2013). However, both private property and common property regimes have insufficiently addressed the notion of sustainability, in particular a strong mandate to not waste resources that could benefit future generations. Here the idea of common heritage of humankind, which strongly embraces the act of inheriting and ultimately also bequeathing, could serve as normative principle necessary to adhere to in order to secure an adequate level of agrobiodiversity.

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