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Breeding Grounds for Biodiversity Renewing Crop Genetic Resources in an Age of Industrial Food

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Renewing Crop Genetic Resources in an Age of Industrial Food

By

Maywa Montenegro

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Committee in charge:

Professor Alastair Iles, Chair
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Abstract

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Seeds are central to agrobiodiversity, and farmers have historically bred a rich array of crop seeds to sustain rural and urban communities. Over the past 150 years, however, trajectories in macroeconomic development, science and research, and agricultural policy have dovetailed with environmental changes to diminish seed diversity and the living agricultures it supports. While genetic erosion has emerged as a global challenge, access to that diversity has also come into stark relief: Industry consolidation, the development of transgenic crops, and intellectual property rights are now seen as constraints on free exchange of seeds and the ability of farmers and breeders to adapt and breed resilient crop cultivars. How can seed diversity – and access to it – be expanded once more?

To address this question, my dissertation develops a 'political ecology of seeds.' Building on the foundational account of seed primitive accumulation by Kloppenburg (1988), I examine several dimensions left underexplored in this and other accounts: new, countervailing forces of *repossession* working against primitive accumulation; the *knowledge politics* of seed production and of seed science; and the *co-production* of institutions, policies, discourse, and knowledge together. Using a constructivist theoretical framework, my project explores how knowledge politics and coproduction are instrumental in carving out new – and retracing old – territories for seed enclosures in the contemporary era. By examining how often-invisible discourses and practices underpin seed dispossession, we are better equipped to organize alternatives – not only to reject colonial and capitalist habits of thought/practice, but to revitalize communal, ethical, and economic strategies of repossession. My thesis includes three core papers, alongside introduction, theory, and conclusion chapters.

In the first paper, I critically interrogate meanings of 'diversity' via rivaling discourses of seed 'loss' and 'persistence' visible in the scientific, international policy, and farmer movement literatures over 40-plus years. On one hand, numerous studies and stories indicate that crop genetic diversity is rapidly eroding worldwide. On the other hand, much data suggests that far from disappearing, seed diversity persists – resisting homogenizing trends within industrial capitalism. Yet in lieu of binary analyses, a more accurate accounting, I argue, can come from investigating the epistemic practices and politics of agrobiodiversity: what is *known* – recognized, measured, valued – as being lost or maintained. Evaluating historical data on farmer naming systems along with newer methods of genomic and biochemical analysis, I develop a multi-dimensional framework for understanding seed diversity.

My second paper considers crop wild relatives (CWR) as a fast-emerging site for new seed primitive accumulation. Faced with imminent climate change, scientists and agribusinesses are vying to develop crops that can survive drought, floods, and shifting pest regimes. CWR offer breeders the allure of 'climate-hardy traits,' infusing genomes of modern crops with 'lost' genetic variety. Paradoxically, wild relatives themselves are endangered, propelling CWR into the limelight as an international conservation and food-security priority. I examine accumulation processes along two fronts: conservation policies, where *in situ* approaches, typically regarded as empowering alternatives to *ex situ*, instead may support appropriation; and breeding and biotechnology research, which produces new use values for CWR while profoundly shaping upstream conservation priorities.

My third and final paper explores the US-based Open Source Seed Initiative as one example of repossession. OSSI has created an alternative to intellectual property rights with a 'protected commons' for seed. Commons scholarship has contributed much on theories of institutional governance. But, I argue, attending to the practice of 'commoning' helps illuminate a more complex triad: *communities* who manage shared *resources* according to negotiated *social protocols.* Employing the metaphor of 'beating the bounds' – a feudal practice of contesting enclosures – I ask how OSSI defends the commons in intersecting arenas. First is legal, as OSSI negotiates a move from contract law toward moral economy law. Next is epistemic, as a 'freelance' breeder network revitalizes informal farmer-breeder knowledge, proving less structurally constrained than formal university breeders to lead commoning efforts. Third is seed sovereignty, as OSSI engages with global South movements whose diverse cosmovisions and seed cultures pose new challenges for constructing transnational commons.

I conclude by using spatial 'centricity' to conceptualize power relations in seed systems. CWR exemplifies 'ex-situ centric' flows of seed knowledge, power, and value away from local communities to centralized, often distant sites of recognizing and classifying diversity. Expertise is conferred primarily upon those scientists and industrialists who can produce commodity goods. By contrast, OSSI mobilizes breeder and farmer knowledge in a countervailing, 'in-situ centric' direction: towards local spaces, towards legitimizing farmer-breeders as knowledge makers. This movement, I conclude, is not merely an opposite force: it triangulates across three bases of 'emancipatory' action at the heart of agroecology, food sovereignty and commoning. Uniting politics of recognition (race, gender, identity), politics of redistribution (class and inequality), and politics of representation (democracy and citizenship), the question of seed diversity and access, I suggest, is ultimately a political one. It calls for recognizing diverse knowledge-makers, redistributing genetic resources as commons, de-centralizing seed reproduction to suit heterogenous agroecologies, and addressing base inequalities in power that drive dispossession.

This thesis is dedicated to

Inti Remko Montenegro de Wit – my brother.

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Acknowledgements

First, there are seeds
— whom I thank for your persistence, your coupling of knowledge and biodiversity, your grit.

Then, there are indigenous and peasant farmers
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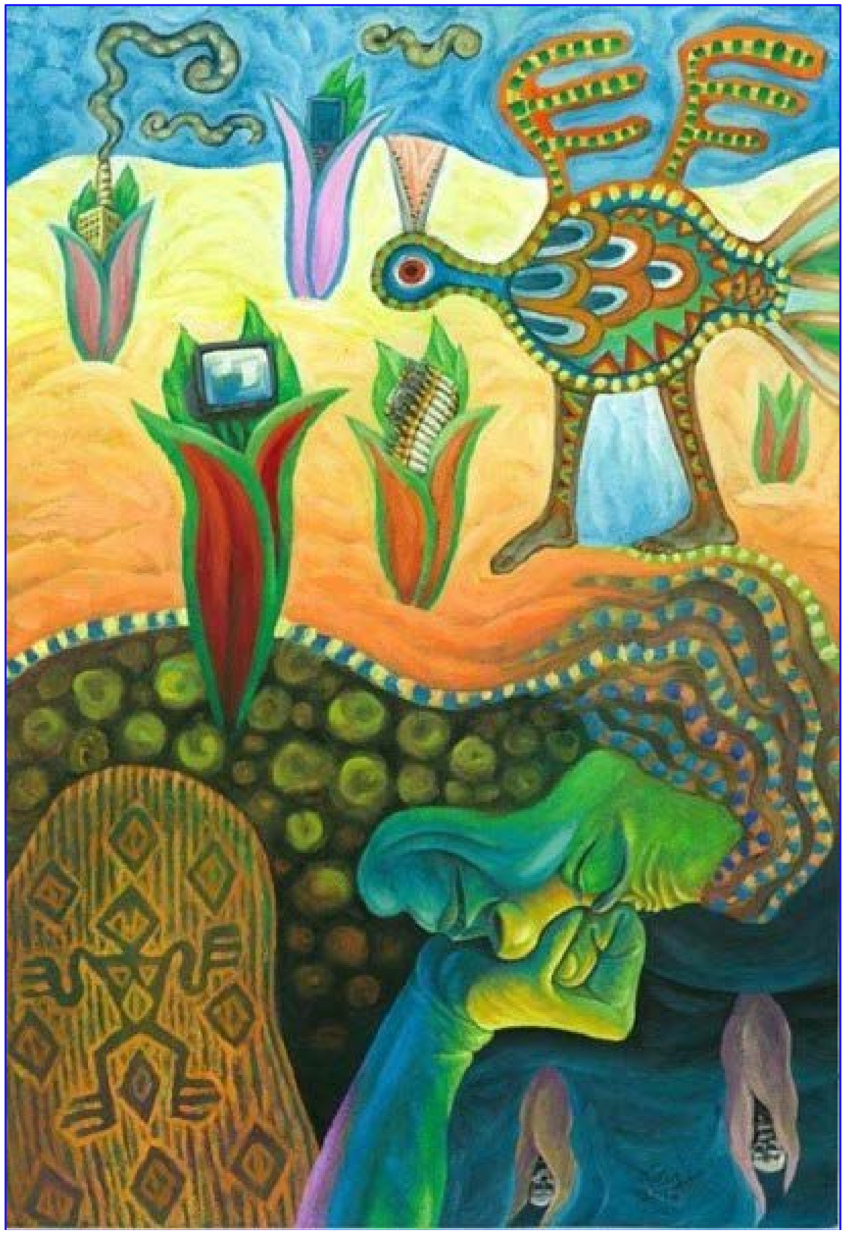

'Tagaynop.' Over the past 40 years, Filipino artist Federico Boyd ('Boy') Sulapas Dominguez has been creating works that put dispossession and repossession at the center of political art. As a Lumad Mandaya – an indigenous group on Mindanao Island – Dominguez is known for evocative illustrations of native peoples' experiences with landgrabbing, extractive mining, and corporate greed. Many of these have been used as cover art in *The Journal of Peasant Studies*. In the painting above, Dominguez portrays 'Tagaynop,' the Mandaya term for nightmare.
(Image credit: Boyd Dominguez)

Chapter 1

Introduction: Rethinking the Epistemic and Material Production of Seed Diversity and Access

Abbreviations

CGIAR	Consultative Group for International Agricultural Research
CRISPR-Cas9	Clustered Regulatory Interspaced Short Palindromic Repeats; CRISPR-associated enzyme
CWR	crop wild relatives
FAO	Food and Agriculture Organization
IAASTD	International Agricultural Assessment of Agricultural Science, Technology, and Knowledge for Development
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture ('International Plant Treaty')
OSSI	Open Source Seed Initiative
WTO	World Trade Organization

It is Spring, and seeds are sprouting – on farms and in the news. Hunched over her experimental plot in Madison, Wisconsin, Dr. Claire Luby examines a small pile of red carrots, the results of her latest breeding project. Free from intellectual property and bred for organic systems, these are some of the world's first 'open source' varieties. Eight thousand miles away in Odisha, India, hundreds of women gather to mark Earth Day with seeds; in support of *bija swaraj*, or seed democracy, these women promote biodiversity-based food heritage through agroecology, education, and more than 120 community seed banks. Meanwhile, in the Netherlands, a year-long International Tribunal has just concluded with a 'guilty' verdict, finding the seed industry giant Monsanto guilty on six counts of human rights and environmental violations. The same week, the European Patent Office announces its intention to grant a broad patent for the revolutionary CRISPR-Cas9[1] gene-editing technology to the University of California. DuPont, Monsanto, and Bayer have already begun purchasing CRISPR licenses and entering into strategic partnerships with both the UC and the MIT/Harvard Broad Institute, which holds a rivaling claim to the technology's intellectual property.

What unites these far-flung storylines is both old and new: These are 21st century seed wars, shaped by currents of dispossession and repossession, strategies of conservation and innovation, relatively new understandings of seeds as commodities, and comparatively old knowledge of seed as coevolving with soils, communities, spirits, and customary law. While the penetration of

[1] CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, and Cas9 is the 'CRISPR associated' enzyme. For readability, I will usually refer to the gene editing system as simply 'CRISPR.'

capital into agrarian relations has been extraordinarily varied worldwide, one element that unites all people is the imperative of seed. All farmers put seed in the ground; all workers rely on energy gleaned from seed reproduction. For centuries, and indeed most of human history, societies of many cultures and traditions have enjoyed relative freedom in sharing, exchanging, and reusing their seeds. This is no longer the case. Colonial appropriation, Green Revolution displacement, privatization of public research, seed industry consolidation, genetically modified crops, and the global imposition of intellectual property rights are all implicated in what Marx recognized as 'primitive accumulation' and what has been since been generalized as 'accumulation by dispossession' (Harvey 2003). One result is that increasingly many farmers today – no matter their scale, locale, or tradition – are confronting their seeds as commodities (Kloppenburg 2010). And yet against these forces of enclosure, new mobilizations of individuals and organizations are coalescing under the banners of seed freedom and seed sovereignty (Navdanya 2012). Foregrounding a bundle of rights – the right to share, to save, to replant, to research, to breed, to participate in shaping policies – such movements counter historical accumulation by dispossession with various strategies, practices, and narratives of seed repossession (LVC 2011, 2017).

Which of these tendencies will 'win out' begs for a subtler understanding of how loss of diversity relates to access to diversity. It calls for scrutinizing how enclosures are contested (or not) by different classes, sectors, movements, and organizations in civil society. It requires attention to the historical and relational interplay of genes, technology, and agricultural development within the neoliberalizing patterns of the past 40 years. It asks for curiosity about language, power, and discourse in the construction of breeding and conservation 'expertise.' It begs, in other words, for a political ecology of seeds.

In my dissertation, I ask: How can seed diversity – and access to it – be expanded once more? What *is* seed diversity in the first place, and whose diversity matters? Which forms and relations of science, governance, and politics engender democratic access to seeds, and which forms preclude it?

Domesticating seed: the production and loss of diversity

Historically, farmers have developed and relied upon a rich array of crop seeds to sustain themselves and their communities (Altieri and Merrick 1987; Zimmerer 1996; Brush 2000; Jarvis et al. 2008; Nabhan 2009; Bellon et al. 2016; Zimmerer et al. 2017). Surveys estimate that out of 250,000 plant species on Earth, roughly 7,000 species have been domesticated and used by humans since the origins of agriculture (FAO 1997; Bioversity 2014). Within these crops, the inter-species and inter-varietal diversity nurtured by human cultivators boggles the imagination. Bangladeshi farmers have developed an estimated 7,000 traditional rice varieties (Hussein 1994), while Peruvian growers have bred some 4,000 distinctive types of native potatoes (Argumedo 2008; Mann 2011). In the eastern United States alone, more than 7,000 apple varieties have been recorded in orchards from Maine to Tennessee (Fowler and Mooney 1990). The diversity of these organisms is a key part of the 'agrobiodiversity'[2] found in and around cultivated

[2] The term 'agrobiodiversity' denotes a multifaceted set of organisms and processes, including agricultural species and varieties, as well as non-cultivated organisms, ecological interactions among organisms, and patterns and processes across landscapes and over seasonal time (Jarvis ed. 2007).

landscapes[3]: Increasing farmers' environmental resiliency; buffering against volatile crop prices, sustaining an array of agricultural ecosystem services, providing nutritional quality, and serving as the basic genetic material for plant-people coevolution – in sum, the stuff of human enterprise and sustenance – are just a few of the well-documented benefits of seeds in all their variety (see Box 1. What is seed diversity good for?).

Yet with the rise of industrial agriculture, expanded international trade in crops and food, worldwide elaboration of intellectual property regimes, and, especially in the 21th century, consolidation of seed-chemical monopolies, crop diversity is in crisis. FAO and CGIAR data suggest that out of roughly 7,000 species domesticated in agrarian history, just *three* – rice, wheat and maize – now provide more than half of the world's plant-derived calories (FAO 1997, Bioversity 2014). Recent global studies indicate that only 12 crop species and 5 animal species provide 75% of the world's food today, reflecting a near 75% decline since 1900 in underlying genetic diversity in crops, across genera, species, races, and varieties (FAO 2010). Declines affect both Northern and Southern regions. In India, an estimated 110,000 traditional rice varieties were planted nationwide until the 1960s (Richharia and Govindasamy 1990)[4]. This agrobiodiversity, almost incomprehensible to modern agriculture, has been decimated by the introduction of Green Revolution hybrids, leaving only a few thousand varieties on marginal farms (Deb 2009). The story is similar in nearby Sri Lanka, where monoculture cropping has left only about 100 rice varieties, down from the 2,000 traditional cultivars tallied in 1959 (Groombridge 1992). In Mexico, high-value agroexport crops now occupy lands once richly populated with maize and associated agrobiodiversity (Wright 2005; González-Ortega et al. 2017), a transition matched only by China, where the FAO estimates that 10,000 distinct wheat varieties in use by farmers in 1949 collapsed down to less than 1,000 just three decades on (Heinemann 2017).

Europe and the US have seen similar erosions in crop and varietal diversity. Documented famously by Fowler and Mooney in a 1990 study of specimens listed by the USDA, records indicate 86% of the aforementioned 7,000 American apples are no longer cultivated, and 88% of nearly 2,700 pear types are no longer available in markets. Later studies by FAO corroborated these trends: Between the 19th and 20th centuries, some 95% of cabbage, 91% of corn, 94% of pea, 91% of tomato varieties appear to have been lost in the US (Heinemann 2017). In Europe, meanwhile, a landmark 1992 survey warned of 'devastating' agrobiodiversity loss wrought by simplified crop breeding strategies, commercialization, and international trade flows (Vellve 1992/2013, 53).[5] In the Netherlands, only four crops (sugar beet, potato, fodder maize, winter

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[3] Crop genetic diversity is a measure of phenotypic and genetic variance within individuals and populations of a given crop variety, species, or genus. Colloquially, most crops are recognized by names that belong to genus-level designations. For example, 'wheat,' 'corn,' and 'rice' are entire genera, *not* species or varieties, which can lead to some confusion when discussing agrobiodiversity change. For consistency (and unless otherwise noted), I use 'seed diversity' to mean richness and abundance of crop *varieties*, the level most frequently recognized by farmers and breeders.

[4] The only reliable data for Indian folk varieties and landraces are found in Richharia and Govindasamy (1990), who estimated that about 200,000 varieties existed in India until the advent of the Green Revolution. Assuming many of these folk varieties were synonymous, they estimate roughly 110,000 varieties were in cultivation (see also Deb 2009).

[5] Amassing data from public agronomic research institutes, gene banks, conservation organizations, and industry across Western Europe, this 1992 survey, conducted by the non-governmental organization GRAIN, acknowledged

wheat) are now grown on 80% of Dutch farmlands. In Greece, a region once home to a bounty of local wheat landraces developed in different climatic zones of the country, experts believe all but 5 per cent of this wheat heritage may be lost – mostly replaced, ironically, by a few 'ultra-modern varieties developed in Mexico' (Vellve 1992/2013, 33). Legumes and pulse crops have a particularly long cultural history in southern Europe: it is thought that rural Balkan growers selected white lupins for their pigment inhibiting genes 4,000 years ago (Zeven and de Wet 1982). Yet Northeastern Greece – Thrace and Macedonia – have been sites of severe genetic erosion of pulses, mostly due to overgrazing and wheat intensification. Horticultural crops have not been spared, as seen from studies of orchards in France, where 93% of France's apple production is dominated by a few imported varieties, mainly Golden Delicious from North America. Almond production, a source of pride and a local trademark of Mediterranean Spain and southern France, has almost totally converted to a few high-yielding varieties from California.

The upshots of these trends are manifold and complex, as they touch on farm, landscape, and food system scales. Farmers have become more vulnerable to climate change, pest, disease, and land use-change impacts, while landscapes planted in monoculture are associated with pesticide pollution, nutrient loading in freshwater and ocean systems, soil erosion, greenhouse gas emissions, and loss of pollinator, beneficial insect, and other wildlife diversity (Vitousek et al. 1997; Tilman et al. 2002; MEA 2005; Scherr and McNeely 2008). Human nutrition, meanwhile, seems to have pivoted toward more dependent on energy-dense foods – and foods that are significantly more similar. As detailed in a study in the *Proceedings of the National Academy of Sciences*, human diets on a world scale have become significantly more homogeneous over the past 50 years – an average of 36% more similar[6] – as the result of a few major grains crowding out regionally and locally important varieties (Khoury et al. 2014). The authors suggested that this increase in homogeneity worldwide 'portends the establishment of a global standard food supply,' which is relatively species-rich in regard to measured crops at the national level (thanks to global trade) but is species-poor globally (thanks to industrialized food).

As significant, and yet far more difficult to quantify, is the loss of cultural identities, livelihoods, and knowledges that can perish through and alongside the displacement, contamination, and/or substitution of seed. To be sure, the linear Green Revolution replacement story – where a few genetically uniform HYVs supplant multiple, heterogenous native varieties – has proven contestable. Decades of ethnographic research indicates that farmers often adopt modern seed types without relinquishing their traditional ones (Bellon and Brush 1994; Zimmerer 1996). Smallholders often employ mixed cropping systems and mixed marketing strategies, where indigenous crops are favored for domestic consumption while modern varieties provide revenue

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the sparsity of knowledge at hand – 'the general feedback was that no one knows with any great precision what has been lost.' At the same time, it surmised, 'lack of imagination should not replace the need to come to grips with the causes and magnitude of the problem.' Challenges in quantifying 'loss,' as I develop further in Chapter 3, include inconsistent names, assembling reliable on-farm use data, and measuring how genetically diverse the different varieties really are. When one look at wheat, for example, the extreme narrowness of the genetic base has troubled researchers for decades (Koenig et al. 1991). GRAIN authors also astutely surmised that 'diversity' in itself says little about the applications for which the diversity will be used (Vellve 1992/2013).

[6] Between 1961 and 2009, dietary homogeneity increased by 16.7%, as measured by the mean change in similarity between each country and the global standard composition, with a maximum (single-country) change of 59.7%. Likewise, mean among-country similarity increased by 35.7% (Khoury et al. 2014).

from commercial sale (Brush 1991; Bezner-Kerr 2010, 2014). Farmers are also adept in interbreeding modern and landrace varieties to make creolized seed, mestizo seed, and other vernacular types (Aistara 2009; Delgado and Rodríguez-Giralt 2014). Such mixing can add new local variety without displacing old, can engender inter-local creolized uniformity, or can add diversity of type but affect abundance ratios by reducing acreage devoted to indigenous crops and occupying the best of fertile, non-marginal lands (Ortega-Paczka 1973; Wright 2005). These dynamics are further confounded by *knowing* diversity. Identity is an issue, as some landraces go by dozens of names, while same-named seeds can be genetically distinct. Scales of observation also affect outcomes, as diversity can be counted per farm, per farmer, per village, in terms of local (alpha) diversity or as a measure of turnover in between (beta diversity). Who is measuring diversity is significant, as farmer-names, phenotypic traits, chemical markers, and DNA fingerprints can all be used to classify seed (Jarvis et al. 2011; Orozco-Ramírez and Astier 2016). What 'we know' about agrobiodiversity loss is seldom clear-cut, as I explore in Chapter 3.

What we are beginning to understand, however, is that informal seed systems around the world are essential to the reproduction of global seed diversity. A 'seed system' is composed of individuals, networks, institutions and organizations involved in the development, multiplication, processing, storage, distribution and marketing of seeds (Maredia and Howard 1998; Loch and Boyce 2003; Dominguez and Jones 2005). Scientists often distinguish between 'informal' and 'formal' seed systems (Almekinders and Louwaars 1999), with formal systems comprised of public institutions and private industry engaged in scientific plant breeding, and informal or farmers' systems dependent on farmers' knowledge and customary law. While newspaper headlines justifiably focus on the growing corporate control of the seed supply – the mergers of Monsanto-Bayer, Dow-Dupont, and Syngenta-ChemChina heralding unprecedented market power – it is worth noting that these percentages refer only to commercial seed, within formal systems.

Meanwhile, the continued importance and relevance of informal seed systems is tough to exaggerate. Many, if not most, rural communities in developing countries continue to use traditional or informal sources to meet most of their seed needs (Almekinders et al., 1994; Tripp 2001; Muthoni and Nyamongo 2008). It is estimated that between 60 and 100 percent of seeds planted in the Global South are farmer-produced and farmer-exchanged, depending on the crop and country (Louwaars 2002). In Latin American and Caribbean nations, FAO data suggests that about 75% of seeds used are supplied through local or 'informal' seed systems (Santilli 2012). In Africa, the figure ranges between 80 and 90 percent in some countries, despite current pressures from Western donor governments, foundations, and multinational seed companies to integrate smallholders into commodity markets (Wise 2016). New census data released in 2015 indicates that as much as 75 % of global seed diversity in staple food crops continues to be held and actively used by a wide range of smallholders, many of them women. In regions spanning peri-urban locations to remote rural areas, this data suggests, smallholders form patchy networks of low- and high-diversity growers, with the latter connected through seed- and knowledge exchanges. 'They're creating many new or so-called emergent agrobiodiversity systems rather than strictly relict or vestigial hold-overs of heirloom crops as is often depicted from the outside,' explains Zimmerer (Penn State 2015). Taken together, argue Almekinders and Louwaars (2008, 15), 'The farmers system of seed supply and crop development form by far the most important source of seed in most farming systems of the world.'

Situating Seed: a literature review

Over the past 40 years, seemingly competing approaches to the challenge of crop genetic erosion and diminished access to seed have appeared in farm and food policy. On one hand, a 'conservation' approach has been instrumental in forging policy and practice framed around regimes of ex situ (offsite) and in situ (in place) strategies of agrobiodiversity protection. International agricultural science institutions have been central to this approach, in particular the Food and Agriculture Organization (FAO), the Consultative Group of International Agriculture Research (CGIAR), Bioversity International, and foundations including the Bill and Melinda Gates Foundation, the Rockefeller Foundation, and the Global Crop Diversity Trust. On the other hand, an 'access' approach has pitted intellectual property regimes such as the World Trade Organization and European Union for the Protection of Plant Varieties (UPOV) against their antagonists in the form of polyglot and decentralized movements – from local seed exchanges to the transnational La Via Campesina – for seed sovereignty and repossession. Corporations, sovereign states, and philanthropy capital are influential in both arenas, funding, legitimizing, and lobbying for conservation and property regimes that favor their interests. Most previous research and practice has dealt either with conservation or with access, separating loss of diversity from loss of access to it.

My method for interrogating entwined problems of diversity and access is to grapple with a set of dualisms that have emerged in the scholarship, discourses, practices, and institutions that surround seed diversity. Narratives of 'rampant genetic erosion' are contrasted with narratives of 'peasant seed persistence.' Policy debates occur over 'in situ' and 'ex situ' development pathways. Tensions play out between 'formal' and 'informal' seed systems. Such debates define and frame our dominant understandings of seeds in the world. They exist 'for real' as prominent discourse in science and policy. However, these dichotomies are artificial and downright paradoxical in many ways: ex situ conservation is intrinsically unsustainable, long-term, without in situ breeding to replenish its stores. Crop genetic erosion is driven by agricultural modernization yet is discursively used to appropriate endangered species from their endogenous communities and landscapes. Formal and informal seed systems are widely understood to coexist, but seldom are disparities in distribution pointedly acknowledged and explored.

One way of unpacking these questions comes from classic agrarian political economy ideas: who owns what? who does what? who gets what? what do they do with the created surplus wealth? (Bernstein 2010) Kloppenburg's seminal work, *First the Seed*, largely took this approach when charting a political-economic history of plant breeding, 'from 1492 to the present.' The historical transformation of seeds from a public good (reproduced by farmers) into a commodity form (purchased by farmers), Kloppenburg proposes, is driven by three interacting trends: (1) progressive biological and legal enclosures of seed; (2) elaboration of a social division of labor between public and private plant breeding, and (3) asymmetries in global patterns of seed commerce and exchange between the less developed countries of the South and the advanced industrial nations of the North.

Inspired by this work, I build upon the story of seed where Kloppenburg leaves off – in a 21st century ecosystem where gene sequencing, CRISPR editing, 'Big Data', and GIS all enable new geographic and genetic sites of appropriation, in turn propelling intellectual property into expanding spatial, social, and biological spheres. The progressive commodification of the seed, I argue, is carving out new enclosures territory, including where climate change and drought are encouraging the collection and exploitation of crop wild relatives with stress-hardy traits (Chapter 3). Divisions of labor between public and private breeding remain deeply entrenched, but they are overshadowed today by a reversal of sorts: in the 'public-private partnerships' that increasingly link the academy to agribusiness in subordinating and extractive relationships (Chapters 2 and 5). Finally, asymmetries in North/South germplasm flow endure as the historical backdrop against which today's seed repossession struggles must be understood, and in which they are deeply rooted. But global seed sovereignty movements are also forging new transnational connections, and in some cases, Northern-inspired commons are helping Southerners reclaim their appropriated and displaced heritage (Chapter 5).

The political economy account of each of these trends is integral and necessary to my story. Yet this lens is insufficient for understanding how the scientific, legal, and political forces which constrain or delimit *access* relate to the question of seed *diversity*, biological and cultural. A troublesome gap persists in the literature. Partly it reflects the rural sociology and law bases of much work on seeds, where the implications for biodiversity at gene, organism, and ecosystem scales is seldom part of the methodological toolkit (Kloppenburg 1988/2004; Aoki 2008; Timmerman and Robaey 2016). Partly it reflects the historical tendency of conservation sciences to underline the proximate, rather than ultimate, drivers of agrobiodiversity loss (Thrupp 2000). Mainstream accounts more readily pin the blame for crop genetic erosion on local ignorance and farmer ineptitude (degrading land-use practices, improper technologies) and on anomic 'natural' tendencies of humans and ecosystems (shifting dietary preferences, urbanization, natural disaster, and human conflict) (van de Wouw et al., 2010).

The subdiscipline of agrobiodiversity studies is one of the few areas that has begun to fill in the gap between seed diversity and access to it. Reviewed by Jarvis et al. (2011) and Patausso et al. (2012) these studies illuminate the ways in which availability of and access to genetic materials – preconditioned by access to adequate land, income, and social connections – lead to traceable patterns in diversity, both within and among traditional varieties, and over time in larger patterns of biodiversity (Hodgkin et al. 2007). Diverse seed sources (eg. friends, relatives, neighbors, and local markets), modes of seed transfer and exchange (gift, barter, farmer-extension, commodity purchase), and scales of exchange (local, regional, international) all produce particular dynamics of movement and mixing that shape seed biologically. In parts of Peru, for instance, most seed exchange of maize, cassava, peanut, chili peppers and cotton, has been shown to occur within rather than among the communities. By limiting gene flow between communities, this relative isolation can contribute to reduced local (or 'alpha') diversity; on the other hand, it can enhance the degree of difference *between* communities, a quotient of 'beta' diversity. Analyses of social seed networks indicate that exchanges tend to concentrate at farmer-to-farmer and community scales, but can also span extensive distances across nations and ecosystems (Patausso et al. 2012; Poudel et al. 2015). Movements and migrations notwithstanding, peasant seeds also *reside*. Several studies show that, in most situations, smallholder farmers prefer to save their own seed (Gildemacher et al. 2009; Hodgkin et al. 2007; Lipper et al. 2010).

Social and kinship networks also affect diversity by configuring differential access to seeds. Heritage and identity, for example, can be advanced when a traditional variety is acquired from someone who is a relative or an elder in the community (Meinzen-Dick and Eyzaguirre 2009).

These social seed networks are deeply dependent on gender, wealth, and age (Morales-Valderrama and Quiñones-Vega 2000; Howard 2003; Lopez 2004; Rana et al., 2007), with varying effects in different parts of the world. In Ethiopia, for instance, female heads of household evidently grow more evenly distributed wheat varieties (Benin et al. 2006), corroborating much literature showing that women are more likely to grow more traditional varieties than men (Gauchan et al. 2006; Edmeades et al. 2006; Benin et al., 2006). But research from Nepal has found no significant effect from gender (Subedi and Garforth 1996). Income status cuts across these findings, given that poor women often have less access to finance, markets, technologies, education systems, thus inhibiting ability to diversify (Vernooy and Fajber 2004).

These agrobiodiversity literatures have taken an important step towards a finer-grained analysis of the choices and constraints farmers face. Trust, for example, has been shown to be a key factor in decisions over which seeds to acquire (Howard 2003; Kruijssen et al. 2009). Communication is key too, Bela et al. (2006) have suggested, in order to improve understanding among stakeholders about tradeoffs between public attributes – such as nutrition and taste – and profitability. Enhanced marketing, according to several authors, could enhance both diversity and access: by increasing the market value of agricultural production, differentiating high-value products, promoting access to processing equipment adapted to diverse raw materials, and building trust among market chains suppliers (Di Falco and Perrings 2006; Giuliani 2007; Lipper et al. 2010).

However, within the spectrum of solutions-oriented texts, several buried epistemologies linger. Improved understanding of 'tradeoffs' already presumes an economistic perspective, in which individuals make rational decisions based on costs-benefit comparisons. Better marketing for agrobiodiverse products warrants serious attention, but context is all-important. The marketist logic of supporting claims often neglect forces that condition contemporary agricultural heterogeneity – or lack thereof: alterations in land tenure systems that threaten the survival of traditional farming communities; subsidy schemes that promote exclusive adoption of uniform commodities; and research programs that neglect traditional varieties and associated knowledge and uses. They seldom deal in historical transitions in food regimes to the current neoliberal moment, or in the dovetailing of food safety standards, marketing rules, and intellectual property laws that limit entry of traditional farmers' varieties into markets. The solemnity and confidence of the best of institutional agrobiodiversity texts makes it awfully hard to see what is unwritten – where technocratic language absent of power, race, gender, and inequality construct prevailing discourses that have come to shape the modern seed.

Here, scholarship by political ecologists has begun to stitch access and diversity into a more critical and colorful pastiche. A multi-disciplinary field that seeks to unravel the political forces at work in environmental access, management, and transformation, political ecology (PE) assumes as a starting proposition that 'politics are inevitably ecological and ecology is inherently political' (Robbins 2011, 3). As such, political ecologists of agrobiodiversity have carried forward Sauer's early impulse out of environmental determinism into contemporary analyses of: (1) nature and society as co-evolved forms (Castree 2014); (2) local problems as traceable through higher order chains of explanation, specifically to broader political economy structures (Blaikie and Brookfield 1987); (3) control over and access to resources as 'defined, negotiated, and contested within the political arenas of the household, the workplace, and the state' (Peet and Watts 1993, 239).

Although it is possible to distinguish amongst political ecologists whose focus is material relations of access to natural resources and those who attend more to knowledge production and epistemic relations, what they share in common, I suggest, is an ontological commitment to de-naturalizing that which seems normal. Attuned to the dispossessed, marginalized, and disenfranchised, PE offers approaches that upend dominant 'a-political' renderings of scarcity, over-population, and ignorant local resource managers. Instead the political ecology lens stresses not only that ecosystems are political but that our *very ideas* about them are defined by and filtered through political power, cultural habit, and social customs. Implicit in this understanding is the further radical provocation: that human and non-human systems cannot be meaningfully prized apart. If on one hand, political ecology pulls the veil from 'inherent natural laws of society' seen in orthodox economics, it simultaneously disturbs dichotomous accounts of 'nature and people' found in classical ecology. It finds, instead, more meaning in 'nature *in* people' – where humans are concatenations of microbes and sugars and metabolic flows[7] reaching inward and outward – and 'people in nature,' in which humans are but one type of organism in larger biophysical communities, and where 'pristine nature' untouched by women and men is seldom more than a convenient colonial imaginary.

Thus, the complex co-mingling of knowledge, power, people, and environment is, for me, the foundation of political ecology upon which my seed story builds. Rather than describe undifferentiated problems of seed diversity and seed access, political ecology pulls us into a more generative project of attending to the production of diversity (for whom, by whom, on whose terms?), knowledge about diversity (how measured, evaluated, described?), and how social 'value' (in economic and cultural terms) comes to be imbricated in the material stuff of seed. With these tools, it becomes possible to explore more fruitfully how access to seed plays out over constitutively uneven terrain. Or, as Robbins memorably puts it, 'the sloped surfaces and tilting fulcrums of uneven power that control the flow of value from the environment and exact the terribly price of accumulation, within the shifting systems of political economy that perpetuate both' (Robbins 2011, 88).

Over the past twenty years, scholarship on what peasant and indigenous peoples *know* and *practice* has gathered momentum, swept in perhaps most clearly with Zimmerer's (1996) and Brush's (1991, 2000) work on biodiversity and peasant livelihoods in the Peruvian Andes. Extending from earlier ethnobotany, Zimmerer and Brush looked extensively at indigenous peoples as active experimenters whose traditional knowledge is threatened by many exogenous forces, but is also skillfully conserved on a 'de facto' basis – and may not be as hopelessly endangered as widely believed. In parallel, critical accounts have sought to de-essentialize

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[7] While the concept of 'metabolism' has long been used in biology and biochemistry, Marx and Engels were likely the first to apply it to social systems (Foster 1999). Anticipating modern-day complexity theory, they described interdependent social-ecological systems in which energy, nutrients, and matter constantly flow between humans and their environs – all elements mutually transformed through the social deployment of human labor. The onset of large-scale industry and agriculture, they believed, would disturb this metabolic connection, principally by cleaving the cyclical return of nutrients to the soil.

indigeneity. Agrawal (1995), Richards (1985), Berkes (1999/2017) and others point to asymmetries of knowledge and power within many indigenous societies, false dichotomies between indigenous knowledge and Western Science, and ongoing hybridizations of traditional and other knowledges, such that 'ancient' wisdom is continually made new. Balancing the critical and celebratory trends, Nazarea and Rhoades developed a participatory-action line of seed research in the US and global South (1999, 2006, and 2013). Looking beyond institutional, 'planned' conservation, they foregrounded the role of memory in anchoring many prosaic, spontaneous, and lived practices of 'everyday resistance.'

Like Nazarea and Rhoades, Carney (2001) deeply understood that seeds – and seed knowledge – *travel*. Since the 1930s work by Soviet scientist Nikolai Vavilov, people have come to a better understanding of the mass re-spatialization of seeds that has occurred since early domestication, with some 150,000 species radiating outward from roughly 20 centers of origin and diversity (see Figure 1). In the 1970s, Crosby sharpened the political ecology of such diffusion in the context of environmental change, colonization, and imperial control of the New World. During the 'age of exploration,' tens of thousands of plant species traveled the world as 'portmanteau biota,' a mutually supporting phalanx that advanced across the neo-Europes of Australia and the Americas, displacing native species, native populations (through disease epidemics), and supporting the coercive efforts of human occupation. But while prior deterministic accounts had suggested that Europeans came to dominate *because* their ecologies allowed and encouraged it, Crosby came to a subtler conclusion: The simplification of New World ecosystems, he argued, was the result of two waves of human invasion: First, the arrival of indigenous peoples (Amerindians, Maori, Aborigines) who began modifying the landscape through hunting and fire which simplified the native ecology. Second, the wave of European colonists and Old World species whose advance was now made possible because of prior simplification (Robbins 2011). In other words, 'advanced whites' did not triumph over 'inferior' indigenous people.

In many ways, Carney picks up where Crosby left off, arguing in *Black Rice* for a revisionist reading of colonial plantation history. Spanning scales from farm plot to intercontinental Columbian exchange and sweeping roughly 500 years, she gathers evidence to support a central concern: elevating West African knowledge systems to their rightful place in the historical record, as the crucible of rice cultivation in the Atlantic basin, and central to the making of American agrarianism.[8] Black rice, Carney contends, is fundamentally about black people and black knowledge – in particular slave women who carried and cultivated seeds. Bought and sold as property by elite men on both sides of the Atlantic, Black women nonetheless managed to transfer a complex knowledge system of *O. glaberrima* cultivation to the Carolina piedmont in

[8] Relying on accounts left by ship captains, slavers, merchants, naturalists, and other early European travelers to Africa's Rice Coast, Carney depicts complex systems of West African rice growing that made use of tidal floodplains, inland swamps, and rain-fed uplands with an array of techniques and practices attuned to specific microenvironmental and climatic conditions. Black slave women managed to transplant this complex system of rice knowledge to Carolina farms in the 1800s, where they helped sow the foundations of US plantation agriculture, while also using their prowess as a bargaining chip: to negotiate for provisioning gardens and better labor conditions for their disenfranchised people. *Oryza glaberrima*, she also shows, is a distinctive species from the more common Asian *Oryza sativa*, indicating rice has more than one biological and knowledge center of diversity.

the 1800s, bringing foodways, ecological memories, and agronomic practices to *re*ground their rice in a new place.

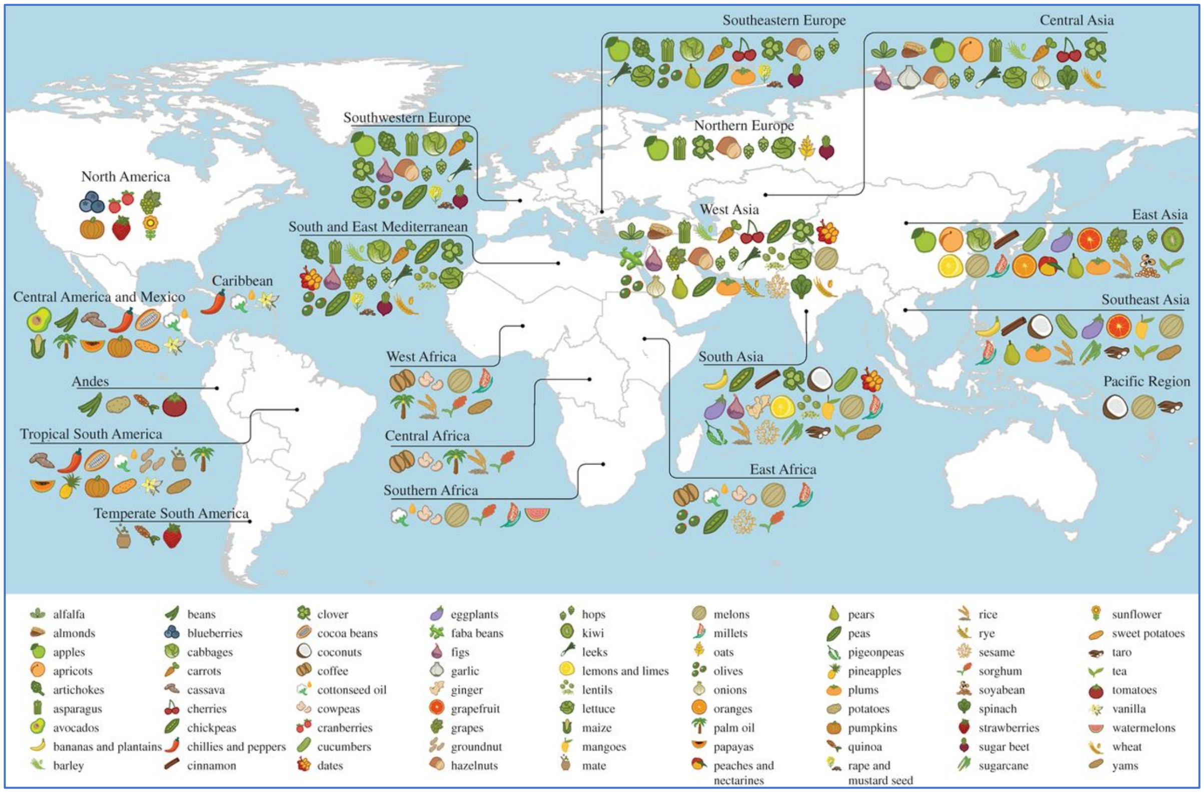

Figure 1. A World of Agrobiodiversity. Recent research by Khoury et al. (2016) identified primary regions of diversity of agricultural crops across the world's tropics and subtropics, extending into temperate regions in both hemispheres. Over a century ago and building on extensive travels across 5 continents, Russian scientist N.I. Vavilov proposed 8-10 'centers of origin' as independent regions where initial domestication was assumed to have occurred, as he found traditional varieties for a wide range of crops, alongside their wild relatives (Harlan 1951; Pringle 2008). Since that time, linguistic, archaeological, genetic and taxonomic information has contributed to many debates over the number and types of these agrobiodiversity sites. The term 'centers of diversity' has come to be preferred over 'centers of origin,' in recognition of the fact that high concentrations of crop varieties and related wild species are not always co-located in sites of original domestication. Radiation of crops outward from their primary centers of diversity has also given way to 'secondary centers of diversity.' This 2016 study uses ecogeographic data to analyze 23 primary regions of diversity, defined as sites 'of the initial domestication of crops, encompassing the primary geographical zones of crop variation generated since that time, and containing relatively high species richness in crop wild relatives.' The resulting map, shown above, indicates centers of diversity for 132 crops in production data and 53 crops in food supplies data.

In turn, a younger generation of political ecologists have continued to deepen seed studies as part of race, environmental justice, STS, feminist, and postcolonial theory. A notable (though hardly comprehensive) selection considers: kinship relations and seed access in Estonia and Costa Rica (Aistara 2009); the criminalizing effects of certification and standardization on informal seed systems in the Global South (Wattnem 2016); and participatory action analyses of rural subalternity and 'seed swaps' in forging US South seed sovereignty (Campbell and Veteto 2015).

Works from Appalachia, a hotspot of agrobiodiversity, have contrasted rural marginality and mountain diversity in cases of Kentucky and Peru (Graddy 2013). They have documented Southern foodways and slave histories (Edge 2017; Twitty 2017), and the place-based recovery and use of Appalachian heritage in efforts to conserve seeds, farming, and culinary traditions (Veteto and Nabhan 2011). Technology has been a site of much agrobiodiversity inquiry, principally seen in studies of genetic engineering. Recent research has traced the complex and contradictory dynamics of 'farmer wisdom' (Stone 2007), provided revisionist histories of biotech success (Patel 2012; Kinchy 2012); and developed the concept of 'rice worlds' to describe how 'more than mere seed types,' different types of seed – hybrid varieties, transgenic golden rice, and heirlooms – can be 'at the center of distinctive concepts of what the crop should be and how it should be produced' (Stone and Glover 2016).

Now that we have reviewed the extant seed literature, I turn to sketch my analytical framework, extending from Kloppenburg's *First the Seed* with political ecology's insights into dispossession/repossession, knowledge politics, and co-production of science, technology, and social order.

Sowing a political ecology of seeds

While groundbreaking, *First the Seed* left underexplored many aspects of seed dispossession that political ecology helps to illuminate. The Marxist framework offered by Kloppenburg helpfully situates seed in the context of classical agrarian questions: What makes agriculture resistant to capital? How does capital transform the structure of agrarian relations, and conversely, how does agriculture contribute to the development of capitalism as a whole? In answer to these questions, we first encounter the uniqueness of the seed as a means of production and re-production: for at least 10,000 years, the natural biology of seeds had given farmers a social system for saving and replanting. If capital was to successfully penetrate agriculture, then, some means of overcoming this obstacle, of breaking this reproductive cycle, would be necessary. A second obstacle to capital penetration was the state. For decades, the state in various forms – the land grant university complex, the Agricultural Research Service, the US Department of Agriculture – served as a rival to industry, and a competitor in a singular niche for marketable plant products. These processes of 'enclosure' define the arc of biotechnology innovations and state formations that give rise to hybridized seed, intellectual property, and emasculation of public sector research by an increasingly powerful commercial agribusiness complex.

What this account leaves open, however, are (1) the countervailing forces of **repossession** continually opposing, obstructing, and/or slowing primitive accumulation; (2) the **knowledge politics** of seed production and seed science; and (3) the myriad ways that seed-related institutions, markets, discourses, governance, and social order are **co-producing** each other. Science, technology, and law are seen to coalesce in critical ways to the advantage of capital. But we are left to be curious about the cultural practices – among scientists, farmers, indigenous peoples, policymakers – that shape seed as a social product, the historical twining of institutions and economic logics; and the environmental politics in which 'science, traditional knowledge, risk, and property rights are contested, fought over and negotiated' (Watts 2000).

My dissertation began, then, as an attempt to graft the epistemic, constructivist, and discursive lenses of political ecology onto the territory of 21st century seed enclosures. I wanted to ask: How might these changes in access affect crop diversity? What *is* seed diversity in the first place, and whose diversity matters? Which forms and relations of science, governance, and politics engender democratic access to seeds, and which forms preclude it?

Dispossession/repossession

This gave rise, in the first instance, to a recognition of enclosures as dialectically[9] related to struggles for repossession. The past 100 years have seen progressive appropriation of seed and accumulation of value in the form of hybrids, agro-chemical packages, licenses, patents, trade secrets, and other forms of intellectual property. The few mega-corporations that control seed IP are in 'a unique position to valorize other inputs' (Lewontin 2000, 98), thus exerting influence and accumulating wealth across the broader agri-food sector by controlling a lynchpin in the system. Against this oligopoly concentration, however, civil society organizations and farmer movements are mobilizing anti-trust suits, Monsanto Tribunals, and everyday forms of 'plant back' resistance. Indeed, for each movement and moment of dispossession, it is possible to trace and analyze a historically contradictory countermovement: a farmer, scientific community, or transnational organization engaged in struggle to repatriate, reclaim, and repossess. In ways both planned and quotidian, such contestations define the broader terrain of 'access' over which today's seed wars are waged. Seeds also have much to say about science as it relates to colonialism and capitalism. This 'long arc' of dispossession/repossession is treated further in Chapter 2.

Commons is one expression of repossession that has galvanized progressive and radical movements in recent years, particularly since the Seattle anti-WTO protests of 1999. Defined as social or natural resources not owned by anyone, but over which a community has shared and equal rights, the commons goes back many centuries in agrarian history, their enclosures marking a crucial juncture in the transition from feudalism to capitalism (Thompson 1971). Indeed, Marx believed, the only way to speak of the origins of industrial capitalism was in the 'letters of blood and fire' used to drive workers from their common forests, wetlands, and farmlands (Marx 1977, Caffentzis 2013). But while such 'primitive accumulation' was once viewed as a one-time historical phenomenon – the Big Bang at the birth of a new economic order – it is now widely understood as structurally necessary for the ongoing reproduction and expansion of capital, producing both 'ex novo' separations on the peripheries of Empire and re-

[9] Dialectics simultaneously describes a way of thinking through a problem – a mode of argumentation or conceptualization – and a theory about inherent contradictions in society under capitalism. As a mode of argument, dialectics holds two seemingly opposing forces to be interdependent, co-constituted, and productive of emergent properties that are greater than the sum of their parts. It therefore animates a particular way of thinking through internal relationships between conceptual categories. In the Marxian tradition, dialectics is descended from Hegel through Marx and refers to an empirical historical engagement with societal contradictions. A nutshell definition I like is: 'development through contradiction' (Robbins 2011).

separations in the hearts of metropoles. Much scholarship has expanded the purview of such 'primitive accumulation,' underlining its ongoing character (Perelman 2000), exploring the gendered dynamics of *re*-production (Federici 2004/2014), and generalizing the conceptual purchase of enclosures across mindscape, landscape, and genescape (Harvey 2003, De Angelis 2004, Kloppenburg 2010).

Struggle remains at the heart of primitive accumulations, old and new. Indeed, De Angelis suggests, what distinguishes the 'primitive' from the 'run-of-the-mill' accumulation – is not merely the extra-economic exploitation. It is the element of social struggle. As long as society accepts 'capitalism's requirement as "natural laws,"' accumulation does not need primitive accumulation (De Angelis 2004, 15). But when confronted with struggle, 'a refusal of subordination to the "ordinary run of things,"' (ibid) – indeed, any '"rigidity" for furthering the capitalist process of accumulation,' (ibid, 14) – capital demands the forcible separation of people from production, of labor from its means. In this move, De Angelis underscores how sites of primitive accumulation can be identified not only where capital encroaches into new terrains, but where social and political counter-movements are vying to *re-appropriate* the commons, to reverse historical enclosures of land, life, and law. The insights here are simple but critical: Places and spaces of historical accumulation announce themselves at active sites of contemporary social struggle. By extension, primitive accumulations become a forecasting tool, as we can anticipate capital will again move to dismantle barriers wherever people have made social gains.

I add to the burgeoning 'new commons' (c.f. Hess 2008) literature by looking at commons as a biocultural form, specifically in relation to seeds. Whereas scholarship now recognizes both social and natural commons, they are often treated as discrete types of 'resources' rather than as living elements that entangle cultural, ecological, epistemic, and political categories. In addition, the emphasis has been primarily on rules and institutions of resource management, following the principles of a well-governed commons (Ostrom 1990). My argument is that seeds, while certainly germane to institutional governance research, shed light on the politics and practices of building alternative modalities of social and economic life. In re-taking access to means of biological and social reproduction, people reclaiming seeds provide entree into how primitive accumulation can be dismantled from the inside out. I consider, in particular, how farmer-led practices of making new varieties – or plant breeding – are generating new models for property rights (or abandoning 'property' altogether), redefining rules for shared access and use, and inculcating norms of cooperation, reciprocity and moral economic decision-making that subordinate capital to negotiated social values.

Knowledge politics

The second recognition I had was that considering knowledge politics can expose unseen parts of the seed story: how science and technology facilitate both primitive accumulation (chapter 4) and the formation of hierarchies of knowledge-makers, from farmers to public breeders to industry technicians (chapters 3 and 5). In constructing discourses of modernization, dominant actors in the food system have long defined a powerful field of knowledge making and use. Just as seeds are historically inseparable from farmers' (re)productive rights, seed are irreducible from science and industry: from the ways in which research institutions and agribusinesses have come to control whose knowledge shapes the form and function of seed. As certain 'productionist'[10] knowledge has become more privileged and embedded into research infrastructure and agri-food regimes[11], other knowledge— women's knowledge, peasant knowledge, indigenous ecological knowledge —have begun to lose social value and apparently 'disappear.'

No other history captures the concept of knowledge politics quite like the Green Revolution. At the height of the Cold War, 'improved seed' – sponsored by international aid agencies, developed by crop-breeding science, backed by multinational agribusiness capital, approved by national governments, and promoted by armies of trained extension workers – arrived in villages from Mexico to India to the Philippines 'carrying the aura of science and modernity' (Yapa 1993, 264; see also Jennings 1999, Shiva 1992, Wright 2005, Cullather 2010).

In retrospect, liberal 'diffusion-innovation theory' failed to account for adoption of seeds driven less by individual farmer pluck than by stark asymmetries in access to land, to capital inputs, and to cultural legitimacy. The magic of Green Revolution seeds now appears to have been only marginally about exceptionally high yielding crop genes.[12] As the US and private philanthropers moved to stanch restive peasants in Asia and agrarian reformers in Mexico with a 'Green' alternative to the 'Red Revolution,' the export of American-style agriculture was resolutely geopolitical (Cleaver 1972; Hewitt de Alcántara 1974; Fitzgerald 1986; Perkins 1997; Cotter 2003; Patel 2012).[13] High-yielding seeds were widely touted as 'scale neutral' – that is, of equal benefit to small- and large-scale farmers (Hazell et al. 2010). Yet, as much subsequent research has shown, only a fraction of that productivity was attributable to advanced genetics and breeding (Evenson and Gollin 2003). The rest came from heavy applications of fertilizers and

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[10] As Fred Buttel (2005, 276) explains, productionism is 'a doctrine that increased production is intrinsically desirable and that all parties benefit from increased output.' The ideology is also nothing new. A 'productivist coalition,' Buttel says, was already influential in the compromises that surrounded the founding of the Land Grant University system in the late 19th century. Among 'elites of several key institutions – farm commodity groups, land-grant administrators, agribusiness firms, and federal agricultural agencies – there was basic agreement that the underlying goal of research was 'to increase agricultural productivity, to enable progressive farmers to modernize their way out of their problems (as opposed to seeing populism and socialism as attractive alternatives).'

[11] I use 'food regime' here in the sense of Friedmann and McMichael, who in the 1980s and 1990s developed the concept of a 'food regime' as a 'rule-governed structure of production and consumption of food on a world scale.' (Friedmann 1993, 30–1).' Key to regimes analysis, notes McMichael (2009), is the act of historicizing the food system – and doing so at a global scale: 'problematising linear representations of agricultural modernisation, underlining the pivotal role of food in global political-economy, and conceptualising key historical contradictions in particular food regimes that produce crisis, transformation and transition.' Food regimes analysis has been especially influential in explaining how particular relations of food production and consumption are central to the functioning and reproduction of global capitalism (Holt-Giménez and Shattuck 2011).

[12] According to Pingali (2012): 'Whereas HYVs of wheat provided yield gains of 40% in irrigated areas with modest use of fertilizer, in dry areas, gains were often no more than 10%. Almost full adoption of wheat and rice HYVs had been achieved in irrigated environments by the mid-1980s, but very low adoption in environments with scarce rainfall or poor water control (in the case of rice) had been achieved. In India, specifically, adoption was strongly correlated with water supply. Worldwide, improved seed–fertilizer technologies for wheat were less widely adopted in marginal environments and had less of an impact there than in favored environments.'

[13] The term 'Green Revolution,' Patel (2012) explains, was coined by William Gaud 'late in its unfolding, at a meeting of the Society for International Development in DC in 1968, in which he described what had happened as a result of US and philanthropic funding for fertilizer, irrigation, improved hybrid seeds, state support and credit: *These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violet Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution.* (Gaud 1968)'

chemicals, from irrigation, and from the money or credit by which to afford these inputs. The fact that high-yielding varieties were particularly bred to flourish under conditions of high irrigation further advantaged better resourced farmers, who tended to have landholdings in flat, irrigated plains as opposed to poor farmers who tended to farm more marginal, hillside landscapes. The resulting dynamic, explain Mazoyer and Roudart (2006), was high barriers to entry that invariably advantaged the better capitalized growers, widening existing social inequality. In other words, as Harris (1988) and Bernstein (2010) argue, we should not confuse scale neutral with 'resource neutral.'

In confronting peasant farmers living in their 'traditional culture of poverty' (Rhoades 1984), Green Revolution seeds also 'succeeded' by alienating indigenous cultural identities. Introduced by local/native agronomists who had trained abroad at US land-grant universities, the seed technologies at once symbolized scientific progress while refracting indigenous knowledge in contrasting shades of primitiveness, ignorance, and racially inferiority. Compared to traditional varieties – selected by farmers and bred for low external-input conditions – GR seeds offered 'better breeds' in a variety of inflections: access to modern knowledge, to White prestige, and to a pathway out of poverty within dominant discourses of development[14] that elite seeds both produced and contained (Escobar 1995/2011; Jennings 1999; Eddens 2017). Fifty years on, the 'persistence of Green Revolution thinking' (Patel 2012) in policy and development circles has evolved apace with neoliberal change. G8 Alliances, Gates Foundations, and myriad public-private partnerships now characterize new frontiers in what is best characterized as a '"long" history of state reconfiguration, capitalist accumulation, concentration of power, disenfranchisement, agricultural investment and innovation' (ibid, 2).

Evidence is mounting that biocultural and agroecological perspectives could help address root causes of hunger, obesity, biodiversity loss, chemical pollution, soil erosion, and climate change, among other crises created and compounded by the Green Revolution (Altieri 1995; Kremen, Iles, and Bacon 2012; Garbach et al. 2014; Gliessman 2015). Yet the knowledge(s) underpinning these regenerative systems tend to be delegitimized within elite scientific and political institutions. The devaluation of the International Agricultural Assessment of Agricultural Science, Technology, and Knowledge for Development (IAASTD) is exemplary of such epistemic politics. Between 2005 and 2007, the IAASTD gathered 900 participants from governments, science and policy institutions, agribusiness, and civil society to deliberate the same big questions facing the FAO today: 'How can we reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development?' The process was one of the first to involve local farmers, indigenous peoples, and grassroots advocacy groups alongside the more 'traditional intellectuals' (c.f. Gramsci 1971/2010) from public and private sectors. The IAASTD produced a book, several reports, and popular articles documenting the results of the 3-year process and providing specific policy guidelines for transitioning to more sustainable and just agri-food systems. (IAASTD 2009)

[14] For Escobar, development discourse is particularly powerful insofar as it is not only about any isolated 'discursive object,' including seed. Rather it is the relationships between capital formation (technology, monetary policy, agricultural development), cultural indoctrination (propagating modern cultural values), and institutional control (World Bank, IMF, UN). These relationships systematically produce interrelated objects, concepts, theories, and strategies, carving an epistemic space 'through which only certain things can be said, and even imagined' (Escobar 1995/2011, 39).

Without discounting any particular technology, the report downplayed the *need* for transgenic crops and instead recommended a move to more agroecological agriculture in both industrialized and developing countries.

But since its launch in 2008, vanishingly few people have ever heard of the IAASTD, let alone its recommendations. Indeed, unlike similarly ambitious international assessments including the IPCC and the MEA,[15] the IAASTD appears to have been ignored or downplayed by the very agencies – the FAO, the World Bank, the CGIAR, among others – that sponsored and enabled its completion. (Feldman and Biggs 2012) This eclipse in the historical record has been described in terms of lack of scientific rigor. As *Science* reported: it was because activist environmental groups 'outmaneuvered' the authoritative assertions and claims made by scientists on the IAASTD committee. (Stokstad 2008, 1476) Similarly, political scientist Robert Paarlberg argued, '[IAASTD] ended up more a collection of opinions than an incisive summary of the scientific literature' (ibid). Nina Fedoroff, then Science Advisor to Secretary of State Hillary Clinton, captured the sentiment of the liberal scientific establishment, affirming with no qualifications, 'The IAASTD report has been completely discredited' (pers. comm.).

Such dismissal of subaltern knowledge – from farmers, indigenous peoples, global South NGOs – spun further out of control in the media, where civil society knowledge was framed as 'opinion' in contrast to 'fact,' where activist bias supposedly clouded scientific objectivity. But nearly ten years on, the IAASTD continues to symbolize much more than a missed policy opportunity. Its history shows wrinkles in the epistemic surface of Green Revolution orthodoxy – when 'rigidities' to the expansion of capital imposed by social movements came not in the form of strikes, boycotts, or walkouts. It came instead via participation alongside dominant knowledge actors in an assessment of the state of agriculture. It also illustrates the force with which threatening evaluations are subsequently captured, re-framed, or simply ignored. The vanishing of the IAASTD calls attention to nothing less than ongoing battle for scientific legitimacy and the ideologies these claims entail (Iles et al. 2017; Jasanoff and Wynne 1998). Who can speak, from which points of view, with what authority, and according to whose criteria of expertise? Who is saying that farmers only have 'opinions' about food, while scientists get to be experts?

As I develop further in Chapter 5, intellectuals play a central role in producing discourses that define worlds and worldviews: 'what can be said, or even imagined' (Escobar 1995/2011). They manufacture wisdom that comes to be commonly held and taken for granted – the contradictory and disempowering form of consciousness Gramsci termed 'common sense' (1971/2010). But not all intellectuals are alike: Whereas 'traditional intellectuals' generally work to stabilize a dominant social order (and their place within it) by positing their knowledge-making as universal, transcendent, and apolitical, 'organic intellectuals' make no pretense to rootless or classless interests. Indeed, they make it their work to disrupt naturalizing discourses, to reveal historical relations of force, and therein, to 'make common sense *critical*' (Hart 2012). In transforming popularly held 'common sense' into 'good sense' (a more sophisticated understanding of society), organic intellectuals therefore help realize possibilities for disruptive, subaltern worldmaking to unfold.

[15] IPCC is the Intergovernmental Panel on Climate Change. MEA is the Millennium Ecosystem Assessment.

Co-production

The third piece in my political ecology toolkit emerges from the basic understanding of knowledge as constructed – that is, science and technology do not merely reflect nature or the mandates of nature, but are inscribed with human agency, cultural norms, and political predispositions. Some researchers responded to the aforementioned colonial biases by incorporating local and 'situated knowledges' into their perspectives (Haraway 1988). To refine observations of nature and create better accounts of ontological reality, they strove to include a plurality of cosmovisions, layering many partial perspectives into a fuller objectivity. But while adding depth and sophistication to the Western scientific view, constructionism remained hamstrung by what Latour[16] (1999) critiqued as yet another asymmetry: 'Why should construction only be able to reveal the erroneous ways in which scientists and society at-large interpret their environments? Why should nature be 'right' and humans be 'wrong'? And what of the role of non-human actors in creating nature and accounts about nature?'

Co-production responds to this asymmetry in viewing the relationship between being and knowing as reciprocal and coeval. Moreover, co-production enables non-human elements to play an equal part in co-creating knowledge. That is, seeds, agroecosystems, and environments more generally are produced from the very ideas through which these elements are apprehended, even while those ideas are 'rooted in the material activities and changes of the landscape' (Robbins 2011, 141). For Jasanoff and Wynne, co-production opens a window onto understanding the evolution and legitimation of dominant social orders. They point to the inadequacy of models that 'employ wholly different explanatory resources to explain the production of scientific knowledge (or uncertainty) on the one hand, and the production of political order (including policy choices) on the other.' From this perspective, we need a more interactive accounting, in which natural knowledge and political order are coproduced 'through a common social project that shores up the legitimacy of each' (Jasanoff and Wynne 1998, 16).

I use co-production throughout my dissertation not as an explicit framework or tool, but as a guiding idiom to analyze conjunctural processes at work. As described below in my case outlines, it helps clarify the *nature-society* dimensions of access and diversity: how non-human nature and humans together coproduce seed enclosures – yet how both also create frictions capital must overcome. It helps illuminate science as *political*: various sites of knowledge-making co-produce – support and emerge from – dominant institutions of political-economy and governance; yet hegemonic order often relies on depoliticizing and de-historicizing the production of knowledge through which its power is held. Finally, it offers a lens onto *discourse* itself as a site of dispossession/repossession. Coproduction helps us see how human agents create narratives about how agriculture *should* develop. People imagine super-crops for the future. They decree what food-related diseases and agricultural problems deserve attention. Particularly powerful humans and their institutions give priority to their framings of everyday agricultural and food conundrums: crop yields that need to be maximized to satiate hunger; farm fields that need to be cleared to make food safe; honeybees that must be mobilized to labor anywhere. Ideas and narratives, then, can reshape physical landscapes and living forms, as much as they can

[16] Latour sometimes comes close to endowing specific forms of inscriptive technology with a life or agency of their own, contrary to more relativistic lines of science and technology studies.

remold social norms and legal and political institutions. These changes can loop back iteratively to change the terms in which people think about themselves and their place in the world (Jasanoff 2004).

To summarize, my dissertation papers collectively explore how knowledge politics and coproduction are instrumental in carving out new – or reviving old – territories for seed dispossession and in the contemporary era. They also trace how alternatives are being generated – not only to fend against dispossession but to actively reappropriate seeds, agrarian practices, and food wisdoms. Diversity is bound up in the patterns and dynamics of reproducing seed materials and knowledge, implicating access at every turn in shaping diversity: who possesses these biocultural values, the social protocols of use, and to what purposes seeds are put.

Chapter outline and learning process[17]

To set the context for these interrogations, I begin with a brief context chapter (Chapter 2) that looks in more depth at seed enclosures and their countervailing resistances. The former, I argue, can be understood in three broad arcs that overlap in time and space. Since at least the time of the Columbian Exchange, colonizers and their descendants have been prospecting for biocultural wealth. Plant breeding science, developed in the 20th century, began institutionalizing how such wealth was folded into agricultural revolutions in the US and globally. These movements, in turn, were brokered by innovations in biotechnology and intellectual property, the enclosures of seed reproduction through interlinked forces of science and law. In turn, and often as a result, anti-enclosure movements are emerging in places from Malawi to Richmond, from urban Venezuela to rural India. I sketch some social resistances taking shape under the umbrellas of food and seed sovereignty.

Further detailed in Appendix 1, I use a mixed methods approach, drawing primarily from qualitative practices in STS and political ecology. Two 'field sites' have defined the territory of my inquiry. The first, emphasized in chapters 3 and 4, is policy and science-policy discourses at the international level. CGIAR documents, FAO reports, and conservation science papers published over several decades formed the crux of historical analyses. I identified key frames, narratives, strategies, and ideologies using both keyword and context-based evaluations. The second, emphasized more in chapter 5, were physical spaces/sites, including local California seed libraries, seed swaps and exchanges, and organic farmers breeding their own seed. Travels to the Pacific Northwest, the Sacred Valley of Peru, and Montpellier, France extended my open source seed inquiry to citizen 'freelance' breeders (in the case of the PNW), indigenous communities (in the case of Peru), and international genetic governance circles (in France). Participant observation, semi-structured, and informal interviews were my primary instruments for gathering data on these site visits. I also developed a simple survey instrument to gather feedback from a larger sample of global South movements – a lesson in the challenges of such techniques that I detail in the Appendix.

A further key component of my general methodological engagement – from day one of my PhD career – has been iterative, informal, and difficult to document rigorously. By participating in seed, agroecology, and food sovereignty discussions online; by participating in conferences,

[17] Citations within the chapter outline can be found in reference sections for Chapters 3-5.

workshops, and symposia that gathered multiple stakeholders from divergent backgrounds (peasant movement, breeder, NGO, biotech, international policy), I became further steeped in seed politics – not simply the keywords or discursive frames, but how those discourses impose on, produce, and manifest in the lived experiences and livelihoods of people and communities in economically divergent strata. Over meals, in halls and corridors, in trips to the countryside and on long hikes, I was able to corroborate and cross-check claims made by key informants against a wider sample of less visible 'supporting actors.' Importantly, and especially during the open-source work, I gravitated from being an invited observer to becoming an active agent and advocate of repossession.

Thus, a note on my positionality is in order. This thesis attempts to take a fair read of the politics of agrobiodiversity in play, but I do not claim that it is value neutral 'objective' – or that such a thing is even possible. Rather, I take a normative approach; this thesis makes no apologies for advocating seed freedom, even while I propose that such freedom requires reflexivity. My second hope is that this thesis is legible. To that end, I have tried to make molecular biology and ecology science more transparent to a social science audience; I have similarly treated high social science theory with patience in hopes that ecologists and biodiversity researchers will find the work accessible. I hope this approach results in a read that is trans-disciplinary – both in the methodological approach and the delivery.

In my first paper (Chapter 3, 'Are We Losing Diversity?'), I unpeel the proverbial onion. To begin interrogating access to seed diversity, it was necessary to ask: What *is* seed diversity? How is seed diversity defined, evaluated, and measured? Which scales of observation – from gene to organism to ecosystem; from farmer to village to nation – best 'see' the tracks of agrobiodiversity change? Why do diverse ways of answering these questions matter – and for whom?

Competing narratives of loss inspired this inquiry: Crop genetic diversity[18] is rapidly eroding worldwide, we are told, and numerous studies support this claim. Ethnographic and agroecological field data (Harlan 1970; Altieri and Merrick 1998), flagship conservation science texts (eg. Frankel and Soule 1981) and numerous surveys by environmental and agricultural science agencies (Fowler and Mooney 1990; Thrupp 1998; FAO 1996, 2011) indicates that crop genetic diversity worldwide is on the decline. Other evidence, however, suggest an alternative storyline: far from disappearing, seed diversity persists around the world, resisting the homogenizing forces of modern agriculture (Brush 1991; Bezançon et al. 2009; Jarvis et al. 2011). Which of these accounts is closer to true?

This puzzle tugged at me for months, as I began charting my dissertation project. How could it be that the FAO's seminal *The state of the world's plant genetic resources for food and agriculture* – published in 1996 and again in 2011 – was contradicting what many authors, including at the FAO, were saying about the strength, resilience, and extant diversity of

[18] Crop genetic diversity is not identical to 'seed diversity,' but is often used as a benchmark of the variance in genetic and phenotypic characteristics of plants used in agriculture. Seed diversity is a broader term referring to the interspecific (within species) and conspecific (between species) diversity that may exist in an agricultural system. Agrobiodiversity, in turn, encompasses the fuller complement of crop seeds within a web of planned and unplanned biological – or better, biocultural – diversity. For storytelling purposes, I sometimes use these terms interchangeably.

traditional seed systems? Was the discrepancy due to different places and time frames? To different types of crops? What were the implications not just of losing diversity, but of *saying* diversity is being lost?

Through my research, I realized that rather than continue to debate if loss is occurring or not, the inroad to more objective understanding comes through interrogating the epistemic practices and politics of agrobiodiversity. My first paper, then, unfolded as a project to consider diversity in three dimensions, ecological, epistemic, and political. I asked about ecological patterns of diversity: across scales, over time, as a function of distribution in space. How is diversity structured in nature? I asked about knowing diversity: culturally specific practices of identifying, defining, and evaluating agrobiodiversity. Who creates and categorizes seed diversity? Why does this recognition matter? I asked about the politics of mobilizing such knowledge in accounts and narratives of diverse interest groups, from agroecologists to the CGIAR. What are the social and environmental implications of 'loss' – or not?

I found that diversity can mean qualitatively different things to distinct observers. What is 'diverse' for a farmer gauging kernel sizes or stem heights may – or may not – be diverse to a biologist comparing phylogenetic distances or single nucleotide polymorphisms. Diversity also varies markedly according to scale of observing nature: local versus global; within locales versus between locales; short versus long time frames. In addition, knowledge of diversity can engender creation of real, material diversity: when farmers or communities believe that a named cultivar has particular properties and uses, they are more likely to employ management practices that reinforce its biological identity and distinctiveness. If knowing and nature of agrobiodiversity are co-produced, they are also wielded strategically. I discovered that 'diversity loss' carries discursive power: 'loss' mobilizes peasants to protect native seed systems from state modernization plans and incursions by transnational agribusiness. Conversely, loss can be wielded by governments and corporations to legitimize 'rescuing' seeds from local people and endangered habitats. In a parallel paradox, arguments that seeds are *not* being lost – 'persistence' – also cut both ways: persistence can be an empowering treatise on behalf of farmer knowledge and skill. It can simultaneously serve as an injunction to maintain the 'do nothing' trajectory – for after all, in spite of everything, peasants and their seeds persist.

Such a multi-dimensional framework of seed diversity, I conclude, ultimately proves more illuminating than the somewhat artificial construct of global genetic erosion. Loss, persistence, and even return of diversity are constitutively uneven from place to place and over time, reflecting historically specific trajectories of development and agrarian transition. They are constructed in farmers' minds and in institutional practices of science, governments, and industry. They can be measured at the evolutionarily important scale of the gene, but coevolve through epistemic and geographic interactions largely mediated by populations who don't 'see' DNA, who don't resolve difference at that scale. Understanding these dynamics is more analytically and strategically important than 'diversity' as an ontologically disembodied concept. By looking to how knowledge practices and politics shape the creation and destruction of diversity, we come closer to intervening, at the appropriate scale, in the processes that reproduce people, landscapes, and seeds. This research was published in *Agriculture & Human Values* (Montenegro de Wit 2016a).

My second paper (Chapter 4, 'Stealing Into the Wild') considers crop wild relatives (CWR) as a potential site for the production of new seed enclosures. CWR are alluring to science and capital for many reasons. Species often endangered by urbanization, desertification, and industrial agriculture, wild plants that are closely related to crops have become a new priority for conservation: prized for ex situ collection and banking, as well as for in situ genetic reserves. Because of CWR's tolerance for extreme environmental conditions, they are also now sought out for crop breeding value. In 'save the species that could save us' logic, such breeding potential has become scientifically and economically powerful. As temperatures climb and floods ensue, the imaginary of 'rewinding the domestication bottleneck' via CWR breeding has begun to exert backward pressure on conservation: informing what is valuable to protect, preserve, and conversely, let go.

Initially, I set out to ask how this might be occurring as a case of primitive accumulation disguised as conservation – the so-called 'Green Grabbing' which has attracted much scholarly attention (eg., Fairhead, Leach, and Scoones 2012). With both ex situ and in situ strategies in play, I wanted to explore the terrain of wild plants being newly commodified, even while land-based habitats became cordoned off as 'genetic reserves' – to salvage CWR from destruction by climate change, urbanization, or 'ignorant' local people. Soon, however, I learned that CWR protected areas are still mostly on-paper ventures, meticulously planned but little developed. So, I instead turned to consider upstream sites of knowledge production. Who was designing CWR conservation? What were the methods, technologies, and practices for their collection and tending? Upon which epistemic baselines were conservation and breeding projects beginning?

In examining two global projects of 'systematic' CWR conservation, I quickly discovered that these designs have strong tendencies to sediment layers of economistic assumptions, values, and ideologies into subsequent methods and practices. For example, CWR conservation can in principle take into account a wide array of social and ecological factors, from cultural values, foodways, and ecological roles, to threatened status and pragmatic costs of conservation. But, I found, the pathways of CWR conservation are increasingly constrained by only two variables: socioeconomic importance of the related crop, and the agronomic value of CWR for crop improvement. This narrowing of priorities, I argue, is helping to create a systemic 'lock in' to existing food regime patterns. By calibrating wild relative conservation according to the commodity importance of their kin – which crops are now most profitable, ubiquitous, and energy-yielding – the structure and organization of predominant agri-food systems tends to be reinforced. Similarly, developing priority listings according to treaties whose own standards embed a priori assumptions about calories, nutrition, and 'food security value' is a self-reifying strategy that conserves only what already dominates an increasingly homogeneous food supply (see Khoury et al. 2014).

The second major pillar of this work investigated the plant breeding side of CWR practice. From marker assisted selection to CRISPR-Cas9, I found that the molecularization formal-sector breeding practices (including 'conventional' and 'GMO') is having strong repercussions for who is creating 'rewilded' crops, for which communities are included and excluded from decisions about climate-resilient crop development, for whose knowledge is reflected in the constitution of 'CWR nature.'

Finally, I considered several factors that surround and condition these conservation and biotechnology activities. I looked at four converging sites: institutional conservation-and-use policy (the 'complementary' discourses merging ex situ and in situ); historical trends in appropriation and commodification (the precedents for value extraction); legal architectures for germplasm governance (the International Plant Treaty), and information technology (the assembly of 'Big Data').

I concluded that co-production offers explanatory purchase towards analyzing enclosures across multiple frontiers. Within S&T, plant breeders and engineers cannot mobilize traits without effective conservation, and conservation gathers credibility for its activities by offering utilitarian CWR value – germplasm with the auspicious potential to weather radically hotter, wetter, more volatile climates. Climate change, crisis narratives, conservation technologies, and plant breeding are thus co-evolving, in ways at once contingent, unpredictable, and yet pregnant with historical precedent. (Malthusian thinking is alive and well in the architecture of systematic CWR planning.) When these S&T elements move into synchrony with enclosures effected by larger institutional arrangements – the aforementioned Plant Treaties, complementary conservation policies, big data, and industry's commodification priorities – it becomes inordinately likely that dispossessions will occur. This research was published in *The Journal of Peasant Studies* (Montenegro de Wit 2017a). A separate paper was published in *Gastronomica: The Journal of Food and Culture* (Montenegro de Wit 2016c) and is included in Appendix 2.

For my **third and final dissertation paper (Chapter 5, 'Beating the Bounds')** I wanted to interrogate the forces that contravene contemporary seed enclosures. Against strong trends favoring primitive accumulation of crop biodiversity, who was resisting, where were they active, and what strategies were they deploying to slow dispossession? What were the real prospects for advancing repossession?

I began my inquiry by looking at seed sovereignty movements, part of the broader 'food sovereignty' movement that has accelerated since the 1990s, mobilizing activist and scholarly domains against free trade, financialization, and the neoliberal food regime (Wittman et al. 2010; Edelman et al. 2014). Seeds are a key pillar of sovereignty for La Vía Campesina, the Landless Workers Movement (MST), Navdanya, and other globally recognized sovereignty advocates (see Chapter 2).

But I found my case study closer to home – and indeed led by the researcher with whom my seed story began. Jack Kloppenburg came to Berkeley in Spring 2014 to give a talk about the Open Source Seed Initiative. It was a new endeavor, he suggested, to 'free the seed' from restrictive intellectual property rights. Founded in 2012, OSSI initially sought to develop an open source system based on legal licenses. It sought to establish a 'protected commons' populated by 'those who agree to share but effectively inaccessible to those who will not' (Luby et al. 2015). But as Kloppenburg made evident on that day in Sutardja Dai Hall, the project had not gone according to plan. OSSI was forced to abandon the licenses in favor of a simple moral 'Pledge.' Instead of a legally binding copyleft model, it would appeal directly to ethical norms that link growers, scientists, seed companies, and eaters.

In the US, OSSI has grown to include 38 plant breeders, 52 seed companies, and 407 crop varieties. Yet challenges remain for OSSI to gain wider legitimacy for 'freed seed,' to build trust in this Pledge, and to establish fair guidelines for which people and which seed can participate in making the commons. Using the metaphor of 'beating the bounds' – a feudal practice of contesting enclosures – my project asked how OSSI defends the commons in intersecting arenas. First was legal, as OSSI negotiated this early move from contract law toward moral economy law. Next, was epistemic, as an informal breeder network revitalizes farmer knowledge, while proving more structurally able and culturally equipped to lead commoning efforts. Finally, I reflected on the nature of boundary beating itself, aided by perspectives from global South sovereignty movements.

Through participant interviews and in-depth study of OSSI's development over the past 4 years, I came to understand this 'open source' project through the lens of commons. Yet it went beyond institutional designs for a well-governed commons (Ostrom 1990). To understand how this community was negotiating contestations – from outside and from within – I turned to new commons literature, which views commons not simply as a resource, but as a relational activity, a dynamic and evolving social activity of *commoning* (Linebaugh 2008; Bollier 2014; Azzellini 2015). OSSI was creating much more than an alternative to intellectual property, I realized; it was commoning through integrating the seed resource, plant breeding communities, and emancipatory social protocols required to repossess seed. Central to this community – and hence, to reproducing shared seed – was a subaltern culture of 'freelance' plant breeders. Self-taught, self-employed, and spanning farmer-breeder-seed company divisions of labor, this community surprised me with its clarity of intent (to breed locally adapted, diverse seed), its pre-existing culture of resource-sharing, and its relative structural agility to participate in making a commons. By contrast, I found, public university breeders have been much less able to contribute seeds to OSSI, for many legal, cultural, and practical reasons. I tell these stories vis a vis the positions of 'organic' and 'traditional' intellectuals, a vocabulary that offers insights into how commoners knowledge can disrupt hegemonic power from within and from below. This research was published in *The Journal of Peasant Studies* (Montenegro de Wit 2017b). ∞

<u>Box 1. What are the benefits of seed diversity</u>?

The ecological, cultural, economic, and political values of seed diversity have been extensively described for individual farmers, for rural communities, and for the agricultural system in general. Though a comprehensive sweep is beyond the scope of this thesis, a few dimensions can be noted. First, on the farm scale, individual farmers may value diversity within and amongst their crops. Agrobiodiversity conservation and agroecology literatures have extensively documented how crop diversity – both within and across species – helps farmers face agronomic challenges such as pests and pathogens (Jarvis et al. 2008; Zhu et al. 2000; Altieri 1995) and differences in soil fertility and rainfall patterns (Bellon and Taylor 1993; Gliessman 2015).

Liberal economic analyses, in turn, have described these in terms of market flexibility: Through increasing farmers' ecological and economic 'option values,' a diversity of crop varieties within the production system may buffer against uncertainties such as flux in market demand, availability and price of inputs, and consumer preferences (Pascual and Perrings 2007; Smale, 2006). The anthropological lens, in turn, frequently calls attention to manifold values realized through non-market uses. Farmers garner distinctive use-values from highly variegated crops and associated household processes. Even individual species can generate many different food products – corn for popping, corn for milling, corn for eating fresh from the cob – in addition to an array of medicines, forages, fuels, and fibers (Bellon et al. 1996; Brush 2004). Sowing diversity, at the farm-scale, is tantamount to building the agroecological foundation for multiple values, from many perspectives, in use and exchange.

On a larger village or regional scale, these benefits can multiply synergistically through social networks of seed sharing, marketing, inheritance, and barter. Most traditional farmers rely on other farmers and communities to provide seed in times of crisis – climatic or economic – or when seed are diseased or low-yielding. Diversity propagated in exchange networks is therefore essential for regeneration of healthy seed; at this larger social and spatial scale, variety reflects a collectively held resource, shared across rural communities and accumulated over farmer generations (Pautasso et al. 2012; Poudel et al. 2015).

The benefits of crop diversity may also extend to society and environment as a whole. Multiple authors have pointed to the socio-ecological benefits of crop diversity, which often ramify at scales much larger than farms, communities, and landscapes (Jackson et al. 2007; Hajjar et al. 2008; IAASTD 2009; Kremen and Miles 2012). For example, varietal diversity in the production system may attract beneficial insects and pollinators, reducing the need for herbicides, pesticides, and monocultures of 'trucked in' pollinators. Polycultures may be intercropped, rotated, and planted as cover to support both below-ground soil health and above-ground crop yield. Such practices reach people and (non-human) nature from farm to world levels: reducing farmer, farmworker, and wildlife exposure to pesticides, lessening nutrient loading in freshwater and oceans, mitigating global greenhouse gas emissions, and protecting the biodiversity base of the food system.

Finally, though it may be self-evident, within the reservoir of crop diversity lies the genetic potential for breeding more diversity. All modern commercial varieties, after all, emerged through the collection of landraces and crop wild relatives, and their meticulous breeding into relatively more stable and high-yielding lines. These 'formal' varieties still can now be gene-edited and engineered, but the pool of genetic diversity upon which biotechnicians depend still rests upon 12,000 years of farmers' selected seed.

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Chapter 2

Seed dispossession and repossession: A brief history

Abbreviations

CBD	Convention on Biological Diversity
CGIAR	Consultative Group for International Agricultural Research
ETC	Group Action Group on Erosion Technology and Concentration
F1	First filial generation (in plant breeding)
GRAIN	Genetic Resources Action International
IBPGR	International Board for Plant Genetic Resources
IP/IPR	intellectual property / intellectual property rights
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
LGU	Land Grant University
LVC	La Vía Campesina
MLS	Multilateral System (of the ITPGRFA)
PBR	Plant Breeders' Rights
PVP	Plant Variety Protection
TRIPS	Trade Related Aspects of Intellectual Property Rights (of the WTO)
UPOV	International Union for the Protection of New Varieties of Plants
WTO	World Trade Organization

To understand seed enclosures, it is necessary to look beyond familiar stories of seed industry consolidation that are much in the news. Monsanto, Dupont, Syngenta, and their peer oligopsony giants are but the manifestations of currents stirring for centuries. Simple accounts, moreover, are quickly stymied by the analytical artifice of isolating 'seed.' Land grabbing, for example, often co-produces seed dispossession in a de facto if not de jure manner. By contrast, decades of Green Revolution assaults on seed saving have left farmers in nominal control of their land, while creating a new consumer class for 'improved' proprietary seeds. Beyond the co-constitution of resource enclosures, we encounter longer and wider chains of explanation: institutions, policies, cultures, and ideologies that condition displacement, replacement, appropriation, and accumulation of other's seeds and knowledge. To contextualize my dissertation, I offer three enclosures pathways that overlap in time and space: (1) the long colonial history of global bioprospecting for biocultural wealth; (2) the 19th to 21th century enclosures of breeding knowledge, in and alongside the privatization of public science; (3) the 20th and 21st century enclosures of seed reproduction through interlinked innovations of science and law.

The Long Arc of Dispossession

Bioprospecting old and new

'Commons' is not a term well-known among most indigenous and peasant cultures, the world's first plant breeders. Yet the concept of shared community use and protection of common resources was endemic, understood, and respected by many agrarian societies. As Cavanagh et al (2002, 93) suggest, for indigenous cultures, it is not really a question of commons in the European sense; 'it is more that all creatures – human as well as plant and animal – are directly related, equal, and with equal rights to exist in a fulfilling manner.'

European colonizers did not recognize this ontological interdependency, but they surely recognized the value of crop diversity. From the 16th century onward, competition between colonial powers sped the diffusion and exchange of crop genetic resources around the world. In what P.R. Mooney (1983, 85) memorably describes as an imperial 'botanical chess game,' gentleman prospectors scoured foreign lands for 'exotics,' ferrying them back to the Royal Kew Botanical Gardens for scientific study. Science and colonial capitalism went hand-in-glove, as corn, tomatoes, beans, squash, and potatoes sailed from New World to Old, while seeds of tropical cash crops – sugar, bananas, coffee, rubber, tea, and indigo, among others – migrated across colonial holdings to fortify new plantation economies driven by chattel slavery (Crosby 2004, Mintz 1985, Kingsbury 2009). Although at the time the genomes of such crops were not considered 'property,' the ability to access plant genetic diversity was understood as fundamental to expanding empire (Aoki 2008).

Founders of the American republic were aware of this value, and in the 19th century, the US government undertook numerous bioprospecting expeditions, directing consular and naval officials to ship samples of native crops back to the US (Kloppenburg 1988/2004). This form of enclosure – through material appropriation – accelerated in the mid-20th century, when the International Board for Plant Genetic Resources (one of the original CGIAR centers, funded by the Ford and Rockefeller Foundations) began collecting germplasm samples from nations across the global South for use in Green Revolution crop improvement. On a putative mission to rescue these countries from imminent overpopulation and starvation, the IBPGR built an infrastructure of international seed banks designed to store and catalogue millions of accessions of peasant and indigenous 'landrace' varieties (Davies 1991; Mooney and Fowler 1990).

Although formal legal designations remained ambiguous until the 1980s, most seed collected by the IBPGR was held under the assumption of 'common genetic heritage,' a label with a spotty past and contradictory implications. Some authors date this distinction to the dawn of agriculture; it was the 'ex ante' form of governance before legal characterizations of plant genetic resources were made (Brush 2004). But while 'common genetic heritage' appears consistent with indigenous cosmovisions of communal and non-proprietary heritage, the construct had a double edge: Imperial powers considered specimens they prospected from the outposts of Empire as 'common' – and therefore 'freely appropriable' (Aoki 2008).

The political economy implications of this colonial designation were far-reaching. Kloppenburg describes how Turkish landraces of wheat, Indian sorghums, and Indian barleys all found their way into the crucibles of American grain agriculture. 'It is no exaggeration to say that plant genetic resources received as free goods from the Third World have been worth untold *billions* of dollars to the advanced capitalist nations' (Kloppenburg 2004/1988, 167-69). By the early 1980s, this transfer of wealth had sparked outcry from civil society groups and the G77 nations of the 'third world' who openly challenged the IBPGR and called for a restructuring of the CGIAR (Aoki 2008).

In particular, the distinction between ‘raw’ and ‘worked’ germplasm put seeds into a contradictory position on the international stage. Northern governments, scientists, and industry leaders argued forcefully to retain their rights to collect raw germplasm as ‘common genetic heritage.’ Their claims, explains Aoki, ‘provided a rationale for protecting germplasm that had been ‘worked’ by professional plant breeders, and denying it to germplasm that was merely ‘raw.’’ (Aoki 2008, 74). Sensing hypocrisy, Southern leaders called for identical legal treatment of proprietary germplasm. Why, they challenged, should elite commercial seed be considered private property, while ‘primitive’ seed – including landraces and crop wild relatives – are designated as commons?

The outcome of this Southern challenge is reflected in the 1983 FAO ‘Undertaking’ which declared *all* agricultural plant genetic resources – raw and worked alike – the common heritage of all humankind. It was a temporary win for allied developing countries, and a glaring rebuke to Northern governments and agribusinesses pressuring to extend intellectual property rights to new/more seed (Kloppenburg 1988/2004). The Undertaking, however, was nonbinding and many advanced capitalist countries, the US included, gave it little heed. Not until the early 2000s did common genetic heritage re-emerge in policy under the aegis of the International Treaty on Plant Genetic Resources for Food and Agriculture, or ‘Plant Treaty.’ (see chapters 4 and 5).

Meanwhile, on a parallel legal track, the world was deliberating governance of biological diversity more generally. The 1992 Convention on Biological Diversity (CBD) reflected a significant legal shift in the characterization of plant genetic resources: towards a principle of *national sovereignty*. Under the CBD, plants, plant parts, and seeds were taken as the ‘sovereign national property’ of the country in which they are located. The CBD incorporated the idea that *the countries of origin* of biological resources exercised sovereignty over all plants, animals and microorganisms within their national boundaries (CBD 1992, art. 15.5).

The push for sovereign national property reflected growing opposition to biological prospecting in the Southern hemisphere and a larger milieu of social critique in which ‘common heritage’ was coming under fire from all ideological sides. Postcolonial scholars argued that common heritage – a legal category akin to ‘open access’ – was a vestige of colonialism that facilitated a unilateral flow of genetic resources out of poor nations of the global south. Chander and Sunder (2004), for example, argued that open access to particular resources does not guarantee *equality of access* nor *equality of ability* to utilize such resources. Neoclassical economists, meanwhile, invoked Hardin’s ‘tragedy of the commons’ to claim that open access resources would inevitably be overexploited and despoiled. Their solution was to treat plant genetic resources in yet another way: as *private property*.

Overlapping legal designations – between common genetic heritage, private property, national sovereign property – have led to a condition that Michael Heller memorably describes as an ‘anti-commons.’ Rather than facilitate an egalitarian flow of seed resources and access to them, the various institutions and frameworks that uphold these legal categories (the CBD, the WTO, the Plant Treaty) generally work to the detriment of those without power and privilege. Indigenous communities, for example, have occasionally tried to patent their own seeds as private property to protect them from appropriation; they have also tried to affirm sovereignty rights in harmony with CBD rules. But in both instances, elites tend to get the upper hand, whether corporations that can easily consolidate intellectual property (or steal it), or national governments whose claims to sovereignty may not reflect the sovereign rights of local communities and agrarian groups.

Indeed, in the past 20 years, corporations have shown their facility in taking advantage of the anti-commons to continue the bioprospecting habit: intensifying a search for valuable plant, animal, and human genes to claim as their own private property (Carolan 2016).[19] Pouring old colonial wine into new bottles, collection is now accelerated by new mapping, bioengineering, and visualization technologies. In the era of GPS and GIS, countries like India remain biopiracy hotspots: plants including neem, mustard, turmeric, pepper, ginger, basmati rice, and eggplant have all been subject to patents, even when indigenous 'prior art' is widely known (Shiva 2002; Twilley 2015). Coupling conservation to plant breeding 'use,' systems including DivSeek and GeneSys have materialized to help researchers search and sequence what is amassed in international genetic repositories (Graddy-Lovelace 2017). For some, this heralds unprecedented mine-ability of harvested genetic wealth (McCouch et al. 2013). For others, it is tantamount to 'digital biopiracy' (ETC 2016), worthy of an annual 'Captain Hook' prize.

Formalizing knowledge, enclosing public science

In 19th century Europe, Augustinian monk Gregor Mendel may not have contemplated the origins of his peas in the Middle East, nor do we know if he was aware of Thomas Malthus' dark predictions of impending food scarcity. But in breeding experiments conducted between 1856 and 1863, Mendel began illuminating mechanisms of biological inheritance that would revolutionize world agriculture. By the early 20th century, with Mendelian and Darwinian principles in hand, scientists in Europe and later the US began to professionalize the practice of plant breeding. Whereas farmers had for millennia 'selected' seeds according to favorable phenotypic traits, these few decades saw a sea change in expertise (who was considered a legitimate seed 'creator'); divisions of labor (who did the breeding work); and larger institutional transitions from 'informal' to 'formal' seed renewal.

The epicenter for this transition was the US land grant university (LGU) system. In 1862, Congress passed the Morrill Act, establishing the land grant colleges, followed soon after by laws providing for nationwide experiment stations and farmer extension programs (Buttel 2005). The LGU marked a turning point in government involvement in agricultural science, including the breeding and distribution of new crop varieties. Fascinatingly, although its breeding programs relied largely on expropriated indigenous lands and stolen Global South seed, a distinctive commoning ethic was visible in the early land-grant system. The LGU complex was designed to support research, extension, and education 'in the public interest' (Krimsky 2003; Warner et al. 2011) Accordingly, plant breeding was to be locally adapted, immediately useful, and consistent with a wide range of local agroecological conditions in the country. In fact, Liberty Hyde Bailey, dean of the Cornell Department of Agriculture in 1903 – and credited with coining the term 'plant breeding' – was known to chastise workers at some experiment stations who were trying to cull crop varieties. 'In order to have the range of potential needed for

[19]In the early 1990s, Ricetec Corporation in Texas famously filed more than 20 patents on basmati, the traditional rice of India. Though four of the patents were dropped, the company now markets basmati inspired 'Texmati,' Persian-styled 'Kasmati,' and 'Jasmati,' a riff on Jasmine, a long-grain aromatic rice native to Thailand.

different environments, a crop must, he argued, maintain a wide and diverse level of variation' (Kingsbury 2009, 146).

In line with its public mission, the land grant complex also emphasized a state-funded system of technology transfer. 'Gratis' extension, it was thought, would facilitate knowledge uptake more efficiently than knowledge commodification; therefore, patents and proprietary research was generally frowned upon. A nationwide free seed distribution program captured the spirit and ethos of the day. Using the samples collected by its foreign emissaries, the USDA sent out mass mailings of diverse seed varieties to farmers across the country – more than 22 million seed packets in 1897 alone (Kloppenburg 1988/2004). This free seed program was wildly popular with farmers, and supported LGU breeding efforts with what amounted to a cross-country experiment in local selection. But germplasm giveaways soon became a target of the nascent seed industry. As companies like Pioneer struggled to gain a market foothold, they found themselves in competition with the state's high quality, reliable, and eminently affordable seed. In 1924, the free seed program was dissolved under growing industry pressure.

Long before this moment, however, a subtler form of seed alienation had been underway. In centralizing and professionalizing breeding expertise, the LGU enabled a pivot away from farmers and rural communities as the locus of breeding and other agronomic knowledge. Prior to the advent of the extension system, many farmer communities had self-organized in order to recruit help from scientific experts. But with the growing dominance of technical extension, a dynamic emerged in which expert scientists were active producers of knowledge and lay farmers were treated as passive recipients (Chambers 1983; Warner 2008; Henke 2008). Colleges and their trained professional plant breeders developed and engaged in systemic plant breeding, 'transferring' the fruits of their expertise to farmers. Starting in the 1930s, 'productionism' became the ideological kernel of US public agricultural science, propelling many a 'big hit' technology: DDT, artificial insemination, high-yielding Green Revolution breeds of corn, rice, and wheat (Buttel 2005).

Race was also an indelible part of these LGU expertise dynamics. Through its focus on uplifting poor and working-class whites, Ferguson (2012, 85) argues, the land-grant university institutionalized 19th century racial divisions. The 'contradictions between freedom for some and unfreedom for others' was assisted, he suggests, by the development of a white professional class necessary for a changing economy. Seed breeding, then, came to reflect not just a re-localization of knowledge away from informal agrarian spaces and into formal LGU labs and experiment stations, but also a whitening of knowledge, insofar as blacks and Native Americans were explicitly excluded from the Morrill Act's promises to expand democratic education to rural America (Ferguson 2012; Eddens 2017)

By the 1980s, the LGU had reached its apogee, its power and legitimacy eroding under forces of neoliberal austerity and technological transitions on the one hand, and social movement critique on the other (Busch et al. 1991; Buttel 2005). Genetic engineering based on in vitro manipulation of plant genetic material was enabled by the 1973 Boyer-Cohen discovery of recombinant DNA and quickly led to a radical 'molecularization' of crop research. Biotechnology and genetics became the most lucrative area of agricultural science, and universities around the country began restructuring departments in favor of molecular biology and genetic engineering, while cutting costs by dissolving research programs in applied disciplines such as plant breeding, biological control, horticulture, and agronomy (Murphy 2007; Warner et al. 2011). As a result, the number of public breeding programs in the US has shrunken by more than one third between 1994 and 2015 (RAFI 2014), and in situ selection research has dwindled relative to ex situ techniques, including gene sequencing that can now free researchers from 'laborious environmental field testing' (McCouch et al. 2013). Within universities like Cornell, 'plant breeding' has become a fragmented field, with 'conventional breeders' separated physically and institutionally from genomics institutes and biotech centers. As NSF grants, intramural funding, faculty hiring and concomitant prestige have gone increasingly to support pure sciences, plant breeders have become the subaltern class within public institutions, even while those institutions are increasingly subordinated to private sector interests (Busch et al. 1995, Warner et al. 2011).

The passage of Bayh-Dole in 1980 was an important legal peg in this transition. Bayh Dole allows recipients of federal funds, including universities and colleges, to claim ownership of inventions resulting from federally sponsored research. Whereas public breeding projects had once given title to federal funding agencies, under the Bayh-Dole rules, any new plant cultivar can be protected and licensed by the university (Barker 2012; Kloppenburg 2014). When the law was passed, public universities squeezed by neoliberal belt-tightening naturally began leveraging this policy to raise revenue from the private sector. Breeding work that could easily be licensed to Syngenta or Dupont took precedence over breeding for less lucrative projects like agroecological resilience, or local seed systems. In this environment of fiscal austerity, private funding of land-grant research began to outpace public investment (FWW 2012), and land-grants today are nested in an array of public-private partnerships whose priorities tend to favor firms over growers and eaters. The breeding knowledge produced by this apparatus, unsurprisingly, is highly disciplined by the structural requirements of agrifood capital.

Vanloqueren and Baret (2009) suggest that such institutional transitions not only 'lock in' some regimes of knowledge and expertise – they lock out others. Although conventional plant breeding underpinned the colonial Green Revolution, in being land-based and applied, it still held open the possibility of being farmer-led: a decentralized and community-controlled practice was still feasible, if not near-at-hand. An ensemble of 'sense and science' (ibid, 972) has since narrowed those pathways, heightening knowledge specialization, reductionism, capital-intensity, and an emphasis on growth and competitiveness. Genetic engineering – including with crop wild relatives – has emerged as *the* tool to fight hunger, boost yields, and combat the spectrum of weeds, insects, and diseases (See Figure 2).

Biotech tends to be expensive, of course, and money spent on GE is not spent elsewhere – opportunity costs are steep for organics, diversified farming, and agroecology R&D (DeLonge et al. 2016). The berth for making agroecological knowledge, then, has become constricted by the same epistemic and structural reins that make public research more susceptible to enclosure.

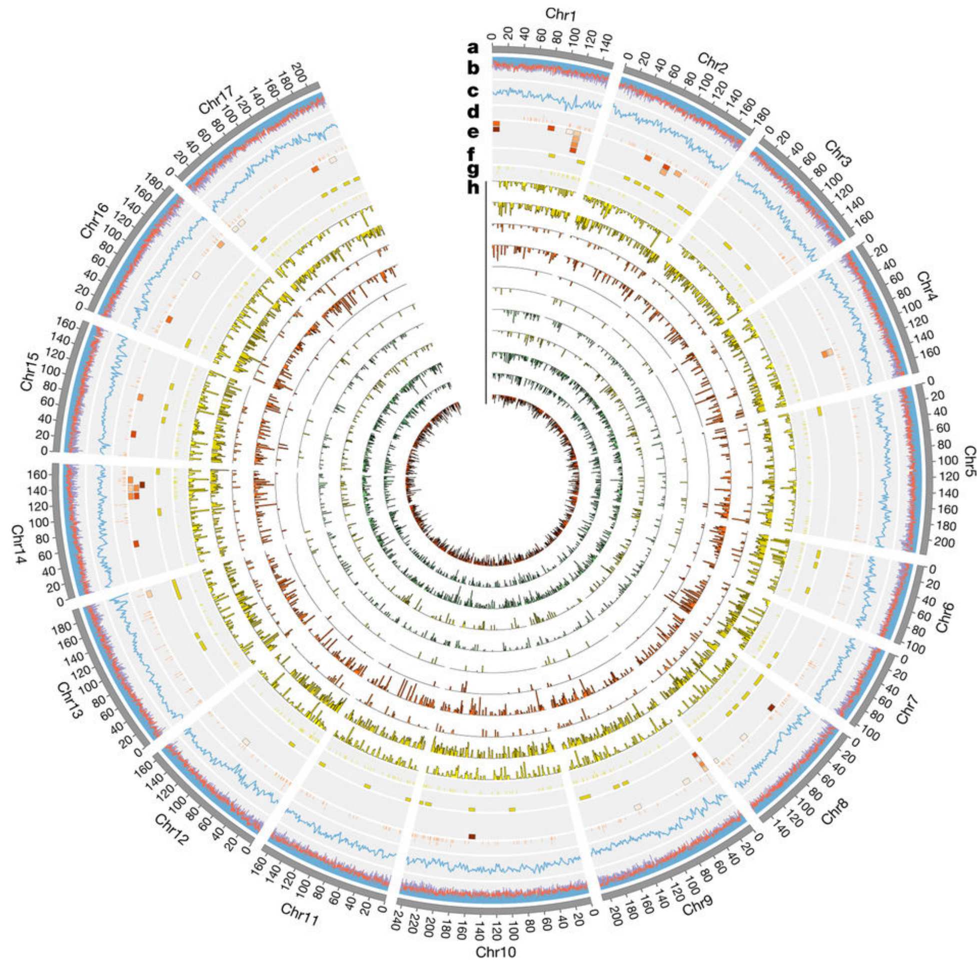

Figure 2. Sunflower Sequence. In June 2017, researchers in Canada and France published the first full sequence of the sunflower genome. Domesticated sunflower (*Helianthus annus*) is a global oil crop with much promise for climate change adaptation. Even greater resilience, the authors noted, 'is achievable through the mining of resistance alleles from compatible wild sunflower relatives' (Badouin et al. 2017). The circular representation above shows markers that correspond to various markers of diversity, genetics, and gene expression. For example, line **d** includes genes mapping to metabolic oil pathways. Line **f** shows regions associated with flowering time. Genomic sequencing projects like these are illustrative of leading-edge biotech and breeding science, touting new abilities 'to exploit genetic diversity to improve biotic and abiotic stress and oil production.' Although molecularization need not dovetail with privatization, as Buttel (2003) argues, these extractive discourses (mining, exploitation) are proving difficult to reconcile with principles of regenerative farming – and even tougher to square with non-proprietary seeds. (Image credit: *Nature*, Badouin et al. 2017).

Biological and legal enclosures

Long before genetic engineering pushed the frontiers of accumulation by dispossession, a central seed paradox needed resolving. As living beings that make more of themselves, seeds have historically been resistant to capital (Lewontin 1982; Goodman, Sorj, and Wilkinson 1987). But in the 1920s, a direct assault on seed reproduction was taking shape, leveraged by twin forces of biology and law.

Hybridization was fueled by both market based and biological innovations (Duvick 2001; Luby et al. 2015). By crossing two parent inbred varieties to create a daughter F1 hybrid plant, breeders learned that they could benefit from so-called ‘hybrid vigor,’ a crop markedly more robust than either of the inbred parent lines. While hybridization originated in public sector land grant universities – where parent identities were disclosed and germplasm was freely available – by the end of the 1920s private companies such as Pioneer Hi-Bred began specializing in hybrid corn, keeping the parent lines as proprietary trade secrets.

It is difficult to exaggerate the ‘ex novo’ separation hybrids implied. For all of agricultural history up until that time, farmers had been able to replant seed with the assurance of relatively stable characteristics. Hybrid seeds broke that cycle, since F1 generations do not ‘breed true’ and cannot be replanted for a reliable crop. Farmers were thus cut off from the basic condition of self-renewal and required to become commodity consumers. Industry, meanwhile, benefited from its new crop of compulsory buyers: hybrids gave companies a much-needed boost in markets previously flattened by government giveaways and open pollinated varieties. By the end of the 20th century, the so-called ‘inbred-hybrid’ method became the dominant paradigm for crop breeding, expanding from corn to all major crops – including wheat, rice, citrus, cotton, and vine crops – amenable to this technique (Walker 2004; Kloppenburg 2010).

Crop hybridization soon co-produced further enclosures, creating what STS scholars depict as path- dependent technological systems (Iles et al. 2016). Trapping farmers and scientists alike into particular trajectories of seed and agricultural development, breeding research, particularly after World War II, pivoted towards seed-input packages, in which crops were designed to perform with heavy applications of fertilizers and pesticides (Perkins 1990, Perfecto et al. 2009). By the 1940s, the land-grant seed paradigm was also upended: Liberty Hyde Bailey’s early call for crop diversity was displaced by Norman Borlaug’s mandate for general adaptation; ‘universality’ became the new breeding motif in land grant schools. As Dawson et at. (2008) astutely explain, it is not that local breeding disappeared, but ‘the local’ became the uniform and centralized land-grant extension station, where breeds were selected for under high-input conditions. Rather than adapt seed to heterogeneous conditions of small and large farms nationwide, breeders were trained to assume rural America could be re-engineered to suit a few universal breeds.

Inculcating such modernist aspiration was central to 20th century agri-food ‘knowledge production regimes’ (c.f. Pestre 2003) of which hybrids were a key element. As private companies like Hi-Bred Pioneer expanded and proliferated, they began to exert strong influence in shaping the modernizing vision, in which development meant progressing from open-pollinated to proprietary seed. One profoundly important maneuver was etching a division of labor between public and private sectors. In the 1940s and 1950s, the seed industry lobbied aggressively with lawmakers and science agencies, successfully compelling the US government to allocate support to LGUs for 'basic' research, while reserving the applied – and profitable – work for fledgling agribusiness. This division of labor not only bolstered industry's advantageous position at the commodity end of the R&D pipeline, it gave corporations leverage over the character of upstream research: What was valuable in the market came to define the scope and imagination of public breeding work (Kloppenburg 1988/2004). Such disciplining of biological research has continued through the age of genetic engineering and CRISPR editing (See: Appendix 4: Montenegro de Wit 2016d, 2016e).

Yet few of these momentous transformations would have been remotely possible without the 'handmaiden' of the law (Aoki 2008). In less than 80 years, the pursuit and control of intellectual property has become central to formal plant breeding in university and industry settings, enabled by the rise of progressively restrictive regimes of IP rights in the US and Europe.

In 1930, Congress granted the first patents on plants through the Plant Patent Act. The PPA protected asexually propagating vine and tree crops (and thus was supported by orchard owners who were afraid their prize apples and grapes could be easily stolen), but it explicitly omitted sexually propagating varieties, including most of the world's important food crops. Forty years later, the US adopted the Plant Varieties Protection Act (PVPA), applying intellectual property to 'new, distinct, uniform, and stable' sexually reproducing plant varieties. This new designation, modeled on Europe's International Union for the Protection of New Varieties of Plants (UPOV) was an explicit 'plant breeders' rights' (PBR) regime. Reflecting hard-fought wins for farmers and public breeders, PVPA carried key exemptions: breeders could still use protected varieties for further breeder and research without royalties. Farmers were also free to save, exchange, and reproduce protected seed.

In 1980, the Supreme Court's decision in *Diamond v. Chakrabarty* radically expanded the category of patentable subject matter in US law. *Chakrabarty* held that an oil-eating bacterium was patentable 'if there was sufficient innovative human agency involved in transforming it from something found in nature into something human made' (Aoki 2008, 125). (Using biotechnology techniques qualified as agency). This new legal ability to place patents on genes, not just phenotypes, was unprecedented in global agricultural history, and the US Patent Office began issuing utility patents on a genetically modified variety of corn, upheld in the 1985 *Ex Parte Hibberd* decision. Not only were utility patents significantly cheaper than PVP certificates and traditional plant patents, they applied to multiple, individual components of varieties. That is, whereas PVP certificates and 1930's plant patents covered only the whole organism, utility patents could apply to DNA sequences, genes, cells, tissue cultures, seed, and the entire plant (Kloppenburg 1988/2004).

Meanwhile, key revisions to the European UPOV framework would have worldwide repercussions. Notably, under earlier versions of the convention (1960, 1978), farmers' saving, using, and exchanging of seeds for non-commercial purposes was not expressly restricted – and as such, were generally accepted and permitted (Yoke Ling and Adams 2016). But in 1991, UPOV was revised to dramatically expand breeders' rights, making them comparable to those granted under a patent. Farmers' 'privileges' (as distinct from rights) to save and exchange seeds were eliminated, and in their place, UPOV introduced an 'optional exception,' which only allows farmers to save seeds of a protected variety on a farmers' own holdings (Moore and Tymowski 2005).

Today, both patent regimes and UPOV '91 PBR regimes are rapidly extending across the global South, facilitated by a variety of free trade, development aid, and investment agreements. The World Trade Organization, for example, requires all member-states to offer some form of IPR for plant materials, in the form of patents, plant breeder rights, or an 'effective sui generis' system (TRIPS article 27.3). Since most countries of the world are WTO members, the power of this international regime is difficult to downplay. In theory, countries are allowed to devise their own '*sui generis*' systems, but in practice few have the resources or capacity to do so (De Schutter 2009). Most states have instead simply taken the path of least resistance by joining UPOV '91 (Smith and Bragdon 2016), or in some cases, by going beyond UPOV to more closely approximate patent systems (Vivas-Eugui and Oliva 2010). The WTO sets compliance target deadlines for developing and least developing countries but is being outpaced in many cases by demands from multilateral trade pacts like CAFTA – which extends across five Central American states – and bilateral trade agreements such as the Peru-US free trade agreement. Colombia, Costa Rica, Peru, and Guatemala have all recently come into UPOV '91 via free trade agreements, reflecting direct pressure from the US and EU to institute IP arrangements that will accelerate innovation and growth (Wattnem 2016; GRAIN 2015). On the horizon now are the Arusha Protocol, which will apply in 19 African anglophone states, and the Asia Regional Comprehensive Economic Partnership, a mega-regional trade deal being negotiated among 16 countries across Asia-Pacific (GRAIN 2016).

Supported by Western donor governments, foundations, and multinational seed companies, these pan-Asian and pan-African agreements promote laws that protect the IP rights of formal sector breeders, ostensibly to promote the use of certified high-yielding crops. But they have been sternly criticized by the United Nations Special Rapporteur on the Right to Food, civil society groups, and peasant organizations. In an open letter, the Special Rapporteur suggests these trade deals 'could adversely affect the right to food,' 'could result in smallholders gradually losing their know-how related to seed selection and seed preservation,' and are corrosive to the free sharing of seed she calls 'the backbone of agricultural systems in sub-Saharan Africa' (Elver 2016). Members of the African Alliance for Food Sovereignty agree, calling the Arusha Protocol an arrangement primarily intend to ensure agro-industrial profits, 'while pushing the already marginalised majority of smallholder farmers further into hunger, poverty and dispossession' (ACB/PELUM/ASFSA 2016).

As a result of these sweeping legal changes, many farmers – in both hemispheres – can no longer sell their harvests as seed, nor can they save or exchange their own seeds on a non-commercial basis. GRAIN notes bitterly: they 'imply total market control for breeders over their varieties' reproductive material' (GRAIN 1999 in Wilkinson and Castelli 2000). But while this quote emphasizes breeders' rights over farmers' rights, public plant breeders are also finding that ever-stricter IP violates *their* 'freedom to operate' – including the ability to pursue scientific inquiry independently from industry. For example, under US utility patents, which extend for 20 years, seeds can only be used for crop production. But plant breeders are similarly hamstrung from using any patented varieties in their breeding programs unless they pay royalties to the patent holders and comply with stringent access conditions. Equally important, breeders are strongly encouraged to seek patents or PVP, not only to protect their individual work but to enable their universities or companies (or both) to reap proprietary benefits. As Luby et al. (2015, 2482) explain, using the example of corn,

> Today, commercial maize cultivars are generally protected by dozens of patents on specific traits, license agreements, contracts, and trade secrets, allowing developers to own and manage the intellectual property associated with their work. 'Bag tag' licenses and associated 'technology use/stewardship agreements' for modern maize cultivars specify that users cannot save, replant, use as a parent, or conduct research with the seed.

The resulting IP thicket, for both plant breeders and farmers, has severely hampered the culture and practice of non-commercial seed exchange. For university breeders, the fairly informal, open environment for sharing materials between labs and campuses has all but vanished under the stringent oversight of technology transfer offices (Goldman pers. comm.). For farmers and amateur farmer-breeders in the US, even farmer-to-farmer sales are now restricted by PVP law (generally considered the mildest form of IPR). Once protected by the so-called 'brown bag' exemption, such sales were eliminated in 1994, in an attempt to 'harmonize' PVP with UPOV. Now, one informant told me, 'You can save seed for your own use only. If your neighbor wants some seed, there is no way you can facilitate that legally. You aren't allowed to even *give* a person seed for free. They must either buy the seed, or grow some plants and save the seed themselves' (Deppe interview).

Yet systems like these only exist because they 'work' from the vantage point of some actors. Corporations have lobbied and leveraged their way into this spot, influencing the erection of IP laws, even while they accumulate portfolios of licenses and patents through consolidations and mergers. As data meticulously collected by Phil Howard (2009, 2015, 2016) shows, the past 30 years since *Ex parte hibberd* have seen remarkable dovetailing of patents and industry concentration, first across the life sciences, later in series of acquisitions, mergers, and spinoffs between chemical, seed, and biotech firms. According to industry data from watchdog groups, as of 2015, just six seed and chemical corporations – BASF, Bayer, Dow, DuPont, Monsanto, Syngenta – controlled 75% of the pesticide market, 63% of the seed market, and more than 75% of private sector research in crops and pesticides. Combined, they were collecting more than $65 billion annually from selling their seed traits, chemicals, and biotechnologies (ETC 2015). Dupont-Dow and Syngenta-ChemChina have merged, and US and European regulators have recently approved Bayer's takeover of Monsanto, meaning further concentration is imminent. The 'Titanic Three,' critics suggest, will not only concentrate capital – each conglomerate is valued at well over USD $100 billion – but will control 61% of the commercial seed supply and 65% of the chemical market (Mooney et al. 2016; See Figure 3).

Seeds are the iconic case of concentration affecting the larger agri-food system. In a 2017 report published by an international panel of agri-food experts, researchers found that roughly three companies supply over 90% of breeder stock for broilers, laying hens, turkeys, and pigs. Five companies account for more than half of the farm machinery market and are moving towards ownership of data and artificial intelligence. At the 'fork' end of the supply chain, record deals are being negotiated in the food processing sector, including mergers between giant entities like Heinz and Kraft Foods (USD $55 billion), SAB Miller and AB InBev in beverages (USD $120 billion), and retail giants Amazon and Whole Foods ($13.7 billion) (IPES-Food 2017). Howard's latest work supports these findings, showing that at almost every key stage in multiple agri-food sectors, four firms alone control 40% or more of the market (Howard 2016). This is a level above which, he argues, these companies have the power to drive up prices for consumers and reduce the overall rate of innovation.

Seed industry consolidation seems to have particularly pernicious ripple effects, given the centrality of seed to all agrarian systems. The imminent 'Titanic Three' will likely mean higher seed prices for grain, dairy, and livestock farmers in the US (Bunge 2016), less availability for farmers of conventional crop varieties as companies trim their portfolios (Barker 2012; Howard 2016), and a long list of human- and environmental health ramifications associated with glyphosate, dicamba, neonicotinoids, and 2-4D (Gillam 2017, Gurian-Sherman 2017). Across the EU, US, and Latin America, several consumer, environment and anti-trust groups argue that the proposed deals 'have the potential to concentrate political and financial power dangerously and could force more countries to adopt a single model of farming that excludes or impoverishes small farmers' (Vidal 2016).

These trends suggest we can anticipate future enclosures in new spaces where Monsanto and its ilk are beginning to tread: companies that own and produce climate data; firms specializing in data-linked farm equipment; fertilizer manufacturers; biotech companies specializing in plant genetic data (plant genotypes, phenotypes, and proteins); food companies relying on such data to pioneer plant-based protein foods.[20] Future enclosures will also advance rapidly in 'old' technological spaces, but new geographic places: where farmers still rely largely on informal seed systems. Says Olivier De Schutter, former UN Special Rapporteur on the Right to Food, 'There is a huge market there, which the seed companies [say] will grow very significant in the next few years' (De Schutter, quoted in Vidal 2016).

[20] In a stunning example of what Goodman, Sorj, and Wilkinson (1987) long ago dubbed 'substitutionism,' the company Hampton Creek proposes to replace eggs and other animal products with high-tech vegetable proteins. Using bioinformatics and molecular characterization of beans and other crops, I was told, Hampton Creek offers not only the more humane alternative to factory farming, but also saves water, reserves edible grain, and cuts animal pollution (Lazimi pers comm). But while the company has achieved a cult following among some 'green-minded foodies' and Silicon Valley investors (Zaleski, Waldman, and Huet 2016), investigations by Bloomberg news and The Atlantic found evidence of false advertising, sales inflations, and other unscrupulous business practices. In 2014, Hampton Creek CEO Josh Tetrick was called out by one of the company's high-profile investors, Ali Partovi (also a donor to the Berkeley Food Institute). 'It's only a question of time before the consequences catch up with us,' Partovi warned Tetrick in an e-mail. 'If an investor discovers it during due diligence, we could lose financing and run out of cash. If they don't, they'll realize they were duped within months, and they might have a case for fraud.'

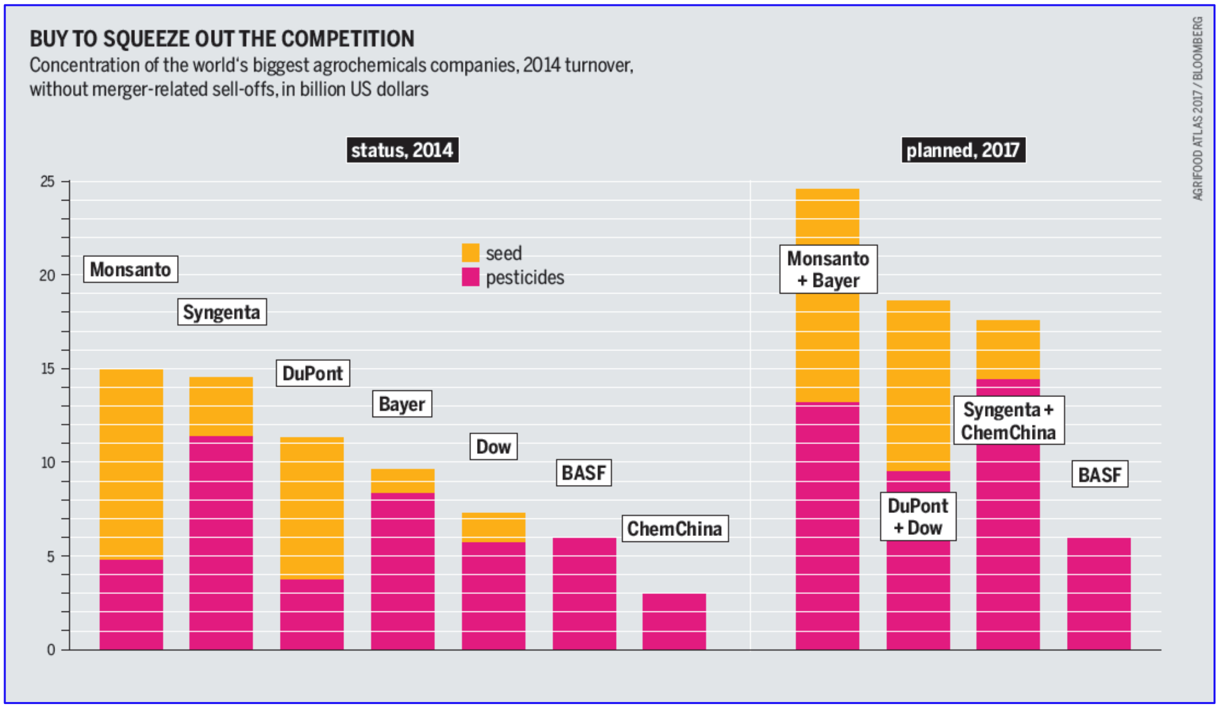

Figure 3. Seed-Chemical Mergers. Seven companies currently dominate the global pesticides market, five of which are also seed giants (Monsanto, Syngenta, DuPont, Bayer, and Dow). Recent mergers have largely resulted from pressure by financial investors, argues researcher Jennifer Clapp (2016): '[T]he onset of low commodity prices and faltering economic growth in emerging economies has weakened demand for commercial seeds and crop protection chemicals, making it harder for agribusiness to generate high returns for their shareholders to and pay their debts.' As a result, the past 24 months have seen investors put tremendous pressure on agribusiness managers to improve their performance – resulting in a series of mergers and acquisitions to cut costs through restructuring.

As of this writing (11.07.2017), the US corporations DuPont and Dow Chemical have merged, ChemChina has acquired the Swiss company Syngenta, and the German chemical giant Bayer is planning to take over US-based Monsanto (Agrifood Atlas 2017). Valued at USD $130 billion, the Dow-DuPont deal is second only to Verizon in corporate transactions of the last decade (ibid). Monsanto-Bayer and Syngenta-ChemChina will not be far behind – those mergers are valued at $100 billion each (Hakim 2016). (Graphic: Creative Commons (CC-BY 4.0) - Atlasmanufaktur/Heinrich Böll Foundation).

Bending the Arc Towards Repossession?

These processes of enclosure have not gone unopposed. In broad strokes, movements to decolonize systems, to revitalize public agricultural science, and to re-embed relations of production and consumption in ecology and society – these movement all provoke and imply repossessing seed. In the late 20th and early 21st centuries such movements can be seen engaging along legal, practical, scientific, and economic fronts, the ensemble of which is beyond the scope of this account. For the purposes of this thesis, I focus on three interventions that directly target international IP laws and the structures of globalization upon which they depend: Farmers' Rights, *sui generis* systems, and seed sovereignty.

Farmers' Rights

The first line of action – Farmers' Rights – emerges from efforts by Southern states and civil society groups to engage in transnational plant genetic governance. As beforementioned, long-brewing tensions over North/South asymmetries in flow of germplasm value came to a head in 1989 with the FAO Undertaking, an agreement that appeared a win for Southern actors insofar as it declared all types of germplasm – 'worked' and 'unworked' – to be the common heritage of humankind. It also introduced 'Farmers' Rights' to balance Breeders' Rights. The power of US agribusiness and state bureaucrats to simply ignore the non-binding Undertaking, however, soon turned Farmers' Rights into a shell victory, and the FAO process was overshadowed by multiple overlapping international governance frameworks for intellectual property rights (see 'bioprospecting old and new'). Since that time, a contested series dialogues between Northern and Southern NGOs, agrarian movements, corporations, agrobiodiversity trusts, and sovereign states has led to a revival of the FAO negotiations, culminating in the 2001 passage (and 2004 implementation) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). The first treaty to legally recognize and affirm Farmers' Rights, the 'Plant Treaty' attempts to reconcile elements of UPOV '91 (private property) with the Convention on Biological Diversity (national sovereignty) in creating a new multilateral system to access and share benefits from the world's most important food crops (Fowler 2013). While recognizing seed as sovereign property of state contracting parties, it creates a type of 'limited commons' for 64 crops, allowing parties to freely access, exchange, and use genetic materials of these crops stored in the world gene bank system (Moore and Tymowski 2005). Patents and other forms of IP are forbidden on these seeds, and if derivatives are commercialized, the Treaty asks that a portion of profits go back into the 'Multilateral System' (MLS). Those monies, in theory, will go to support conservation in ex situ seed collections and within in situ farming systems globally.

Yet 15 years since the Treaty went into effect, many academic and civil society observers wonder if the struggle for Farmers' Rights has only just begun. La Vía Campesina has participated in new rounds of Farmers' Rights hearings, but remains highly critical of the overall framework's gaps (LVC 2011a, 2016). The 'florid language' the Treaty uses to describe Farmers' Rights, LVC argues, is incongruent with devolving responsibility for implementation of those rights to national levels. 'States do not apply them,' LVC alleges, and therefore invoking 'Farmers' Rights' serves 'to inoculate the Treaty against our possible protests and denunciations' (LVC 2011b). Early on, Olivier De Schutter, former Special Rapporteur on the Right to Food, warned of such troubles, including that Farmers' Rights may be upheld only rhetorically (2009). A recent review by Yoke Ling and Adams (2016) corroborates that prediction, finding that in more than a decade, almost no countries have taken concrete steps to enact Farmers' Rights, particularly in the arena of local decision-making. As for funding of agrobiodiversity conservation, Graddy-Lovelace (2017) reports that no benefit-sharing payments have yet materialized from the commercialization of MLS derivatives. The very logic of such a financing mechanism is off-kilter, legal scholar Aoki (2008) points out. The Treaty was designed to render the 64 MLS crops as public goods. Intellectual property is therefore restricted on any germplasm 'in the form received,' with payments required whenever new varieties or traits (i.e. no longer in the form received) are derived from this germplasm and patented. But while the insinuation is that such commercial activity will be relatively insignificant, it currently serves as the core financing mechanism for the MLS – essentially *requiring* privatization in order to keep the system afloat. 'It is a contradictory and ambiguous treaty,' LVC concludes in the 2011 Bali Declaration, 'which in the final analysis comes down on the side of theft' (LVC 2011b).

Sui generis systems

With Farmers' Rights still hotly contested from grassroots to international levels, a second line of repossession involves efforts to exploit the WTO's Trade Related Aspects of Intellectual Property Rights (TRIPS). As mentioned previously, TRIPS requires that WTO member nations offer some form of intellectual property rights through patenting, plant breeders' rights, or an 'effective *sui generis* system.' Many countries and communities have been mobilizing in recent years to avoid the low-hanging compliance mechanism – UPOV – and create such unique systems. For example, in southern Peru, a five-community collective known as Parque de la Papa has developed an 'indigenous biocultural heritage' model that reflects Andean cosmovisions (Argumedo 2008; ANDES, Potato Park, and IIED 2011; Graddy 2013). In India, Malaysia, and Thailand *sui generis* systems have been developed around Southeast Asian traditions, mixed with Western elements of Plant Variety Protection. These *sui generis* alternatives differ from UPOV in that they allow registration of varieties developed through *informal* as well as formal breeding programs – the former of which do not typically meet UPOV requirements of 'distinctness, uniformity and stability' (DUS). Ideally, note Smith and Bragdon (2016, 21), *sui generis* PVP systems 'invite farmers' participation' by exempting formalities in the application process such as providing complete genetic data on parent lines and paying high registration fees. The relaxed eligibility requirements with regards to distinctness, uniformity, and stability (in Malaysia and India) also allow for more crop diversity: heterogenous farmer varieties can be registered, meaning greater protection of farmer landraces, creole varieties, and mixed populations. In Malaysia, such diversity is further promoted by explicitly allowing what US PVP law now forbids: the exchange of 'reasonable amounts of propagating materials among small farmers' (Section 31(1)(e)).[21]

In theory, *sui generis* options like 'indigenous biocultural heritage' grant local communities greater authority to design and implement guardianship of native seed diversity. Yet, as again predicted by De Schutter (2009, 6), many countries' protocols simply adopt a UPOV-like Plant Breeders' Rights framework rather than develop an authentically alternative approach. Zimbabwe, Ethiopia, and Zambia, for example, have mimicked UPOV's highly restrictive

[21] The US 'brown bag' exemption of farmer-to-farmer sales was eliminated in 1994, when PVPA was harmonized with UPOV 91.

attributes in the design of their *sui generis* IP laws. Benefit-sharing provisions found in the *sui generis* laws of Costa Rica, Thailand, India, and Malaysia attempt to recognize and reward farmer contributions to agrobiodiversity conservation, but practical sharing is marginal in relation to the extent envisioned (Andersen and Winge 2013). Even where the *sui generis* systems of India, Malaysia, and Thailand have buffered the strong PBR aspects of UPOV with additional provisions for farmers' informal seed systems, many smallholders in these countries have been unimpressed, expressing little interest in registering their varieties, despite a statutory framework in place for doing so. In India, a government body tasked with granting 'Plant Genome Saviour Community Awards' and a prize for the 'Plant Genome Saviour Farmer' has given only 32 individual awards since 2012 (PPVFRA 2015) – in a country with an estimated 99 million smallholders (Dev 2012). Thailand's *sui generis* PVP fund to reward 'local custodians' has been even less successful, a failure Robinson (2008) suggests is due to farmers' remaining very skeptical of benefits circulating through a central government authority.

Seed sovereignty

A third line of defense is organized under the umbrella of 'food sovereignty.' Broadly defined as 'the right of local peoples to control their own food systems, including markets, ecological resources, food cultures, and production modes' (Wittman 2011), food sovereignty emerged in the 1990s as an alternative to the reformist 'food security' (Fairbairn 2010), and is considered by social movements and allied scholars to be a radical, bottom-up response to financialization, free trade, and the corporatization of global food networks (Burch and Lawrence 2009; see also Conclusions). Seeds have always been central to food sovereignty, insofar as control of this basic means of (re)production is a precondition to larger sociopolitical autonomy. Indeed, the first invocations of 'soberanía alimentaria' are traceable to US dumping of corn seed in Latin America, which undermined domestic maize production (Edelman 2014) and the viability of indigenous seed systems. By 2007, at the Nyéléni International Forum on Food Sovereignty, a working definition of food sovereignty had expanded to include explicit rights to access seed (Nyéléni 2007:1; Patel 2009). Ten years on, at the VII International meeting of La Vía Campesina, seeds had become even more central to food sovereignty discourse: 'La Vía Campesina promotes peasant agroecology and seeds as the very foundation of its political vision. Peasant agroecology is based on biodiversity and ever-evolving indigenous and ancestral knowledge – and that starts with seeds' (Tramel 2017).

These recognitions notwithstanding, '*seed* sovereignty' as a distinctive concept is more diffuse and difficult to pin down. Five of the most prominent organizations around the world working on seed matters are La Via Campesina, GRAIN, Navdanya, ETC Group, and the African Centre for Biodiversity.[22] Their texts invoke seed sovereignty, but also 'seed freedom,' 'seed justice,' 'right to seed,'[23] and other variations on the theme. These groups also differ in important ways: LVC is

[22] Countless other peasant organizations, indigenous rights groups, and NGOs also work on issues of seed diversity and access (see for example, the 2012 compendium *Seed Freedom*). A particularly tight-knit relationship between historical seed struggles and food sovereignty appear in and around centers of agrobiodiversity: Andean Peru, Southern Mexico, Northern India, and Ethiopia among others. In these biocultural 'hotspots,' contestations over seed often predate (and inspire) later food sovereignty struggles.

[23] Within and alongside sovereignty activities, several prominent civil society and peasant organizations are working for 'rights to seeds' under a human rights framework. Such seed rights could be recognized by the United Nations as human rights (Human Rights Council and the UN General Assembly). This process of securing recognition has been

a huge meta-organization comprising agrarian reform groups representing ~200,000,000 peasant farmers. GRAIN is a decentralized think tank made up of 8-10 researchers in 5 countries with expertise on landgrabbing, seed grabbing, and other resource dispossessions. Navdanya, co-founded by the charismatic Vandana Shiva, is first and foremost about seeds, with principles grounded in Indian *bija swaraj*, or seed democracy. ETC Group, meanwhile, is a Canadian non-governmental organization whose energies are principally dedicated to monitoring corporate seed concentration and trade in genetic technologies. The African Centre for Biodiversity, based in Zimbabwe, is a pan-African organization that foregrounds dismantling inequalities in the food system, with a core emphasis on protecting Africa's biodiversity, traditional knowledge, and seeds. Differences aside, it is possible to see in the activities and practices of these organizations a shared analysis of seed which shapes into something like 'seed sovereignty' (Kloppenburg 2014). Principles include:

- the right to save and replant
- the right to share seed
- the right to use seed to breed new varieties
- the right to participate in shaping policies for seed

These principles, in turn, engender particular activities and political pursuits. For example, La Via Campesina has been harshly critical of the International Plant Treaty, particularly in the wake of US ratification in 2016. Rather than withdraw from Treaty working groups and consultation sessions, however, LVC has continued to lobby assertively for concrete implementation of Farmers' Rights, closing IP loopholes in the Treaty, and separating the Treaty from the DivSeek genetic information system.[24] What separates these activities from the aforementioned 'Farmers' Rights' approach is both formal and substantive: LVC and its allies engage in global policy discussions as part of a larger inside/outside strategy of food sovereignty and agrarian reform. While LVC seeks to improve the status and recognition of peasants in dominant institutions of policy and governance, reform is not a singular (or even priority) focus. 'Whether or not the Treaty recognizes those of us who are the stewards of biodiversity, we will continue to work within our own peasant seed systems,' LVC suggests (2011b; see Figure 4). Priority efforts are therefore aimed at a variety of subaltern initiatives: supporting worker cooperatives, building agroecology training schools, creating governance structures that affirm customary knowledges of peasant communities and indigenous peoples, and cultivating political 'formación' as the epistemic foundation for non-hierarchical, decolonizing approaches to production, consumption, and learning (McCune et asl. 2017; Meek and Tarlau 2016).

Beyond LVC, many regional and national manifestation of seed sovereignty can be seen in struggles against dispossessive seed laws. These laws include not only intellectual property rights, but also marketing regulations, trade and investment agreements, and biosafety laws that collectively impinge upon territories of farmer-reproduced seed (Wattnem 2016). Such is the case in Ghana, where students and trade unions have joined smallholders in mobilizing against a particularly pernicious PVP bill, which states that 'in absence of proof to the contrary,' breeders

underway since 2012, with new developments visible in publications such as GRAIN's 'The Right to Seed' (2017) and LVC's 'Our Seeds, Our Future' (2013).

[24] 'The DivSeek initiative do not consider at all Farmers' Rights, but threatens them dangerously,' wrote Guy Kastler of La Via Campesina and coauthors on the IPC Working Group on Agricultural Biodiversity (2017).

can be assumed to be the owners of a variety in question. By these rules, breeders, but not farmers, become the default 'owners' of seed. Similar struggles have recently been documented in more than 22 countries: from Venezuela, Chile, Costa Rica, and Mexico to Ethiopia, Malawi, Tanzania, Niger, Mali, and Mozambique; from India, the Philippines, Indonesia, and Thailand to Italy, France, Austria, Germany, Greece, the UK, and the US (USFSA 2014; GRAIN and LVC 2015; GAFF 2016; Wise 2016).

Figure 4. La Vía Campesina and the Plant Treaty. At the 2016 Global Consultation on Farmers' Rights in Bali – organized by the International Treaty on Plant Genetic Resources for Food and Agriculture – Tanmay Joshi, a young farmer from the state of Maharashtra, condemned ongoing subordination of peasant seeds to IPR laws. Representing La Vía Campesina and the Indian Farmers Movement, he reminded the assembly of real-world exigencies. 'Right here in Indonesia where the consultation is taking place,' Joshi said, 'peasants in East Java have been criminalised and jailed for using their own seeds' (LVC 2016). How can rights be a subtext of an IPR law when peasants come from traditions in which seeds are the collective heritage of people in service of humanity? 'Our rights, our needs, our identities,' he concluded, 'have been defined on behalf of us, but not by us.'

Seed laws also provide insight into struggles over sovereignty often imagined as emancipatory struggles against corporations and neoliberal States. The reality on the ground is almost always more knotty. In Ecuador, for example, peasant and indigenous grassroots movements were instrumental in incorporating food sovereignty into the country's progressive 2008 Constitution; it is now *de jure* state obligation and national strategy to ensure that all peoples have access to culturally appropriate, nutritious, and healthy food. In turn, the food sovereignty clause has become the legal basis for a number of policy changes in Ecuador, including the 2009 Food Sovereignty Law, the 2014 Water Law, the 2016 Land Law, and the recently approved 2017 Seed Law. Taken together, these laws represent a cornerstone of Left-wing government commitments across Latin America to enable agrarian revolution through radical reforms (a.k.a. the 'pink tide' in Southern politics; Weinbrot 2017). However, Peña suggests, the Seed Law is already provoking widespread social movement concern. Approved by Ecuador's President Moreno in June 2017 after Rafael Correa accepted a preliminary version, the Seed Law calls for protection of agrobiodiversity and recognition of traditional forms of seed saving and exchange. But without popular consent, the law was amended to allow for genetically modified organisms in the country as long as they are used for scientific research. Now a number of local agrarian and environmental groups are claiming that the Seed Law – originally designed to protect their agrobiodiversity – is unconstitutional, on the basis that GMOs are banned in Ecuador.

With Left-on-Left contestations, bottom-up and top-down invocations of 'sovereignty,' and indigenous territorial rights in play, the broader issue, argues Peña (2017), are the social processes by which seed laws designed have come into place. Like the Land Law, the Seed Law initially seemed to evoke 'participatory democracy' in action. More than 15,000 people, representing hundreds of grassroots organizations, convened over two years in a series of policy-making workshops. They drafted early model seed legislation based on these discussions. A pre-legislative Consultation process garnered approval of Ecuador's indigenous peoples. Over lengthy dialogue and debate, a range of Ecuadorian civil society groups, native communities, and peasants were eventually able to devise protocols that would support their interests (and be in harmony with international ILO standards). But these drafts, though approved by the national Congress, were later partially vetoed by Correa, opening the door to GM crops and their affiliated corporate interests. 'Both the Land Law and Seed Law are clear examples of the limits of participatory democracy in Ecuador,' says Peña.

Such are the politics of sovereignty in seed. Even where socialist governments struggle against the very forces of colonialism and capitalism that widely simplify seed systems and dispossess their cultivators, state institutions infrequently escape the nature of state sovereignty to be sovereign 'over' rather than sovereign 'with.' In their current ambits to thwart neoliberal power, Bolivarian governments therefore illustrate seed sovereignty as an aspirational movement: emerging as a product (and sometimes in spite) of state-social movement interactions, grounded in locally specific seed and land struggles, and pulled through 'the looking glass world' (c.f. Galeano) of historical engagements with globalization. Where Leftist states aren't willing/able to empower local people to reclaim their seeds and seed cultures, they call attention to unsettled tensions in sovereignty: Who gets to be sovereign? What happens when overlapping sovereignties conflict? If the State is a traditional 'guarantor' of rights, who guarantees the sovereignty of popular movements? The sovereign rights of refugees, migrants, and stateless peoples?

In vivo

To be sure, many contemporary reclamations of seed do not explicitly invoke 'sovereignty.' They have nothing to do with negotiating Plant Treaties, nor with crafting *sui generis* governance. Countless acts of repossession fall under the looser net of uncertain intentions, quotidian life, and contingent everyday practices – what Nazarea, Rhoades, and Andrews-Swann (2013) have termed the 'in vivo' expressions of renewing diversity. Examples can be seen in St. Louis, Missouri, where bitter eggplants are making their way into local cuisine, courtesy of refugees fleeing conflict regions of Burundi, Myanmar, and Nepal (Hesson 2015). They can be found in the Little Garden Haiti of Miami, a spot where the area's Haitian expatriates come to plant native *callallo* and *calabaza*, reconnecting to each other and to familiar crops and seeds (MacKenzie 2016; see also Figure 5). They can be found as well in Richmond, California, where schoolteachers started a quiet revolution in public libraries. Today, and despite significant legal challenges in some states, the 'seed recirculation' model has taken root, and there are now at least 300 public seed libraries in 46 states (Steinberger and Petersen 2016).[25]

Differences and internal frictions notwithstanding, the preceding activities represent promising complementarities, insofar as they occupy distinct niches in the broad terrain over which dispossession treads. Farmers' Rights and *sui generis* strategies combine legalistic and community-based approaches in negotiations that span conservation organizations, agrarian reform movements, transnational policy institutes, governments, philanthropy capital, and industry. Using what may be called a 'master's tools' approach (c.f. Lorde 1984), they work with extant structures of political economy and law endeavoring to transform the system from within.[26] By the same logic, master's tools embed their own biases, and negotiating tables are seldom 'flat': uneven positions of wealth, power, and epistemic legitimacy limit the range within which participants can maneuver - who gets to speak. In answer, the declarative posture of 'sovereignty' moves to reconstitute social and material means of reproduction. In foregrounding political rights, seed sovereignty abandons the master's tools in favor of radical redistribution of resources and epistemic justice. Emphasizing local decision-making, food democracy, and non-hierarchical recognitions of race, gender, and class, seed sovereignty joins food sovereignty in being, at their core, *attempts to address base inequalities in power* (Patel 2009, emphasis added). Less explicit than seed sovereignty, *in vivo* resistances ferment in quieter spaces around and within it. What tethers many everyday practices together is an embodied and living memory of seed – a ghostly recalcitrance to dispossession, a form incorporated 'into values that are smuggled into the present and future' (Nazarea 2013, 24).

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Despite these ongoing resistances, the forces of late neoliberal enclosures are proving difficult to impede. For every re-possession, there appears to be another free trade agreement, another merger, another IPR law, another move to separate people, land, and their seed. Marx's *Capital* predicts where such trends should be headed: The tendencies of capitals to concentrate and monopolies to form predicts the polarization of economic enterprises into the antagonistic classes of capital and labor. By this logic, peasants and their seeds should both differentiate, melting into proletarian categories, dwindling in varieties and numbers, vanishing as a category, if not actually going extinct.

That peasants and their seeds have manifestly *not* disappeared could mean many things. Perhaps it implies, as much Agrarian Question scholarship suggests, that agriculture is 'exceptional' – it will not conform neatly to trajectories of industrial development. It will not abide smoothly by

[25] Illustrating the interdependence of 'formal' and 'informal' institutions, policy work has also been instrumental to the success of the seed library movement. Several states, including Delaware and Pennsylvania, were attempting to establish libraries based on the Richmond model when it became apparent that state biosafety and commerce rules would make doing so illegal. The Oakland-based Sustainable Economies Law Center was pivotal to overcoming these obstacles in California. After months of SELC lobbying to remove regulatory barriers to non-commercial seed sharing, in 2017, Governor Jerry Brown signed into law the California Seed Exchange Democracy Act. The CSEDA has now become model legislation for seed access advocates in other states.

[26] 'For the master's tools will never dismantle the master's house. They may allow us to temporarily beat him at his own game, but they will never enable us to bring about genuine change' (Lorde 1984, 112).

Figure 5. Refugee Seeds. Renuka Pokhrel of Bhutan works in her family's garden plot in the Global Garden Refugee Training Farm in the Albany Park neighborhood of Chicago. About 100 families, including refugees from Bhutan, Myanmar and elsewhere, have plots in the community garden. At a time when President Donald Trump has called for a reduction in the number of refugees admitted to the US, says reporter Alison Bowen, 'the farmers here on the Northwest Side find comfort and purpose in the digging, planting and harvesting that made up their life's work in their home countries' (Bowen 2017). Refugees, as defined by the UN, are persons forced to flee from their countries to escape war, persecution, or natural disaster. Perhaps the custodians of these gardens are not particularly motivated by seed conservation, nor by struggles to reclaim sovereignty. Yet in their everyday – in vivo – practices, they are often keeping alive the memories of seed breeding and cultivation. These are epistemic tracks in which repatriation treads (Nazarea 2013). (Image credit: Erin Hooley/*Chicago Tribune*.)

logics of efficiency; it will refuse pat divisions of labor, specialization, and the unrepentant march toward labor-saving machine. Maybe it implies that obstacles of nature interfere, that weather, soils, and organic life interrupt capital's control of labor – and, thus, the accumulation of profit – with their own quirky rhythms in space and time.

Perhaps it means, too, that peasants are not passive actors here. Individually and collectively, they are both re-active and active. They respond to dispossession in ways predicted by Polanyi – moving to defend themselves against 'disembedded' markets, and the inevitable immolation of life, labor, and land. They also inform a more active theory of social change: one more imbued with politics, more expressive of subaltern agency. Deploying shared meanings, symbols, and knowledge-making strategies, peasants are reclaiming political discourse, identifying strategic points of intervention, and educating organically. Uniting groups beyond conventional class formations, they are learning what it means to organize. It is this light, I suggest, that the broad front of seed resistances depicted above –Farmers' rights, *sui generis*, seed sovereignty, 'in vivo' renewal – collectively sketch a more robust line of repossession. Where communities are working in many civil society spaces, at diverse ecological scales, and employing a critique of political economy, alongside tactics based on jurisprudence, human rights, and embodied memory, they match the diversity and dynamism of capital's advances. In time, and by coordinating together, they may not only slow the advances of enclosures, they may overtake them – making the material and cognitive space to organize an alternative social order.

Just as the question of peasant persistence continues to embroil scholars, activists, and social movements to this day (Bernstein 2014; van der Ploeg 2008, 2014; Akram-Lodhi and Kay 2010), I began my thesis by considering the 'paradox of seed persistence' as a puzzle worth unfolding. Applied to seed, a determinist Marxist theory would predict that all around us, peasant seeds are destined to differentiate into classes of, on one hand, hybrid, genetically modified, and otherwise 'capitalist' seed, and on the other hand, 'worker' germplasm stowed in genebanks and from which traits (and surplus value) are mined. The living, in situ, form of agrobiodiversity reproduced by farmers? These peasant reproductions should predictably perish, a casualty of the IPR portfolios that Dow, Dupont, and Monsanto expand year-to-year. Much data indicates that such developments are imminent: severe crop genetic erosion is documented around the world. Fewer crop varieties are grown, and diets are globally less diverse. Other evidence, however, points to curious contrary currents. My first paper thus began by dropping seeds into the Agrarian Question: 'How much of this, to borrow from Lenin, is 'an already accomplished fact,' where peasant seeds are 'completely subordinated to the market' (1899, 130)? How much, to borrow from Kautsky, will 'follow a complicated and contradictory line of evolution?' (Banaji 1980 [1899], 65) Why does the answer to this seed paradox matter – and for whom? ∞

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Chapter 3

Are We Losing Diversity? Navigating Ecological, Political, and Epistemic Dimensions of Agrobiodiversity Conservation

Montenegro de Wit, M. 2016a. Are We Losing Diversity? Navigating Ecological, Political, and Epistemic Dimensions of Agrobiodiversity Conservation. *Agriculture and Human Values* 33(3): 625-640.

Abbreviations

CBD	Convention on Biological Diversity
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
GCDT	Global Crop Diversity Trust ('Crop Trust')
FAO	Food and Agriculture Organization
HYV	High-yielding varieties
NSSL	US National Seed Storage Lab
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture ('Plant Treaty')
SNP	Single nucleotide polymorphism
SSR	Simple sequence repeat
STR	Short tandem repeat
USDA	United States Department of Agriculture

Abstract: Narratives of seed 'loss' and 'persistence' remain at loggerheads. Crop genetic diversity is rapidly eroding worldwide, we are told, and numerous studies support this claim. Other data, however, suggests an alternative storyline: far from disappearing, seed diversity persists around the world, resisting the homogenizing forces of modern capitalism. Which of these accounts is closer to the truth? As it turns out, crop biodiversity is more easily invoked than measured, more easily wielded than understood. In this essay, I contend that the impasse reveals an error in the asking. We must, instead, look to the ontological, epistemic, and narrative dimensions of agrobiodiversity–and to the science, politics, and cultures of each. How is diversity empirically defined and measured? Who creates and categorizes diversity? Who does not? How is such knowledge mobilized in the accounts and narratives of different interest groups? Where, when, and why does a narrative hold true? This multi-dimensional view of agrobiodiversity makes space for a greater understanding of how diversity is created, maintained, and renewed. It suggests policy and institutional support for systems that engender such renewal of diversity, both in and ex situ.

Keywords: Agrobiodiversity; Seeds; Ex situ; In situ; CGIAR; Agroecology

Introduction

Researchers, science writers, documentarians, and even Twitter tell us we are in the midst of mass extinction. The planet is losing biodiversity more rapidly than at any point in history since the start of the Holocene. The sixth extinction is upon us, and agricultural loss is no exception. FAO data indicates that just 15 crops now account for 90% of the world's energy intake, with the majority of ingested calories coming from just three plants: rice, wheat, and corn (FAO 2015). According to a 2014 study published in the Proceedings of the National Academy of Sciences, human diets on a world scale have become significantly more homogeneous over the past 50 years – the result of a few major grains crowding out regionally and locally important varieties (Khoury et al. 2014). At the 2014 World Organic Congress, one speaker noted 'In the last half century, the industrial food chain has destroyed 75% of the genetic diversity of our food chain' (Lappé 2014).

As modern production systems, globalized supply chains, and free trade press Northern farmers to grow fewer crops and fewer varieties of each, and as 'improved' cultivars displace, replace, and contaminate traditional seeds across the global South, there seems plenty of reason to fear a decline of crop diversity around the planet.

But, as I discovered when trying to unpeel the agrobiodiversity onion, the question of 'loss' is far from settled. Amidst global concern over crop genetic erosion, there is conflicting evidence as to whether loss is indeed occurring. For every account of vanishing species and varieties, counter-evidence finds stability, or even increase – in colloquial terms, 'persistence.' How much diversity is being 'lost,' where, why, and how is such loss measured? Is loss continuous and smooth? Sporadic and punctuated? Equally distributed amongst places and peoples, or spatially and socially uneven? For whom and by whom do losses occur? What are the effects of loss narratives – that is, the upshots of saying species are vanishing?

Despite many advances in botany, ecology, and biogeography over the past 25 years, the empirical data on crop genetic diversity loss remains sketchy enough to fan an intransigent debate. Are farmers everywhere being pulled into the orbit of high-yielding, homogenous cultivars? Or do they persist in feeding themselves – and meeting 50–70% of the planet's food supply – with diverse, indigenous seed? Is the world losing crop genetic diversity at a breakneck pace? Or are more varieties being planted, bred, and marketed than ever before? Is agrobiodiversity being lost? Or not?

In this essay, I contend that agrobiodiversity debates remain at a stalemate because of the very way these questions are conventionally posed. The impasse may expose an error in the asking. What first appears to be a contradiction between accounts of loss and persistence reveals, instead, a conflation of ontological, epistemic, and narrative dimensions. 'Loss,' I will argue, is inseparable from the being, knowing, and telling of agrobiodiversity – as well as from the scientific, cultural, and political forces these engagements invite. How is diversity empirically defined and measured? Who creates and categorizes diversity? (Who does not?) How is such knowledge mobilized in the accounts and narratives of different interest groups? Where, when, and why does a narrative hold true?

Loss and persistence are changes in diversity over time and space. So this essay begins with evolution and migration, where movements of seed shape the geography of diversity, while human and environmental selections inscribe its genetic foundations. It then moves to the puzzle of diversity's structure: how is agrobiodiversity distributed within and across geographic sites? How do different scales of analysis affect conclusions about where and how much diversity exists? Next, I consider social practices for recognizing and identifying crop resources, comparing farmer-names and descriptions with the genotypic portraits now standard in science. Narratives of loss and persistence seldom capture these underlying complexities. Yet they influence policies and practices for conserving crop diversity in ways that warrant our attention. Claims of loss (often inflected with urgency and apocalypse) help legitimize a particular strategy for seed conservation, while potentially skirting the underlying drivers of loss. A look at uneven social and spatial patterns in agrobiodiversity helps elucidate for whom, where, and why loss occurs. Building on this analysis, I conclude with questions that researchers and practitioners can ask, informing strategies to strengthen seed systems that are rich in diversity – of genes, knowledge, and ecologies of many types.

See me? I'm on the ground, saving seeds

In a 1991 piece in the journal *Economic Botany*, anthropologist Stephen Brush questions conventional wisdom about crop genetic erosion. Reviewing empirical research in Peru, Mexico, and Thailand, Brush finds that widespread adoption of contemporary 'improved' varieties has seldom had the effect of displacing traditional landraces. In many cases, farmers who adopt hybrid seeds continue to grow traditional varieties – often dividing their fields into mixed cropping systems for this purpose. These farmers see no need for 'either/or,' as there are different purposes for different seeds: hybrids are seen as commercially valuable, good for cash revenue. Landrace varieties, meanwhile, hold superior value for coping with ecological and climatic stresses, as well as for cooking and eating – they are the staff of life and the stuff of many a medicine, salve, and ritual. As a result, at least in Peru, Brush finds more genetic diversity in commercialized agroecosystems than in traditional ones. Though details and conditions differ, case studies in Mexico and Thailand suggest similar 'de facto' conservation of crop diversity.

Brush is far from alone. In a major review of farming systems worldwide conducted by Jarvis et al. (2011, 126), the authors conclude not only that traditional varieties are being maintained, but that farmers may be increasing their use of landraces in response to climate change:

> Although it was widely assumed for many years during the 1970's and 1980's that traditional varieties would be rapidly and completely replaced by modern varieties…, this has not been the case in many production systems. Traditional crop varieties still meet the needs of the farmers and communities where they occur. Indeed, recent studies suggest that one of the responses of poor rural communities to climate

> change is to increase the use of traditional materials in their production systems…

Over the last two decades, many studies, both small-scale and large, have provided substantial evidence that significant crop genetic diversity continues to be maintained in farmers' fields in the form of traditional varieties (Bellon et al. 1997; Brush et al. 1995; Brush 2004; Jarvis et al. 2004, 2008; Bezançon et al. 2009; Kebebew and McNeilly 2001; Guzmán et al. 2005; Bisht et al. 2007; FAO 2010; see also Jarvis et al. 2011).

Juxtapose this portrait with a large literature that takes as its point of departure a roll call of species loss and varietal decline. In a heavily cited 1990 work, *The Threatened Gene*, Cary Fowler and Pat Mooney describe uniformity in agriculture growing at an accelerating rate, as control over the gene pool shifts from farmers to scientists to titans of industry. 'Genetic erosion is fast gathering pace,' they warn, and the losers will inevitably be the planet's poor. Their argument is not purely rhetorical. Gathering data from the US National Seed Storage Lab (NSSL) – among the world's largest repositories of crop germplasm – Fowler and Mooney document a steep decline of diversity in food crops over the past 80 years (1903–1983). For vegetables and fruits, they cover the A–T (asparagus to turnip) of varietal loss, which ranges from a high of 97.8% to a *low* of 89.9%. Common beans (*Phaseolus vulgaris*) that used to number some 578 varieties have dwindled to 32. Carrots (*Daucus carota*) have gone from 287 distinct types to 21. What were once 46 discrete asparaguses (*Asparagus officinalis*) have collapsed to just one. In the eastern US, more than 7000 apple varieties once dotted orchards from Tennessee to Maine. Nearly 90 percent have all but disappeared.

A World Resources Institute publication (Thrupp 2000 [1998]) depicts similar losses in both Northern and Southern hemispheres, highlighting the roles of agri-food industrialization and expansion of Green Revolution technologies. 'In Bangladesh, promotion of HYV (high yielding varieties) rice monoculture has decreased diversity, including nearly 7000 traditional rice varieties and many fish species…In the Philippines, where rice has been the principle staple for generations, HYVs have displaced more than 300 traditional varieties.' Similar patterns in staple grains are reported in the US and Europe as traditional cultivars suffered the introduction of hybrid and biotech crops. Thousands of flax and wheat varieties have vanished from Europe after the introduction of HYVs, and oats and rye are also on the decline. 'As diverse systems have been displaced, eroded, and eliminated,' the author concludes, 'monocultural models have become predominant…These changes affect the broad agricultural landscape, transforming the countryside from a rich mosaic of crops and plants to monotonous uniformity' (Thrupp 2000, 273).

The contrast between these narratives, and the evidence they marshal, is striking. Their respective claims, furthermore, have hardly budged in the last 25 years. What are we to make of their dissonant data, their seemingly irreconcilable accounts of loss? Is one more reliable, adequate, even true, than the other? If so, how are we to know? As it turns out, crop biodiversity is more easily invoked than measured, more easily wielded than understood. Before turning to the complexities that confront empirical verifications of diversity loss or persistence, it helps to turn to the fields of political economy and rural sociology. Here, a debate with striking parallels has unfolded over the past century in the guise of the 'Agrarian Questions.' These questions, I suggest, are also implicitly about diversity – diverse pathways of development and diverse farming systems, diverse ways in which capitalism articulates with farmer cultures, knowledges, and ecosystems in shaping agrarian change.

Planting a seed in restructuring

Since the time of Lenin, Kautsky, and Chayanov, most political thinkers concerned with the fate of agrarian society have predicted that small farmers would vanish under the weight of industrialization, globalization and capitalist expansion. But so far, this prophecy has yet to be fulfilled. The work of van der Ploeg (2008, 2014) is exemplary here: peasants have not disappeared, his work reveals, and globally, rural populations have stabilized. While most population growth in the past three decades has been in urban centers, at least 1.5 billion smallholders continue to inhabit farmscapes around the world. We may, in fact, be witnessing re-peasantization, as people return from city to countryside in non-negligible numbers. The peasantry is infinitely more persistent than anyone imagined.

The more obvious relationship between these long-standing Agrarian Questions and agrobiodiversity stems from the issue of peasant viability. If traditional, indigenous, and small-scale farmers are destined to differentiate and 'disappear,' lost in their traces will be their knowledge and practices, the territories they cultivate, the spaces and processes in which agrobiodiversity is created and maintained. If, on the other hand, there is some stability to be found in the articulation of peasants and capitalist expansion (however uneven or unstable), perhaps agrobiodiversity in situ has a longer lease on life.

In order to measure agrobiodiversity loss and persistence, of course, we must first define 'agrobiodiversity' – which is a tricky matter. We must reflect on how crops evolved from undomesticated plants to constitute all the crop variety there is. We must consider geographical flows of germplasm, and movements of people and seed over history and territory. These movements have configured where diversity exists, and the benefits conferred when it persists.

Genes in the field: Where does diversity come from?

As defined by Qualset and Shands (2005), agrobiodiversity refers to the variety and variability of living organisms that contribute to food and agriculture in the broadest sense, and the knowledge associated with them. Although I will return to this more expansive definition later, my focus here is on cultivated crop diversity, with particular attention to farmer varieties, or 'landraces.'[27]

[27] Landraces are mixed populations of seed recognized as morphologically distinct from other landraces, with a degree of genetic integrity, but also with considerable genetic variation. Like a polyculture within a single variety, each individual in a landrace population is genetically distinct from the next individual. Being genetically dynamic, the phenotypic makeup of a population is likely to be different from year to year, conferring both benefits and risks (Kingsbury 2011).

This focus is merited partly because these crops support an estimated 1.4 billion people, whose farm families are largely self-reliant and self-provisioning for their seeds and other planting materials. These small-scale farmers are thought to produce somewhere between 50 and 80% of the world's food supply (Graeub et al. 2015; FAO 2014).

It is also merited because landraces are the fulcrum of the crop diversity 'loss' debate. Like all biological evolution, crop evolution involves two fundamental processes: the creation of diversity and the selection of diversity, a means of identifying and screening the most suitable variants (Harris and Hillman 2015; Murphy 2007). As agriculture emerged some 10,000–12,000 years ago, people began – unintentionally, at first – shaping and adapting wild plants through the simple act of saving seed. Diversity was continually wrought through random gene mutations and recombinations, while selection included two types: 'natural selection'[28] within the always changing ecosystem, and 'artificial selection'[29] by human eaters. These co-evolutionary processes first emerged in eight 'Vavilov Centers' of origin for domesticated crops, and from there, radiated outwards to agroecological niches around the world.

Seeds cannot radiate themselves, of course, and this movement was far from passive. Imperialism, spanning the fifteenth century to nineteenth centuries, dramatically remixed gene pools and brought a proliferation of new varieties. European explorers, traders, travelers, and plunderers brought 'Old World' crops to 'New World' frontiers, transplanted germplasm across tropical colonial holdings, and shepherded commercially promising seeds back to the European continent. As crops were introduced to new soils and climates, a flurry of selection activity ensured that transplants could succeed in their new homes, where pests, diseases, and other maladies were unfamiliar to both the plants and their cultivators. In the eighteenth century, a network of botanical gardens and research institutions was established in Europe and, later, in the US, to spearhead this formal adaptation effort. Yet it was farmers on the ground who informally led the way. 'Arguably, the most important work,' according to horticultural ecologist Noel Kingsbury, 'was done by countless small farmers in South America, Africa, and Asia who grew the newly arrived crops, and over the first few generations began the process of making new landraces, adaptable to their conditions and tastes. Such innovative traditional farmers are truly among the great unsung heroes of plant breeding' (Kingsbury 2011, 100).

The diversity in landrace gene pools is therefore unsurprisingly vast: it reflects millennia of interplay among genes, ecosystems, biological and cultural knowledge. It embodies flows of germplasm through conquest, exchange, appropriation and emergence of new political economies. It represents constant local human-ecosystem adaptation – with the opportunity to

[28] An important wrinkle for 'natural selection' within agroecosystems is that the nature in agriculture is profoundly shaped by human hands: by removing competitor plants ('weeds'), offering water when there is otherwise none, and enhancing soil fertility.

[29] Charles Darwin described three types of selection, natural selection and two types of human selection—one conscious and the other unconscious: '*Methodical selection* is that which guides a man who systematically endeavors to modify a breed according to some predetermined standard. *Unconscious selection* is that which follows from men naturally preserving the most valued and destroying the less valued individuals without any thought of altering the breed' (1875, 177–178; original emphasis).

differentiate on a world scale. 'The result,' Brush notes, 'is a legacy of genetic resources that today feeds billions of humans' (Brush 2000, 3).

Measuring diversity: How much is out there? How do we know?

Patterns of distribution

If the importance of crop genetic diversity – biologically, ecologically, socially – has been affirmed through decades of empirical research, the question of 'loss' still runs headlong into issues of quantifying diversity to begin with. Analysis of how diversity is structured – that is, its extent and distribution – therefore become central to understanding the lineaments of change.

Ecology and conservation biology have supplied useful tools for measuring diversity. Metrics of 'richness,' 'evenness,' and 'divergence,' often used in wildlife research, are now being increasingly applied to agricultural systems, where crop varieties can be parsed both within and among communities on the farm (Jarvis et al. 2008, 2011). Richness here refers to the number of types of a specific crop, regardless of their abundance – 35 potato varieties, for example, grown in an Andean farmers' field (Huamán 1986). Evenness, in turn, takes into account the population sizes; this relative abundance provides a glimpse into whether the community structure is very even–say, 10 plants of each of 10 potato varieties–or is dominated by a select few (a potato ratio of 91:9). Divergence, meanwhile, reflects how evenness and richness are structured between, rather than within, individual farms (Frankel et al. 1995; Magurran 2003). Two neighboring farms may host the same 40 crop species; they would be equally rich and the divergence would be nil. But the first farm might host a different 40 crops than the second farm, making their divergence very high. Divergence, then, measures turnover between spaces/places, as opposed to local diversity.

With these metrics in mind, it is possible to return to headline grabbers such as: 'Our Global Diet is Becoming Increasingly Homogenized–and That's Risky' (Walsh 2014). This popular media article, and many others like it, highlighted the sobering conclusions of a study published in the *PNAS* in early 2014 (Khoury et al. 2014).

Gathering more than 50 years of data from the FAO, the researchers discovered that human diets are becoming more similar over time – by an average of roughly 36% in the past half century. With liberalized trade rules allowing the spread of global food brands, and farms matching consumer demand with vast monocultural production systems, the contribution of a few staples– namely, corn, soy, and wheat – have grown to mammoth proportions. As a result, lead author Colin Khoury told the press, 'the regionally important, locally important crops are becoming marginalized' (Baragona 2014).

These findings are seemingly straightforward: more sameness everywhere. Yet closer scrutiny illustrates the importance of clarity when it comes to defining and bounding 'diversity'–and the handiness of metrics such as richness, evenness, and divergence. What the *PNAS* study revealed, paradoxically it initially seems, was both more diversity and more sameness. Globalized trade has brought more diversity into individual countries: kiwis traded from the tropics, shellfish shipped from Southeast Asia, ‘ancient grains’ imported from Andean hills. If diversity is measured in terms of the number of types of food available – that is, the ‘richness’ quotient–most countries’ diversity index has gone up. On the other hand, if diversity factors in ‘evenness,’ which takes relative abundance into account, it becomes clear that the world food supply is highly uneven, dominated by a few major grains. Different metrics of diversity, in other words, mark the difference between the modern consumer’s view of eclectic variety – supermarket shelves stocked with assorted goods, delivered from all parts of the world – and the actual contribution of crops to world food supply and human diets.

Historical changes in crop diversity can also be illuminated through patterns of richness, evenness, and divergence. In the mid-nineteenth century transition from landraces to the first modern varieties, the rich genetic diversity of mixed landrace populations gave way to varieties with more genetic uniformity within each varietal ‘line’ or ‘strain.’ Yet these varieties were also highly distinct from one another (high divergence). This was the teething phase of systematic plant breeding in Europe and the US, during which time landraces of grain and horticultural crops became the basis for developing more uniform and stable varieties; breeders would select just one or a few promising individuals from a landrace population and propagate them to form homozygous inbred lines. Thus, the breeder-led explosion of diversity spanning the mid-nineteenth to mid-twentieth century brought a gain in diversity of one type, but loss of another: across much of the European ‘Old World,’ a long legacy of farmer-bred diversity was slowly edged out. Patterns of loss were different, however, in the newer agro-economy of America, where one of the most ambitious public seed distribution programs in history unfolded in this era, emphasizing local agroecological adaptation. Over the next 50 years, Green Revolution innovations would press the frontier of seed introduction and seed displacement into the global South. By this time, however, breeding practices had shifted as well, resulting in changes to crop genetic diversity all presaging ‘loss’: less richness, less divergence, and greater dominance by a few high-yielding grains.

Here, the ontologies of diversity (what ‘is,’ or exists, materially), the epistemologies of diversity (how we know about what is), and the narratives of diversity (the claims we make, based upon what we know) reveal conflicting currents. These frictions are further illustrated in practices for naming and identifying agrobiodiversity. Distinctive methods employed by scientists and farmers to describe and measure crop diversity make for a fascinating, at times contradictory, picture of what exists on the ground, in society and nature.

Naming diversity, culturally and biologically

Farmers have traditionally identified their seeds and crop varieties using a combination of distinctive farmer names and descriptive traits. Evocative names such as Mattamuskeet, Forward Sour, Hollow Log, and Frost Proof describe traditional varieties of apple from Appalachia, for example (Veteto et al. 2011). Such farmer names can give insight into how crops have adapted to farmers’ environments and their preferences – whether agronomic, aesthetic, or culinary. Farmers also distinguish varieties with descriptions of their traits, including growing behaviors and ecological adaptability as well as harvesting, processing, cooking, and nutritional qualities.

Plant researchers, meanwhile, may employ taxonomic categories to identify crops and agro-morphological field data such as rooting depth, leaf size, or stem thickness. Molecular methods, especially those based in genetics, provide further entrée into classifying diversity at the DNA level.

All of these methods represent distinctive epistemologies of recognition – different ways of 'seeing' crop diversity and marking one set of organisms as distinct from another. Taken together, they allow for investigations into how observed (i.e. epistemological) diversity relates to environmental, social, and cultural factors in agricultural systems. They also offer insight into how different classification systems – say, between farmer names and genotypes – may conflict or be reconciled.

In a paper published in 2011, Jarvis and colleagues conducted an ambitious review of natural- and social-science studies that consider various aspects of identifying diversity. Much like the different structural aspects of diversity explored above (richness, evenness, and divergence), classification and naming customs provide critical information about how diversity is patterned and distributed in agricultural systems.

As importantly, farmer-names offer clues into the cultural and ecological systems that create and maintain such diversity. In Mexico, the primary center for maize diversity, X.E. Hernández's work revealed that indigenous farmers have extensive knowledge of maize populations. This knowledge, he found, was highly specific to local agroecologies, including soil and water management and intercropping of multiple species. To further understand how farmers perceive different characteristics of named varieties, Bellon and Taylor (1993) surveyed indigenous farmers in Chiapas. They discovered a sophisticated folk soil taxonomy, which helped guide maize variety choice. Farmers spoke of six distinct maize races – Olotillo, Tuxpeño, Argentino, Tepecintle, Zapalote Grande, and Naltel – each of which encompassed several varieties that farmers understood to have particular traits, and therefore, particular purposes. Conversations with farmers reflected their deep knowledge of how each variety responded to ecological conditions (drought, wind, weeds, performance with intercropping), technological requirements (input intensity, timing of cultural practices), and yield and use (aptness for subsistence or market, storage properties, taste).

Farmer-names may also yield information about trends in crop diversity over time – essential when it comes to interrogating 'persistence' or 'loss.' In rice systems in Gambia, Nuijten and Almekinders (2008) found that farmers distinguished amongst three types of names: those referring to common 'old' varieties, to common 'new' varieties, and to uncommon or 'rare' types.

Provocatively, some research has even suggested that naming practices do not merely recognize diversity, but actually help *create* it. Work by Brown and Brubaker (2002) indicates that when farmers or communities believe that a named cultivar has particular properties and uses, they are more likely to employ management practices that reinforce its identity and distinctiveness. Such dynamics may help explain the cornucopia of diversity seen in US Appalachian landscapes. Like other mountain agroecosystems, this region is characterized by multiple microclimates, and relatively isolated farming communities in hills and 'hollers' across the region. If Brown and Brubaker are right, such diversity would likely gain reinforcement through the names that farmers and gardeners have attached to their Appalachian varieties.

Farmer-given names have proven remarkably reliable over time and space, and are a strong first approximation of the extent and distribution of on-farm diversity. But researchers have become curious as to whether farmer typologies might square with knowledge systems based in Western scientific practice. Do scientists resolve 'difference' in a manner consistent with the diversity recognized through lived experience?

Biologists have in their toolkit a number of molecular methods to assess crop diversity. Phylogenetic analysis, functional genomics, and an alphabet soup of microsatellite markers–SSR, STR, and SNPs[30] –now enable researchers to assemble a picture of the extent and distribution of diversity at the gene scale (Brown and Hodgkin 2007). As described by Jarvis et al. (2011), several studies have reviewed these technologies, assessing the advantages and disadvantages of each, their utility in breeding for stress tolerance, and their role in a composite approach to the molecular characterization of plant genetic resources. Markers also confer predictive power, as a crop's genetic makeup enables breeders to select for successful variants without ever having to grow seeds to maturity.

But arguably more interesting than the advances ushered in by these new molecular portraits is their juxtaposition with cultural taxonomies. To what extent do genotypic renderings correspond to human experience with phenotypes in a landscape? How faithfully do scientific metrics of diversity map onto farmers' perceptions and assessments of difference?

Many studies have compared descriptions supplied by farmers to distinguish their crop varieties with agro-morphological, biochemical, and molecular descriptors used by researchers in an attempt to assess overall diversity in traditional varieties. Jarvis et al. (2011) review a swathe of this work, which is, unsurprisingly, capricious. In some cases, the number of traditional varieties in a production system as tallied by farmer-names is corroborated by genetic data. In other cases, names do not appear to fit the patterns of diversity suggested by molecular mapping, but do align with those measured by farmer descriptions of crop traits in the field (Sadiki et al. 2007; Baymetov et al. 2009). Several findings are unique to crop and country. For sorghum in West Africa, there is a low correlation between diversity of farmer-names and genetic diversity assessed by microsatellite markers (Sagnard et al. 2008). By contrast, in low-lying regions of Nepal, the richness of traditional rice diversity as counted in farmer-names maps closely onto diversity measured by biologists' SSR methods. However, at higher elevations in Nepal, where farmers distinguish amongst 20 different rices based on color, the varietal discrepancies are not borne out by simple-sequence repeats.

[30] Microsatellites, also known as simple sequence repeats (SSRs) or short tandem repeats (STRs), are sequences of 2–5 base pairs repeated hundreds of times in a DNA strand. STR analysis can compare specific loci from two or more samples, measuring the exact number of repeating units. Single nucleotide polymorphisms (SNPs) are DNA sequence variations occurring commonly (e.g. 1 %) within a population.

In short, there is as much heterogeneity across these comparative studies as across the landraces they seek to investigate. Distinctive ways of knowing evade tidy reconciliation: the lens of a farmer, a cook, a plant physiologist, and a geneticist all yield different views. When the truth according to microsatellites collides with the truth of Mattamuskeet, it becomes evident that diversity – and therefore 'loss' – hinges, in part, on the observer. How, and by whom, is diversity defined? What meanings and values affix to the experience of biodiversity? To the cognition and recognition of its loss? Diversity, it seems evident, cannot be decoupled from the processes through which we humans come to ascertain it. Indeed, farmers not only recognize biodiversity, through their naming, seed saving, and planting practices – they create it.

Discourses of diversity

With this deeper insight into the meanings and constructions of diversity, we can now return to the original schism over agrobiodiversity loss, where writers such as Fowler, Mooney, and Thrupp presented a portrait of rampant genetic erosion, displacement of traditional practices, and homogenization of the agri-food system. Meanwhile, others such as Brush and Jarvis argued that landraces persist on landscapes around the world, where marginalized farmers – and even not so marginalized farmers – continue to sow diverse, native seed despite their supposed decline.

As it turns out, however, what seemed diametrically opposed claims were in fact appeals in both camps for in situ conservation: the maintenance and recovery of plant diversity 'in its original place.'[31] Against trends dating back to the 1920s in favor of ex situ storage of plant genetic resources, both sides of this particular discursive divide build arguments for on-farm approaches to sustaining seed.

For Brush, the 'de facto' conservation of diversity on farmlands provides compelling evidence that smallholders are fully capable of maintaining biological diversity in situ. He is concerned that narratives of loss may be a convenient way to legitimize the extraction of seeds from traditional farmers and indigenous communities. On the basis of farmers being unable – or unwilling – to maintain diversity in living landscapes, the obvious solution is to rescue seed by shepherding it away, to the safety of centralized gene banks. Intentionally or not, accounts of alarming genetic erosion may then undercut efforts to foster living ('in vivo') farming systems in which people make their livelihoods and landraces continually to adapt to changing socio-ecological conditions.

It is remarkable, then, that other authors who also champion in situ take as their point of departure a roll call of species loss and varietal decline. Nabhan (1979, 1989), Prescott-Allen and Prescott-Allen (1981, 1982), Alcorn (1984), Wilkes (1991), Altieri and Merrick (1987), and Norgaard (1988) were pioneers in prompting a shift away from a conservation strategy of 'collect, freeze, and diffuse' towards efforts that acknowledge the contributions of indigenous

[31] As defined by the Convention on Biological Diversity, in situ conservation of crops and their wild relatives consists of ''conservation in the place where the domesticated or cultivated species have developed their distinctive properties'' (Heywood and Dulloo 2005).

populations, women, and smallholders to the reproduction of agricultural diversity. Reflecting its emergence in the run-up to the Convention on Biological Diversity, this scholarship invokes the 'conservation and sustainable use of biological resources' (CBD 1992, Art. 10a) while heavily underscoring imminent loss. By 1990, with Mooney and Fowler's *The Threatened Gene*, the loss narrative had become strongly linked to conservation in situ.

Science had, by then, also begun to unravel the logic of gene bank security: the degradation of banked germplasm resources over time meant that no cached seed was in effect 'safe.' Genetic bottlenecks associated with sampling became a vexing issue. Most importantly, ex situ storage could not support the co-evolution and adaptation that occurs with germplasm in place. Without natural or farmer selection, without cultural or biological context, seeds seemed as good as committed to extinction. These arguments also aligned with decades of ethnographic work finding strong, reciprocal relationships between biological, linguistic, and knowledge diversity in agroecological systems (reviews in Orlove and Brush 1996; Collins and Qualset 1998).

Comparing these two accounts reveals provocative tensions. For Brush inter alia, the loss narrative is seen as a potential liability–a way to delegitimize the ability of farmers to conserve their own resources. Poking a stick at modernist economic theory, Brush attempts to show that development is in fact multilinear; far from teleological displacement of farmer varieties by HYVs, what occurs on the ground is far more eclectic. Institutionally and politically, 'de facto' conservation suggests an array of activities to keep traditional farmers on the land, continuing in the conservation they are demonstrably so skilled at. Rather than argue loss, he suggests, we should underscore persistence. For Mooney inter alia, the loss narrative serves the opposite function. As social and natural science converge around the insufficiency of gene banks to sustain agrobiodiversity, loss becomes a pressing argument for keeping farmers in place. The maintenance of their in situ worlds emerges as an urgent matter of livelihoods and food security, from local to global levels.

These discursive contrasts suggest that agrobiodiversity politics are not so very different from agri-food politics more generally, where the 'restructuring' debates circled around similar themes. What is at stake in the construction of such loss/persistence narratives is the global approach to agrobiodiversity conservation–a surprisingly heated policy arena that sometimes pits farmer against nature against gene.

The persistence of ex situ

Contests over ex situ and in situ conservation strategies of crop genetic resources have a long history beyond the bounds of this essay. Many readers of this journal will be familiar with the Consultative Group for International Agricultural Research (CGIAR) and its network of seed banks, which began accumulating large stores of seeds collected from Green Revolution regions around the world from the 1950s onwards. Roughly two centuries earlier, Great Britain had pioneered such collecting, with its network of Royal Kew botanical stations–stretching from Jamaica to Singapore to Fiji – and 'plant hunters' who systematically gathered plant genetic materials across the planet to assess their commercial utility. These appropriations became the basis for the Millennium Seed Bank, a repository of more than of more than 34,000 species and nearly two billion seeds today (MSB 2015). In the US, plant prospecting peaked between 1900 and 1930, with USDA-led expeditions to seek useful germplasm from abroad. To house these materials, Congress constructed the US National Seed Storage Labs (NSSL) in Fort Collins, Colorado in 1958. Alongside the CGIAR systems (a total of 11 mega-gene banks), the Millennium Seed Bank, the NSSL, and national seed banks held by most countries, there is now the Svalbard Global Seed Vault, which opened its doors in 2008. Envisioned as a 'backup' for the world's existing 1750 ex situ collections, Svalbard holds replicate samples of seeds, tubers, and plant cuttings in a deep Arctic freeze.

Some researchers have declared the ex situ system moribund because of shifting thought in agroecology and conservation biology: away from the preservation of static, isolated accessions of germplasm, and towards the maintenance of evolutionary and ecological processes that create and sustain diversity (Norgaard 1988; Nazarea 2013). Yet ex situ conservation continues to receive significant financial support from governments, foundations, and importantly, the private sector. While it is true that many national and regional seed banks struggle for adequate funding, the Global Crop Diversity Trust – manager of the Svalbard vault and a principal financing mechanism of ex situ conservation globally – is well resourced. Operating as an endowment, the Trust currently provides long-term grants to support 20 international collections of 17 major food crops in CGIAR gene banks and two other institutions.[32] The Trust, in turn, is funded by a consortium of public and private entities, with primary moneys coming from the CGIAR Fund, the Bill & Melinda Gates Foundation, sovereign states including Norway, the US, Sweden, and Australia, and corporate financiers Syngenta, Crop Life International, and Dupont/Pioneer Hi-Bred. From these donors, the Crop Trust has raised roughly $413 million for ex situ conservation since its inception in 2003 (GCDT 2014). It aims to reach $500 million by 2015 and $850 million by 2018 (GCDT 2013a).

The staying power of ex situ conservation comes into relief when these figures are contrasted with corporate returns generated by these same donors – Monsanto, for example, reports a net income of $2.7 billion from sales of $15.9 billion for 2014 (Monsanto 2014). The Crop Trust and CGIAR have come to support an effective (and, from industry's standpoint, cheap) commodity pipeline: germplasm, collected from agricultural landscapes worldwide, circulates through the coffers of gene banks, into public and private sector R&D channels, and, frequently, towards patenting and licensing arrangements to secure proprietary seeds. Acquired freely from farmers, germplasm returns to confront these farmers as commodities in the market – a classic example of 'primitive accumulation' without full expropriation.[33] Indeed, the Crop Trust operates with an

[32] The Crop Trust currently provides long-term grants of $2.4 million annually to these institutions. This in-perpetuity funding is complemented by up to $18 million per year from the CGIAR Consortium Office to finance the core costs of operating international collections in all 11 CGIAR genebanks (Crop Trust 2013b).

[33] The separation of farmers from their seed is classical 'primitive accumulation,' defined by Marx as 'nothing less than the historical process of divorcing the producer from the means of production' (Marx 1977, 875). The 'draconian approach' of complete expropriation, notes Kloppenburg, had the effect of instantaneously establishing both a labor pool and market in one transformation. Yet even farmers who retain control of land can be brought 'gradually but effectively into capitalist commodity production' (Kloppenburg 2004, 25).

explicit objective of availing its crop resources not only to public plant researchers but also to private industry and private-industry affiliated philanthropic plant researchers– so as to ‘‘stimulat[e] the flow of conserved genetic diversity down the ‘use pipeline' to growers (GCDT, cited in Graddy 2013). Yet, corporations have pledged just $7 million to the endowment over the past decade. The residual $393 million? A helpful subsidy from sovereign states and foundations.[34]

In 2006, the Crop Trust was recognized as an ‘essential element' of the International Plant Treaty's[35] funding strategy, with scientific autonomy and the authority to raise and disburse capital. From 2007 to 2012, with backing from the Gates Foundation and Australia's Grains Research and Development Corporation, the Trust undertook what it called the ‘biggest biological rescue operation ever,' collecting and duplicating nearly 88,000 varieties of crops from 88 countries and 143 agricultural institutes (GCDT 2015a). Meanwhile, at the FAO, where in situ and ex situ priorities have long competed for prominence, a key document for agrobiodiversity conservation – the ‘Global Plan for Action for Plant Genetic Resources for Food and Agriculture' – was reworked in 2011 to align with Plant Treaty (and Crop Trust) architecture.

Climate change has only added to the urgency of ex situ efforts. With researchers predicting shifting agronomic zones, increased pressures from diseases and pests, and dramatic fluxes in temperature, moisture, and salinity, the demand for genetic variability in breeding stocks has never been greater. Scientists also predict accelerated rates of plant species extinctions, compounding the exigency of the banking endeavor: the race is on to save the seeds that will save us. The seeds in question are increasingly not just crops but also their wild relatives–cousins of domesticated species that typically display climate-hardy traits. The Millennium Seed Bank, the Crop Trust, and International Center for Tropical Agriculture (CIAT) have recently embarked on a global strategy to ‘identify those CWR that are missing from existing gene bank collections,' ‘collect them from the wild and conserve them in gene banks,' and ‘prepare them for use in crop improvement' (Dempewolf et al. 2014, 373).

If the theory of gene banking is supposedly moribund, these activities suggest there is much life in its practices yet.

Narratives of loss, as previously noted, figure prominently into the discourse of these dedicated ex situ institutions. These narratives animate a collect-stock-and-freeze mentality long considered passé in much of ecology and conservation biology (not to mention many social sciences). They are also highly pragmatic. ‘Loss' legitimizes the very existence of gene banks, and elevates seed collecting from what may be seen as quixotic botany, or more insidiously, bioprospecting, to a matter of saving the world. In the principal texts and documents circulated

[34] Four corporate donors – Dupont Pioneer Hi-bred, Syngenta AG, Australia Grains Research and Development Corporation, and Kleinwanzlebener Saatzucht (KWS) AG – have donated a sum of $7,030,000 to the Trust as of January 21, 2015 (see funding report: GCDT 2014).

[35] The International Treaty on Plant Genetic Resources for Food and Agriculture, established in 2004, governs access and benefit-sharing for 64 food crops considered globally important. As of 2014, there are 131 contracting parties to the Treaty (130 countries and the European Union).

by such organizations, this salvation rhetoric is easy to surmise, and is often cast in highly exclusive terms.

> Crop diversity is disappearing, and the Trust is the sole dedicated worldwide funding organization for its conservation (GCDT 2012a).
>
> …even short-term breaks in funding can lead to cutbacks in basic maintenance and the loss of unique varieties… And there is only one organization working worldwide to solve this problem–the Global Crop Diversity Trust (GCDT 2012b).[36]

Indeed, according to the Crop Trust, ex situ storage is not merely a stopgap or complementary approach to in situ conservation: 'It is the only solution' (GCDT 2012a). They say: 'Diversity is being lost and with it our ability to keep agriculture productive' (GCDT 2012b). In response, the Crop Trust offers 'a unique opportunity to put in place a rational and cost-effective system for the conservation of the resources which underpin all agriculture and the world's food supplies' (GCDT 2012a). The challenge, moreover, is urgent because 'rising populations, diminishing resources and deteriorating environments only raise the stakes' (GCDT 2013b).

'Loss,' then, works effectively to collapse diversity loss into a problem of agricultural productivity, and productivity into the sole determinant of food security. It also ensconces agrobiodiversity, rather ironically, in a neo-Malthusian logic, where scarcity provokes solutions of streamlining and efficiency. Indeed, a romp through major planning documents of the Crop Trust reveals a laser focus on the 'rational and cost-effective.' Such a fixation might be less notable in isolation, but as manager and funder of seed collections worldwide, the Crop Trust is empowered to extend this ontology widely. Between 2004 and 2010, as described in the recently released 'Strategic Work Plan: 2014-2024,' the Crop Trust brought together experts from around the planet to agree to a series of global conservation strategies: Crop by crop, these documents describe the holdings of existing collections, how experts will address gaps in conservation, and ways to reduce inefficiencies (GCDT 2013b). The goal, presented to participants in the first Global Stakeholder Discussion in Berlin, is a 'World of Gene Banks'– a 'global, rational and cost-effective system' (GCDT 2015b).

Reminiscent of the World Bank during the McNamara years (1968-1981), the global in situ system envisioned by the Crop Trust exhibits a highly hierarchical and numbers-based managerial style. 'Individual crop experts' and 'formal technical groups' have designed the centerpiece global crop strategies (26 in all). Linked together through information technology, bank managers track 'Performance Indicators' (e.g. number of accessions with health status tested), and strive to meet quantitative targets for availability, security, and data (e.g. 90% of germplasm accessions with data online). These data, together with cost efficiency and quality management, can be compiled through online reporting tools, where all 12 mega-gene banks are assessed in relation to prescribed 'Performance Targets.' At the center of this operation, the Crop

[36] The Global Crop Diversity Trust re-launched its website in January 2015, removing many of these statements. They can now be found in the Internet Archive (see references).

Trust provides fundraising, global information portals (e.g. Genesys, Divseek), and monitoring and oversight (GCDT 2015c).

If under McNamara, the World Bank was refashioned into a ‘knowledge bank,’ becoming a headquarters for research, economic modeling, data collection, report writing, and dissemination of information on the ‘so-called less developed world’ (Goldman 2005), the Crop Trust and its network run a similar system of scientized expertise. They, like the World Bank’s knowledge experts, help roll out projects and programs for development and conservation, even while formulating the very definition of what this development should be, and how to measure and evaluate ‘poverty’ and ‘loss.’

To be sure, farmers and breeders are not wholly absent from the texts of ex situ organizations. However, they tend to appear at the receiving end of crop diversity – as actors who rely upon it, but have no role in creating or shaping it. That traditional farmers and landraces still persist at all is fiendishly difficult to deduce from some ex situ accounts. A 2014 commentary in *Nature*, for example, reflects opinions aired at an elite meeting of international crop genomicists in Asilomar, California in December 2012. Depicting landraces as ‘primitive seed varieties...stored in 1700 gene banks worldwide,’ the authors – representing the CGIAR, the USDA, the Global Crop Diversity Trust, the Chinese Academy of Agricultural Sciences, Cornell University, UC Davis, the University of British Colombia, Agri-Food Canada, Dow, and Monsanto, among others[37] – make no mention of landraces’ ongoing use and renewal in agroecosystems around the world (a number far outnumbering 1700). Absent, too, is explicit regard for the farmer innovation and ingenuity embedded in ‘primitive’ varieties. They are reduced, instead, to mere germplasm that humanity must exploit for the greater good: ‘How,’ the authors inquire, ‘can we begin to mine biodiversity for food security?’ (McCouch et al. 2014).

Loss narratives, in sum, appear to serve a variety of functions for ex situ institutions. They legitimize the work of gene banks as essential (indeed salvational), align well with neo-Malthusian logics of scarcity and efficiency, and posit production/yield as central to food security. In edging out narratives of persistence, ‘loss’ also serves to circumscribe the role of farmer labor, farmer knowledge, landscapes, and ecology as active participants in conserving – or, more aptly, regenerating – agrobiodiversity. Instead, the problem of loss is rendered simple. As the Crop Trust puts it: ‘The conservation of crop diversity is neither technologically complicated, nor, considering the importance of the task, expensive. The varieties of many of the most important crops can be simply stored as seed in freezers’ (GCDT 2012c).

Uneven losses

Simply storing seeds in freezers would have stricken Russian scientist Nikolai Vavilov (1887-1943) as a remarkably myopic thing to do. Among the first researchers to recognize the problem of crop biodiversity loss – indeed, he is credited with coining the phrase ‘crop genetic erosion’–

[37] McCouch wrote on behalf of attendees and organizers of the Crop Wild Relative Genomics meeting held in Asilomar, California in December 2012. See go.nature.com/nrpoe3 for full author list.

Vavilov traversed hill slopes from the Levant to California, the Po to the Great Rift Valley, in search of native landraces and their wild relatives. For these epic collecting activities – gathering specimens in 115 research expeditions through 64 countries – he is often remembered as the godfather of gene banks.[38]

Yet what is less frequently recalled is Vavilov's biocultural acuity. Biogeographer and ethnobotanist, he began to recognize that crop diversity was frequently concentrated in montane regions, where steep elevation gradients and rugged terrain enabled plants to differentiate into distinctive species and varieties. The same geographies that fostered plant diversity, he reasoned, would also create microniches in which human communities must have evolved unique characteristics. Linguistic diversity and cultural diversity might then overlap with crop genetic diversity in mutually reinforcing ways. He mapped these biocultural hotspots onto eight regions of the world now commonly known as the Vavilov Centers of diversity. Vavilov's expeditions to these centers, spanning roughly 1916-1943, provided subsequent researchers with some of the most extensive empirical agrobiodiversity data against which to calibrate future change. A longitudinal glance at one of these Vavilov Centers – Ethiopia – reveals the historical contingency of loss – the difficulty in asserting 'loss' or 'persistence' (or both) without attention to particular crop, particular locale, the specific conditions that engender or impede viability of farmers and their seed.

Abyssinia and Eritrea, bound together as Ethiopia, encompass a region with precisely the sort of topographical diversity that Vavilov surmised would engender cultural and biological diversity. The highlands, now identified by biogeographers as the eastern Afro-montane center of diversity, stand apart from the rest of the country, which is part of the broader Afro-tropical center of diversity.

Peasants living in the highlands converse mostly in Amharic – the dominant Semitic language – while dozens of Cushitic and Omotic languages prevail in the South.

Retracing Vavilov's path on a mountainous stretch between the Great Rift Valley and the Blue Nile Gorge, researcher and author Gary Paul Nabhan (2009) documents apparent losses. In 1926, the Russian scientist had collected and catalogued several unique cultivars as he moved from lowlands onto the Abyssinian plateau where agricultural habitats became more heterogeneous: chickpeas, lentils, and vetches of numerous types. But some legume varieties – field peas, in particular – had not been encountered by any other scientist since Vavilov's first expedition some 80 years before. 'As commercial varieties have been introduced from Europe, North America, and Japan,' Nabhan suggests, 'many local varieties appear to have simply disappeared and may now be lost to humanity' (p107).

These observations mirror rapid declines that Nabhan catalogues on five continents, and that Vavilov and US botanist Jack Harlan were among the first to document. Yet legume losses notwithstanding, Ethiopia is simultaneously a study in persistence. Both Vavilov and Nabhan

[38] Vavilov's expeditions are a potent reminder that crop diversity losses are not limited to capitalist economies. The rationally planned, large-scale production systems of many a Communist regime have also led to simplified agroecosystems (Scott 1998).

describe the extraordinary on-farm variation in teff, a small-millet like grain used to make Ethiopia's national staple, enjera. Recent morphological studies have found 14 different traits in the admixtures of teff strains found across a range of elevations in Ethiopia's central and northern regions (Assefa et al. 2001). These mixtures are highly variable for grain and stalk weights, seed yield gleaned from different parts of the plant (main versus side stalks), and number of days from planting to harvest. Teff itself is a polyculture, and farmers seldom grow teff alone: wheat, barley, and lentils of various hues – yellow-green, yellow-brown, green, and orange-red – turn farm fields into genetic mosaics, providing farmers with agronomic, economic, and climatic resilience.

Local markets provide another window onto extant diversity – one which captures a broader geographic scope, as farmers, traders, and vendors gather food crops, meats, and spices from across the region. The Ankober market scene of 2006 has not changed much since Vavilov's time: durum wheat, teff, barley, amongst the grains, and a cornucopia of favas, melons, corn, peaches, and chiles. Although many of these species are not endemic to the region, farmers have bred them into landrace varieties that are now highly localized. Such burgeoning marketplaces – found from the Rift Valley to the Levant, from Peru to the Philippines – suggest that transnational trade need not be a unidirectional force for homogenization. In many cases, foreign varieties are taken up and incorporated into local production, in effect adding to local crop diversity, without displacing it.

Ethiopia's eclectic portrait of loss and persistence frustrates easy attempts to categorize. It insists on appreciation of unique geographies, linguistic cultures, and their coevolution. It also points us to the constraints and contingencies of political history. In 1976, the Ethiopian government established a national seed bank – an event believed by historians to be linked to a crisis some decades earlier, when California barley was rescued by African anti-virus genes, yet without compensation to Ethiopian farmers or the state. The bank, then, was poised at asserting Ethiopia's sovereignty over its national seed heritage. In the 1980s, drought, compounded by political upheaval, led to one of the deepest – and most infamous – famines in recent history. Nearly 2.5 million people fled their farmlands and abandoned their homes, threatening the downward spiral of farmer loss, knowledge loss, and agrobiodiversity loss. Meanwhile, foreign development agencies and multinational corporations offered hunger relief in the form of packaged high-yielding seed varieties and agrochemical inputs. Few Ethiopian smallholders, however, saw their yields increase enough to offset the increased costs of seed, fertilizer, herbicides, and pesticides, further deepening the extent of debt and malnutrition.

But losses weren't monolithic, thanks to concurrent grassroots efforts to support agrobiodiversity in situ. During the same era in which the national seed bank was established, its director, Melaku Worede and his students were simultaneously fostering community-led seed conservation; Worede himself became advisor to Seeds of Survival, a pan-African NGO dedicated to in situ. A change of political leadership also shifted terms of conservation engagement. When the communist Dergue council came to power in the mid-1970s, the national gene bank was instructed to collaborate with Seeds of Survival. 'Rather than simply locking away rescued seeds in the institute's gene bank for later use, the collaborative effort invested in on-farm conservation and improvement of indigenous crops by the rural communities themselves' (Nabhan 2009, 110). An extensive network of on-farm conservation sites eventually involved some thirty thousand families.

The long-term traction of in situ, however, likely emerges less from NGO efforts (even farmer-led), than from the resilience that farmers begin to realize in practice; they therefore become more able, willing, and empowered to reproduce agrobiodiversity anew. In the case of Abyssinian smallholders, the post-drought years revealed that polyculture cropping of grain landraces provided more stable yield in times of drought and climate stress. These ancient grains also proved recalcitrant to UG99, a devastating wheat rust sweeping Africa at the time. The first line of defense suggested by plant pathologists was fungicide, but many local farmers found in their landrace wheats either partial or total resistance to rust. Today, Ethiopia's total acreage dedicated to indigenous cultivars like teff has actually increased since the famine abated. Vavilov's legacy – exalted in photographs in the halls of the Ethiopian Institute of Biodiversity Conservation – is not of a timeless seed banker, but of a researcher who affirmed the work of Ethiopian farmers and scientists to keep their crops alive, in place.

Conclusion

By some accounts, agrobiodiversity losses are sweeping and imminent. Out of a total of 250,000 known plant species, approximately 7000 have been used for human food since the origin of agriculture. Out of these, just 12 crop and 5 animal species provide three-quarters of the world's food today (FAO 1997; Bioversity International 2014). Such losses have been affirmed in numerous studies over the years, with the most recent global survey completed in 2010: the FAO's 'Second State of the World's Plant Genetic Resources for Food and Agriculture' found that the underlying genetic diversity in crops (across genera, species, sub-species, and varieties) had declined by 75% since 1900 (FAO 2010). These studies come as close to empirical 'fact' as seems possible. But counterevidence abounds in the work of both academics and activists. Farmers meticulously incorporate modern varieties into traditional cropping systems; they set aside land for community and kitchen gardens in which to cultivate heritage foods; they even interbreed HYVs and landraces in arrays of 'creolized' seed. In some places, germplasm is being repatriated from gene banks back to indigenous ecosystems and peoples. In others, immigrant and refugee gardeners carry seed to new locales, bringing memory and practice to reconstruct in situ in a new home.

I contend that what at first appears to be a contradiction between accounts of loss and persistence reveals an error in the questions being posed. It is more fruitful, instead, to inquire how diversity is defined and measured, who is creating and categorizing diversity, and how such knowledge is produced and mobilized by different interest groups. In brief, scientific evidence indicates a definitive 'yes' – loss of crop genetic diversity is occurring at a global scale. However, world averages can obscure the multitude of local losses and persistences that configure aggregate trends. A resurgence of diversified seed networks in one place can be occluded by monocultures in another – though the effects hardly 'cancel out' for the specific people and nature involved.

Moreover, taxonomic and genetic categories customary to Western science provide a strong index of allelic variation, a benchmark for evolutionary potential. But genes and gene erosion is not the only way of understanding – or experiencing – loss. Interrogating loss, instead, demands a wider view: in terms of genetic variation, as categories of recognition (whether farmer names, scientific taxa, or company labels), and in relation to the agrarian landscapes and food systems that create and sustain diversity. In all cases, scale is intrinsic to how loss is observed and understood: Whether change in diversity is measured globally or locally; over a day or a decade; within sites or between sites – be they plots, farms, and landscapes or households, countries, and nations. The scale at which the 'loss' question is asked profoundly shapes how it is answered.

Homogenizing accounts of loss – whether wielded by the CGIAR/Crop Trust or by social movements radically opposed to the gene bank agenda – seldom capture these gradations. Nor do they make room for the possibility that loss is a spectrum, occurring unevenly over space, at different rates in different places, and driven, in any particular situation, by a historically specific amalgam of factors. Yes, it is true that we can count on ten fingers the proximate and ultimate 'global' causes of loss: fragmentation of landscapes, climate change, replacement of traditional varieties with high-yielding cash crops, linguistic homogenization, lack of young farmer retention, intellectual property and free trade agreements, the industrialization of agriculture and food. But within those broad forces, as van der Ploeg would remind us, 'the many contradictions that characterize everyday life scarcely have easy, unilinear and predictable outcomes' (van der Ploeg 2008, 12).

Our challenge, then, is to make space for seed losses that are specific and contingent – as demonstrated by Ethiopia's particular historical path – as well as to recognize that certain contradictions are likely to be reproduced over time and across space. Such an understanding enables 'loss' and 'persistence' to co-occur, depending on time, place, and circumstance. Both narratives could in effect be true.

For those invested in transitions to renewable and just agri-food systems, we must ask: (1) What important aspects of agrobiodiversity have we failed to appreciate, by framing the issue as a debate about loss versus persistence? (2) What are the conditions – broadly speaking – that engender persistence? I suggest that understanding agrobiodiversity as an interweaving of ecology, knowledge, and political economy can shed light on aspects that are critical to the regeneration of agrobiodiversity but are left out of current conservation approaches. Such an understanding can also inform practical strategies to strengthen seed systems in at least two regards.

First, it points to agroecology as a critical means of protecting agrobiodiversity, both in- and ex situ. Off-site seed collections will continue to be invaluable. In a world in which the likelihood of rapidly reversing conditions of loss remain slim, seed banks can 'back up' endangered species and harbor relatively protected stores for future crop improvement. But to the extent that large, centralized ex situ institutions (the 'mega gene banks') often support the perpetuation of simplified, industrial production systems, they tend to erode the very genetic diversity they seek to save. Moreover, the proximate recipients of germplasm are usually corporate and academic plant breeders, who then gain privilege to shape the trajectory of seeds to come. When improved seed re-circulates to farmers, it is often in proprietary form. If more than plant breeders are to participate in a food democracy, ex situ can only ever be a complement to farmer-led in situ. If ex situ has a place, it must support an agroecological in situ, where the renewal of genetic materials animates a wider web of diversity: of plants, microbes, animals, and people. Policies to nurture agroecology will help ensure that when genebanked seeds eventually return to the land, they don't summarily encounter monoculture fields, or landscapes scarce in farmers and their knowledge. Meanwhile, international and national scientific/policy institutions should move to support the breeders, public and private, who avail themselves of ex situ germplasm, encouraging participatory breeding for agroecological and diversified systems.

Of course, in situ is hard. It raises vexed issues of land and land rights, for example – the politics of which many governments and corporations would rather avoid. Indeed, the further we interrogate the conditions for successful in situ, the more ambitious–ecologically, socially, and politically – it appears. From abolishing fossil fuels (as climate change is a core driver of agrobiodiversity loss), to tackling inhibitory intellectual property rights, to re-instituting controls on capital flows. The conditions for in situ begin to pull at the threads of the larger agri-food fabric, challenging the industrialization of production and consumption systems, and political economies on the whole. Not that we should be cowed, but it does help to put in perspective the scope of the task.

A second line of defense against agrobiodiversity loss is greater support for seed networks, recognizing the social and biological integuments of diversity. Seed requirements in most farming communities are fulfilled through informal seed supply systems, including exchange (trading one variety for another); barter (trading of seed for another good/service); gift; and purchase. While the majority of farmers in the developing world depend on saved seed as their primary seed source, they depend extensively on networks of neighbors, kin, and friends to replace poor quality seed, to experiment with new varieties, and to fight disease or pest infestations. Studies on the informal flows of seed material through farmers' networks have shown that they are vital for maintaining genetic diversity on-farm and for creating social relationships between the farmers (Subedi et al. 2003; Hodgkin et al. 2007; Poudel et al. 2015).

Yet what might be the mechanism through which social seed networks promote biological diversity? How do farmer-to-farmer connections maintain the integrity of landrace populations? Meta-population patch dynamics, recent research indicates, could be at work (Alvarez et al. 2005). According to metapopulation theory,[39] local losses of biodiversity happen all the time; they are normal and inevitable. But as local extinctions occur in patches of natural habitat, they are counterbalanced by colonizations from other patches. The result is a shifting mosaic of occupied patches, with individual patches 'winking in' and 'winking out,' while the larger metapopulation remains stable. Social networks could foster similar dynamics: when farmers

[39] See Hanski and Simberloff (1997) and Hanski (2010) for good reviews of metapopulation theory. Perfecto et al. (2009) and Perfecto and Vandermeer (2010) apply the theory to agriculture in fragmented tropical landscapes, where improving the farmland matrix can reconcile goals of conservation and food security.

bring in new populations through exchange, gift, barter, and purchase, these farmer-preferred seeds effectively recolonize patches left empty by local landrace extinctions. In other words, local seed loss would not be extinguished, but seed exchange could preserve the crop genetic diversity across the metapopulation. The informal seed swap could hedge loss with persistence.

What becomes important then, are the conditions that foster these recolonizations. Agroecologists have suggested that constructing a higher-quality matrix – a wildlife friendly agricultural terrain – between patches in fragmented landscapes could greatly enhance biodiversity (Perfecto et al. 2009; Perfecto and Vandermeer 2010). The social matrix, it seems, is equally vital for seed diversity to persist in a dynamic mode, where the larger social network conserves meta-population stability while local re-introductions provide an opportunity for evolutionary and human selection. Very little research has been done in this domain, suggesting exciting work yet to come.

Therefore, I suggest, agrobiodiversity needs to be understood in political, agroecological terms: not just as something that 'exists' but that is created and sustained; and not just as something that is lost (or that persists) globally but as something that is bred, experimented with, and used at multiple scales. Whose knowledges configure a loss? Who gets to decide? How do we begin to cultivate high quality social and biological matrices that will sustain people and nature in the long term? Perhaps what has truly been 'lost,' in debates about the fate of agrobiodiversity, is the opportunity to engage with the real questions that should impel us. ∞

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Chapter 4

Stealing Into the Wild: Conservation Science, Plant Breeding, and the Makings of New Seed Enclosures

Montenegro de Wit, M. 2017a. Stealing Into the Wild: Conservation Science, Plant Breeding, and the Makings of New Seed Enclosures. *Journal of Peasant Studies* 44 (1): 169-212.

Abbreviations

AACC	'Adapting Agriculture to Climate Change'
CBD	Convention on Biological Diversity
CIAT	International Center for Tropical Agriculture
CIMMYT	International Center for Wheat and Maize Improvement
CRISPR-Cas9	Clustered Regulatory Interspaced Short Palindromic Repeats; CRISPR-associated enzyme
CWR	crop wild relatives
FAO	Food and Agriculture Organization
GCDT	Global Crop Diversity Trust
IPR	intellectual property rights
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture ('Plant Treaty')
MLS	Multilateral System (of the Plant Treaty)
PGRFA	plant genetic resources for food and agriculture
PVP	Plant Variety Protection
SADC	South African Development Community
TRIPS	Trade Related Aspects of Intellectual Property (of the WTO)
WTO	World Trade Organization
UPOV	International Union for the Protection of New Varieties of Plants

Abstract: Faced with pressing climatic changes, scientific and industrial interests are vying to develop crops that can survive drought, floods and shifting pest regimes. Increasingly, they look for solutions in an unlikely place: the gene pools of wild plants. Crop wild relatives (CWR) – species closely related to crops, including their ancestors – offer breeders the allure of retracing the domestication bottleneck, infusing genomes of modern crops with 'lost' genetic variety. Yet wild relatives also confront threats from climate change, urbanization and expansion of industrial agri-food. Thus, CWR, seen as both salvational and threatened, have become an international conservation and food-security priority. It is my contention that, in their common project to harness wild-relative potential, conservation and breeding science are co-evolving to extend seed commodity relations into new spheres. I examine enclosures along two fronts: first within 'systematic CWR conservation,' where 'in situ' approaches, typically regarded as empowering and sustainable alternatives to 'ex situ,' instead may support a complementary system of value

extraction; second, in breeding and biotechnology research, which produces new value for CWR while profoundly shaping upstream conservation priorities. An important finding is that although today's 'ex situ-centric' complementarity favors dispossession, an 'in situ- centric' approach could foster democratic renewal of biocultural diversity.

Keywords: crop wild relatives; primitive accumulation; climate change; biotechnology; conservation science; ex situ/in situ; intellectual property

Introduction

If you have not yet heard that wild weeds can feed the world, you soon will. With climate change already affecting crop systems worldwide, scientists increasingly say we have no choice but to adapt agriculture to drought, floods and shifting pest regimes. While some research communities focus on agronomic practices – changes to cropping, soil, water and biodiversity strategies – another large subset of research is trained on crops themselves, improving seeds at the core of production. Much of their emphasis is on genetics. To quote an influential *Nature* article, 'We will have to give crops a genetic helping hand, infusing them with new genes to allow them to better cope with new climates, and the new pests and diseases they will bring' (Guarino and Lobell 2011).

Such statements call to mind industry's invocations for genetically modified seed. Yet it is not the promise of GMOs being spoken of here. Today, another possibility is inciting the attention of governments, companies, scientists and conservation professionals who work in the field of plant genetic resource for food and agriculture, or PGRFA. Crop wild relatives (CWR), defined as 'species closely related to domesticated crops, including their wild progenitors,'[40] offer the potential to infuse crops with traits necessary to cope with climate change. By dint of being wild, these species have evolved adaptations to extreme conditions – precisely the rugged adaptations agriculture now needs. Many of these hardy traits were winnowed out of the domesticated gene pool when ancestral farmers instigated seed sowing more than 10,000 years ago. Researchers suggest that reintroducing CWR traits offers a chance to retrace this genetic bottleneck, accessing an abundance of genetic variety that was inadvertently 'lost.' The incentives for retracing and rewilding are clear. The paradox? Like many wild plants, CWR are themselves threatened by climate change, development and other anthropogenic forces, agriculture included.

Because CWRs are increasingly seen as both important and threatened, their conservation has become an international priority, with two apparently rivaling conservation paradigms in play. Ex situ strategies focus on collecting seeds for storage in gene banks, identifying critical sites and species for wild relative collection. They address what is seen as a gene-bank 'gap': a deficiency of CWRs in global PGRFA repositories. By contrast, in situ programs stress the

[40] 'Progenitors' indicates the 'parents' of current cultivated crops – that is, the wild species that were domesticated by ancient farmers. The term CWR includes the progenitors as well as other more or less closely related species. An example is domesticated sweet potato (*Ipomoea batatas* (L.) Lam.) which is thought to have originated from cross-species hybridization involving *I. trifida*, *I. littoralis* and/or *I. leucantha*. These progenitors are among the 14 species scientists count as the close relatives of cultivated sweet potato (Khoury et al. 2015).

‘dynamic evolution of diversity’ found only in natural settings. Centered on conserving crop relatives in situ – that is, ‘in the ecosystems and native habitats where they have acquired their distinctive characteristics’ (CBD 1992) – they underscore ecology as the essential means of maintaining and renewing diversity in populations of wild relatives. In the past five years, major CWR initiatives have been launched on both ex situ and in situ fronts, in response to a widely perceived failure of CWR conservation efforts to date: a lack of ‘systematic’ planning and implementation (Heywood et al. 2007; Maxted and Kell 2009; Hunter et al. 2012; Vincent et al. 2013; Dempewolf et al. 2014; Kell et al. 2015).With efforts underway to lay the scientific basis for such a systematic practice, conservation science is producing new knowledge about wild relatives: where they exist, how their diversity is spatially distributed, whether their genotypes have adapted to particularly climate-hardy local ecologies and landscapes. In parallel, breeding science, propelled by advances in molecular breeding and biotechnology, is now bringing previously ‘unwieldy’ wild relatives into reach for crop improvement. In the genes of these ‘exotics,’ many breeders believe, lie latent capacities to develop crops with greater yield, greater resistance to drought, pests and disease, even higher quality foods.

It is my contention that, in their common project to harness the potential of wild relatives, conservation science and plant breeding science are now co-evolving to enable a new frontier of primitive accumulation to materialize. The collection and conservation of CWR – in banks and on land – provide the foundation from which valuable traits can be extracted and bred or engineered into new climate-hardy varieties. The scientific strategies are internally related and co-productive. Crop development relies fundamentally on the conservation of wild relatives – in and ex situ – for access to germplasm and related genetic information. There is no breeding or biotechnology without genetic diversity – and hence without sustained conservation. But conservation science – its priorities, its objectives and even its basis of legitimacy – hinges, then, on ‘use’ and its valorization. The marketable form comes to exert a backwards pressure on conservation: delimiting what is important to salvage and why. As a result, multiple enclosures could develop: around germplasm, around wild landscapes, around agroecosystems and traditional knowledge.

In order to better understand how these interrelated enclosures cohere, it helps to begin upstream, with the production of scientific knowledge itself. How are conservation plans being designed? What values are embedded in the measures and priorities that guide CWR planning? Who is participating in breeding new crops from ancestral DNA?

Looking at the discourses and practices of CWR science, I have found that ex situ and in situ are commonly framed as antagonistic strategies. Ex situ is the colonial paradigm of exploitative collection and off-site storage. In situ is the anti-colonial response: a liberatory strategy of place-based renewal. In CWRs, we find a decidedly different ontology taking shape, in which land-based and bank-based strategies not are only nonrival, but are complementary. The character of complementarity may, however, be highly uneven – or ‘ex situ-centric’ (cf. Graddy-Lovelace 2015). By favoring a flow of material, epistemic and economic value away from local sites and peoples, I will argue, complementarity is helping forge a frontier of primitive accumulation for wild relative social and ecological value. But complementarity need not take this tenor, and the sciences of conservation and breeding could support paradigms for CWR characterized by in situ-centricity: in which the flow of genetic resources and rights gravitates towards the landscapes and agrarian societies with whom wild relative diversity has co-evolved.

This paper begins with a brief review of primitive accumulation, before turning to narratives of climate change, food security and biodiversity preservation – the entwined justifications for saving and using CWR. Systematic conservation is then explored, with a look at the scientific practices of counting, prioritizing and establishing plans for collections and protected areas. Next, I consider advances in breeding science, which are not only producing new value for wild relatives – especially in the form of climate-hardy crops – but are also profoundly shaping conservation priorities. I then examine the potential for primitive accumulation to emerge vis-à-vis these scientific developments, in terms of uneven geographical distribution of CWR, market potential, international genetic governance and data-fication.

Primitive accumulation: seed enclosures from domesticated to wild

In his groundbreaking work, *First the seed* (1988), Kloppenburg recounts a history of plant biotechnology through the lens of primitive accumulation. Scientific technology and changing legal standards helped guide germplasm into property form, reshaping long-standing relations between farmers and their seed. But conformity to capital was not easily achieved – or easily kept. It required nothing less than new configurations of nature, state and market, which Kloppenburg considers along three main strands: (1) the privatization and commodification of plant genetic resources; (2) a division of labor between public and private research; and (3) the highly uneven, and unjust, international flow of plant genetic resources between countries.

Like Berlan and Lewontin's earlier work (1986), Kloppenburg's interrogation of the seed stems from its dual nature: as a living, reproducing organism, the seed links both ends of the production process. It is at once the means of production and the result of production, a potential exchange-value if sold, or a use-value if replanted. This regenerative capacity of germplasm, at once cultural and biological, has been antagonistic to enclosure for most of human history – exemplifying the variety of natural and social obstacles to the penetration of agriculture by capital (Mann and Dickinson 1978; Friedmann 1980). As a result, until the 1930s, farmers in both the global North and South enjoyed nearly complete sovereignty over their seeds (Aoki 2008; Kloppenburg 2010). They decided what to plant, which varieties to crop under what conditions, and whether to eat or replant the fruits of their harvests. Surely such decisions were not altogether egalitarian – patriarchy and other status divisions have long configured uneven access in traditional and indigenous communities. But, as Zimmerer (1996) argues, most agrarian cultures operating on bases of gift and reciprocity worked to facilitate, rather than restrict, wide dissemination of seed.

However, in just the past 85 years, the combined forces of crop biotechnology and intellectual property rights (IPR) have moved swiftly to enclose common genetic heritage as private property, turning public goods into private benefits. Biological and legal strategies have been complementary here. The development of hybrid seeds, beginning in the 1930s, separated farmers from effective biological reproduction of their own germplasm. Since hybridized seeds do not 'breed true' from one generation to the next, the incentive to replant seeds was replaced by the requirement to purchase anew. In the same decade, Congress passed the Plant Patent Act, the first legal enclosure in a line of progressively restrictive IPR legislation. The 1961 establishment of the Union for the Protection of New Varieties of Plants (UPOV) in Europe, followed by the 1970 Plant Variety Protection (PVP) Act in the United States, instituted exclusive breeders' rights but with important exemptions for scientists and farmers. Since the 1980s, the strictest form of IPR – the utility patent[41] – has been applied in both the US and Europe, while revisions to UPOV (1991) have come to mimic patents: both systems now preclude farmers' ability to save and reproduce protected seeds, even criminalizing the practice. These IPR enclosures also work in concert with marketing rules, biosafety policies, and international trade regimes and investment agreements (e.g. World Trade Organization (WTO), TTP and TTIP), rapidly extending corporate reach in both developed and developing country contexts (GRAIN and LVC 2015). Control of the biological seed, some argue, has become a linchpin in control of the entire agricultural system. The 'provider of this input,' notes Lewontin, is in 'a unique position to valorize other inputs' (Lewontin 2000, 98).

It might at first seem odd to cast such changes to seed systems as primitive accumulation, defined by Marx as 'nothing less than the historical process of divorcing the producer from the means of production' (Marx 1977, 875). Marx illustrates this process as immediate and complete, with the effect of instantaneously establishing both a labor pool and market in one transformation. The case of seeds is different: farmers are neither manifestly separated from their land, nor 'freed' to sell anything but their own labor. Yet even farmers who retain nominal control of their resources can be brought 'gradually but effectively into capitalist commodity production' (Kloppenburg 2004, 25). Indeed, primitive accumulation can be identified in myriad creeping dispossessions: where appropriations and accumulations are separated in time and space (Kelly 2011), and in which the everyday articulations between dominant (capitalist) and non-dominant modes of production continuously extend the commodity relation into new spheres. In this sense, the majority of US family farms and increasingly many smallholdings worldwide are already deeply enclosed. Farmers may retain nominal control of land, yet are often trapped in monopolistic factor markets, chronic indebtedness and contract systems that reduce them from autonomous farmers to 'disguised wage workers' or 'propertied labor' (Kautsky 1899; Davis 1980; Mooney 1983; Goodman, Sorj, and Wilkinson 1987).

Science and technology have been instrumental to commodifying seed resources, not only through direct means like hybrid seed, but insofar as they have eliminated barriers to capital in agriculture more generally. In the US, wartime science led the way, first with WWI increases in manufacturing heavy equipment, and second with WWII advances in nitrogen fixation for bomb production. At land grant universities and extension stations, breeding science responded by designing machine-compatible crops, adapting hybrid lines to heavy fertilizer inputs, and – when it became apparent that genetic uniformity and dense cropping engendered great susceptibility to

[41] In the software industry, distributors commonly require purchasers to agree to express licensing restrictions printed on software packaging (often called 'shrink wrap' licenses). Seed corporations have mimicked this practice with 'bag tags' on packages of seed that serve as license agreements for patented products. Farmers need not actually sign a contract, but by tearing open the tag, they effectively agree to terms of limited licensed use. A typical Monsanto bag tag forbids replanting of seed, resale of seed or supply of saved seed to anyone (Janis and Kesan 2002).

pests and disease – creating seed varieties compatible with high quantities of insecticides, fungicides and herbicides. Green Revolution interventions subsequently 'diffused' these technological innovations to the global south, dramatically extending the accumulative scope of transnational chemical, fertilizer, feed and seed industries. Since the 1990s, the science of genetic modification, entwined with patent protections, has continued in much the same vein, contributing to a rise of 'gene giants' now emblematic of the concentration of power in modern agri-food supply chains (Howard 2009). The past 150 years have demonstrated amply that agricultural research can itself be understood 'as the incorporation of science into the historical processes of primitive accumulation and commodification' (Kloppenburg 2004, 10).

Scholarship to date has drawn critical attention to the myriad ways that dispossession of crop genetic resources is imposed – and how peasants, actors, local people resist (and persist) in ways that are forceful, intentional, organized and quotidian. *Domesticated* seeds, however, have commanded most of this attention. Despite the fact that Darwin himself noted their under-recognized status,[42] wild relatives have remained neglected, many researchers argue, compared with food crops (Davies 1991; Maxted and Kell 2009; Ramírez-Villegas et al. 2010; Hunter et al. 2012; McCouch et al. 2013; Bioversity 2015a). Enclosures of CWRs reach back at least to the mid-nineteenth century, when naturalists and gentleman plant hunters collected plant specimens for storage in seed banks and botanical gardens. Russian agronomist Nikolai Vavilov first recognized the breeding value of wild species, and he crisscrossed the globe – more than 115 expeditions in his lifetime – gathering wild relatives in hopes of 'improving' disease-prone Russian cultivars (Nabhan 2009). Insofar as primitive accumulation consists of appropriation *and* accumulation, however, conservation of plants and seeds awaited the breeding science that could valorize these genes. Not until the 1930s were breeders regularly accomplishing the 'wide' inter-species crosses capable of mobilizing wild traits into domesticated varieties that could be bought or sold. There is little food market value, after all, in a wild seed that, by definition, people do not cultivate and usually cannot eat. But slowly, imperceptibly by most accounts, wild relatives crossed the boundary into agriculture, achieving a nascent foothold in the commodity form.

Today, a nexus of forces has converged to change the disregard Darwin spoke of. Discourses of climate change, food insecurity and the ongoing challenge of 'sustainable development' are helping drive interest in conserving and utilizing CWR genes, just as advances in biotechnology and information systems are expanding scientific capacity to do so. Re-commodification of current crops, infused with climate-hardy traits, is therefore one dimension of the enclosure frontier. But the potential sweep is much larger and variegated. In situ conservation calls for genetic reserves, opening up the issue of land enclosure. Traditional and local knowledge is bound up in the biology of wild relatives, whether or not intentional management occurs. The potential for industry to propertize this knowledge through IPR is thus a salient epistemic enclosure. In turn, human and ecological knowledge is increasingly being collected, centralized and parsed in a data-fied idiom by conservation and breeding scientists in the vanguard of their research fields. These innovations entail risks of enclosures with restricted access to such data.

[42] Darwin (1868) observed: 'it appears strange to me that so many of our cultivated plants should still be unknown or only doubtfully known in the wild state'.

CWRs offer an entrée into this complex terrain: some appropriations are occurring 'upstream' as part of science and technology (S&T) developments. Others are occurring 'downstream' in the field of implementation and use, where breeding with CWR will occur, and where seeds will be banked and land-based genetic reserves will be established. Here, science will have 'policy-relevant' say in locating, managing and regulating access to ex situ and in situ sites and their resources. Prior research has suggested how science practices and discourses can facilitate primitive accumulation. In the context of green-grabbing, Fairhead, Leach, and Scoones (2012, 239) consider the rapid assemblage of players – scientists, park managers, state and conservation organizations, the tourist industry – that are 'more deeply embedded in capitalist networks, and operating across scales, with profound implications for resource control and access.' Extending this approach, I look more closely at the production of S&T knowledge in the conservation and use of wild relatives. I focus on two 'upstream' sites of scientific discourses and practices: (1) systematic CWR conservation planning: the conservation science that, in a complementary system, precedes downstream ex situ or in situ implementation (i.e. the design and thinking upstream from gene banking and managing land reserves[43]); (2) breeding and biotechnology, here traits from wild relatives are identified and used to develop a new array of crops to join the agri-food system.

To investigate how science and technology research is enabling enclosures now and in future, I conducted largely documentary analysis of the technical and policy literature on CWR. Using electronic database searches, I surveyed the scientific literature on conservation science, breeding science and biotechnology relating to CWR for the last 30 years. In particular, I identified a number of significant review articles and edited books that define the state of the field. There is a fairly small community of conservation scientists focused on CWR, so their work over time can be traced. I studied the policy documents (e.g. reports and statements) news briefings and webpages that international institutions and NGOs – such as FAO, Bioversity, the Global Crop Diversity Trust, and CGIAR – have issued on conservation and use of crop relatives over that time. I also reviewed journalism and media coverage of emerging biotechnologies, as well as the popular writings of leading scientists working with wild relatives. I coded the discourses visible in this technical and popular literature, and I analyzed the kinds of practices being developed in conservation planning and plant breeding. To understand the history and politics of germplasm flows, I looked at international plant genetics resource treaties and their histories and secondary analysis. Finally, I sampled extant business and biotechnology industry news to determine whether companies are beginning to exploit CWR resources. The intention of my study, then, was to go beyond a simple political economy of dispossession/enclosure to scrutinize how such moves are discursively constructed and generated in practice through processes of elite science and policy. Wild relatives offer something rare: a concrete opportunity to take the 'primitive accumulation' concept and ask how it pertains not only to genetic resources, but to enclosures that assemble around it – to information, land, knowledge and the possibilities of agrobiodiversity

[43] I did not cover land in this paper, specifically the many issues of land access, use and rights that in-situ conservation raises. This terrain is premature for CWR specifically, though the land-grabbing literature suggests that such appropriations for wild relatives are likely to occur.

renewal.

My look at the upstream scientific discourses and practices is a conceptual contribution, rubbing together the two bricks of agrarian political economy and STS/political ecology. I hope the friction sparks a means to better understand enclosures effectively, in seeds and beyond.

Wild relatives gather recognition

The Asilomar Conference Center in Pacific Grove, California, has an illustrious history. In 1975, more than 140 biologists, lawyers and physicians gathered there to discuss the potential biohazards of genetic recombination, and how to regulate the rapidly advancing sphere of biotechnology. Less than 40 years on, in 2013, Asilomar hosted a meeting of the world's top plant genomicists. Representing land grant universities, plant science institutes and the seed industry, the attendees convened to discuss the value and potential of breeding with CWRs. The broad consensus amongst participants was reflected in an essay published months later in the journal *Nature*. In it, lead author Susan McCouch expressed both concern and optimism. The bad news: modern agriculture has shed much of the genetic diversity found not only in farmer-bred landraces but also in the ancestral progenitors of cultivated crops.[44] The good news: much germplasm is stored in gene banks around the world – some 1750 by last count. More bad news: this vast stock was merely sitting there, untapped, because the global community had not invested the time, resources or technical acumen necessary to make use of it. 'How,' McCouch and her co-authors asked, 'should we begin to mine biodiversity for food security?' (McCouch et al. 2013, 24).

Such scientific enthusiasm for wild relatives is nothing new. Indeed, both De Candolle (1855) and Darwin (1868) discussed the origin of cultivated plants and recommended the study of related CWR species. In the 1920s, Russian agronomist Vavilov championed their collection and conservation; species of wild *Aegilops*, *Secale*, *Haynaldia* and *Agropyron*, he believed, were promising plants for improving Russian wheat. By the 1940s and 1950s, breeding with CWR had become a routine affair, and successes with introducing wild traits accelerated through the 1960s and 1970s (Meilleur and Hodgkin 2004). A 1988 booklet published by the International Board for Plant Genetic Resources[45] to increase public awareness of CWR describes their little-known contribution to a very familiar fruit: 'The tomato could simply not exist without the genes from its wild relatives, which have helped it resist a long line of viruses, moulds, wilt, nematodes, and other pests' (Hoyt 1988, 15). In Asia, the pamphlet suggests, combating rice disease has been one of wild relatives' greatest successes. When brown planthopper threatened to devastate rice fields in the 1970s, genes from three wild *O. nivara* plants found in a water-logged field in Uttar Pradesh were bred into IR36 – and are still found in every high-yielding cultivar of rice grown in

[44] It is sometimes thought that 'ancestral' means the wild species has gone extinct or has been transformed entirely into the cultivated form. But domestication generally involved only a subset (a population) of any given species. Thus, many wild ancestral lines continue living and evolving alongside their crop kin today. Wild emmer, for example, still grows in the wild in the fertile crescent of the Near East.

[45] Established by CGIAR in 1974, the International Board for Plant Genetic Resources became the International Plant Genetic Resources Institute (IPGRI) in 1991. IPGRI joined with a network for banana improvement and, in 2006, the two organizations formed Bioversity International.

tropical Asia.

More recent surveys of crop improvement programs (Hajjar and Hodgkin 2007; Maxted and Kell 2009) indicate that wild relatives have been tapped for a wide array of attributes: to confer resistance to pests and diseases, to tolerate extreme temperatures, to withstand drought and flooding, and to enhance nutrition, color, texture, flavor and handling qualities. They have made their way into numerous crops from banana to tomato and from lettuce to chickpea. 'Nearly all modern crops contain some genes derived from CWR,' write Maxted and Kell (2009). Over the years, efforts have been made to tally the commercial value of this bounty. Prescott-Allen and Prescott-Allen (1986) calculated that yield and quality contributions to US-grown or -imported crops were over USD 350 million per year. Most famously, a Cornell research team estimated that CWR genetic resources contribute approximately USD 20 billion to increased crop yields in the US, and roughly USD 115–120 billion worldwide every year (Pimentel et al. 1997; Bioversity 2015b).[46]

Few people outside of traditional/indigenous farmers know what CWRs are, let alone that they are ubiquitous in the modern food supply. Within PGRFA circles, however, it is evident that CWRs have long been recognized as vital for food security and economic stability (Prescott-Allen and Prescott-Allen 1986; Hajjar and Hodgkin 2007; Kell et al. 2015). If the Asilomar conference is any indication, they remain scientifically beguiling, and a potentially lucrative resource.

For the genetic potential of wild relatives to be realized, however, CWR must not be vanishing under pavement, industrial plows and pressures of climate change. For breeding and biotech to have any purchase on the 'use' end of a germplasm pipeline, conservation upstream becomes vital (Vincent et al. 2013). Hence, the imperative of wild relative conservation has emerged prominently in the discourse of mainstream PGRFA institutions, including the CGIAR, FAO, the Millennium Seed Bank and the Global Crop Diversity Trust. Although these institutions have been involved in germplasm collection for many years, they now speak of 'systematic' efforts at local, national and global scales, both in- and ex situ.

The Global Crop Diversity Trust, spearheading ex situ efforts described further below, speaks of 'the most systematic and comprehensive ever bid to conserve the world's crop wild relatives on a global scale.' Bioversity International, a central hub for organizing in situ strategies, maintains a research platform dedicated to CWRs, and recently helped launch the Global Crop Wild Relative Portal. Their websites declare 'Crop wild relatives a key asset for sustainable agriculture' (GCDT 2015) and 'Importance of Crop Wild Relatives – Genes with immense value' (Bioversity 2015c). Wild relatives have also become a key priority activity for FAO, which notes: 'Natural ecosystems contain important PGRFA, including rare, endemic and threatened CWR and wild food plants. These species are becoming increasingly important as sources of new traits for plant breeding' (FAO 2011, 33-34). Such narratives herald the institutionalization of CWR in these 'global' organizations as well as across the constellation of research and policy bodies with whom they partner.

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[46] These impressive figures must be an underestimate, as they do not reflect the historical and ongoing intermixing of wild and domesticated genes in traditional agroecosystems, or the role of farmers in promoting such mixing.

Ex situ and in situ: from competing to complementary

The combining of land-based and bank-based strategies in 'complementary' designs reflects decades of frictions and evolutions in the natural and social sciences associated with conservation. Despite early calls by researchers such as Frankel (1970) and Jain (1975) for in situ strategies, for many years, the dominant trend in CWR conservation mirrored that for plant genetic resources in general. Ex situ approaches received (and continue to receive) the majority of funding, institutional support, technological advance and policy directives (Cohen et al. 1991). For nearly a quarter century, wild and weedy species were swept up in a general treatment of PGRFA as museum material: best saved through the strategy of 'collect, stock and freeze.' It became evident, however, that ex situ strategies were not succeeding as expected in safeguarding acceptable levels of wild relative diversity – just as they had struggled to conserve domesticated diversity (Hoyt 1988; Davies 1991; FAO 1996a). Simultaneously, in situ functions of wild relatives rose to prominence, as field-based researchers began to uncover the numerous ecological roles that CWRs play (Harlan 1992).

By the early 1990s, in situ conservation of CWR had joined ex situ conservation as 'a key element of the integrated tool kit most agricultural scientists feel is needed' to conserve plant genetic resources (Meilleur and Hodgkin 2004). The new paradigm of 'complementarity,' a win-win combining both approaches, was detailed in the writings of anthropologist Brush (1991) and endorsed by the national program leader for germplasm at the USDA – who expressed his opinion that the complementarity of ex situ and in situ approaches was already accepted by a majority of agricultural scientists (Shands 1991). Complementarity became more specific to wild relatives when in situ protection for CWR broke into world policy circles. The Convention on Biological Diversity (CBD 1992) and the FAO Global Plan of Action for Plant Genetic Resources (FAO 1996b) began to recognize the importance of CWR in their natural habitats – not as an alternative to ex situ collection, but as complementary to it. Today, updates to the FAO global plan (FAO 2011), the CBD Strategic Plan (Aichi Targets), and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA 2004) all buttress a regime of in situ-ex situ complementarity.

Within the past six years, ambitious programs have been launched on both fronts. A global ex situ initiative, 'Adapting Agriculture to Climate Change' (AACC), was announced by the Global Crop Diversity Trust in 2013. The Crop Trust is managing the 10-year, USD 50 million project, in partnership with the Millennium Seed Bank of the Royal Botanic Gardens at Kew and funded by the Norwegian government. Described as an effort 'to identify and fill gaps' in existing collections (Dempewolf et al. 2014), AACC focuses on wild relatives in the gene pools of 29 crops considered important to global food security – all included in Annex 1 of the International Plant Treaty. The first phase of the project, explored below, focused on constructing inventories of CWRs and conducting research to determine species and geographical areas for collection. This research phase was implemented with partners at the International Center for Tropical Agriculture (CIAT) and the University of Birmingham, UK.

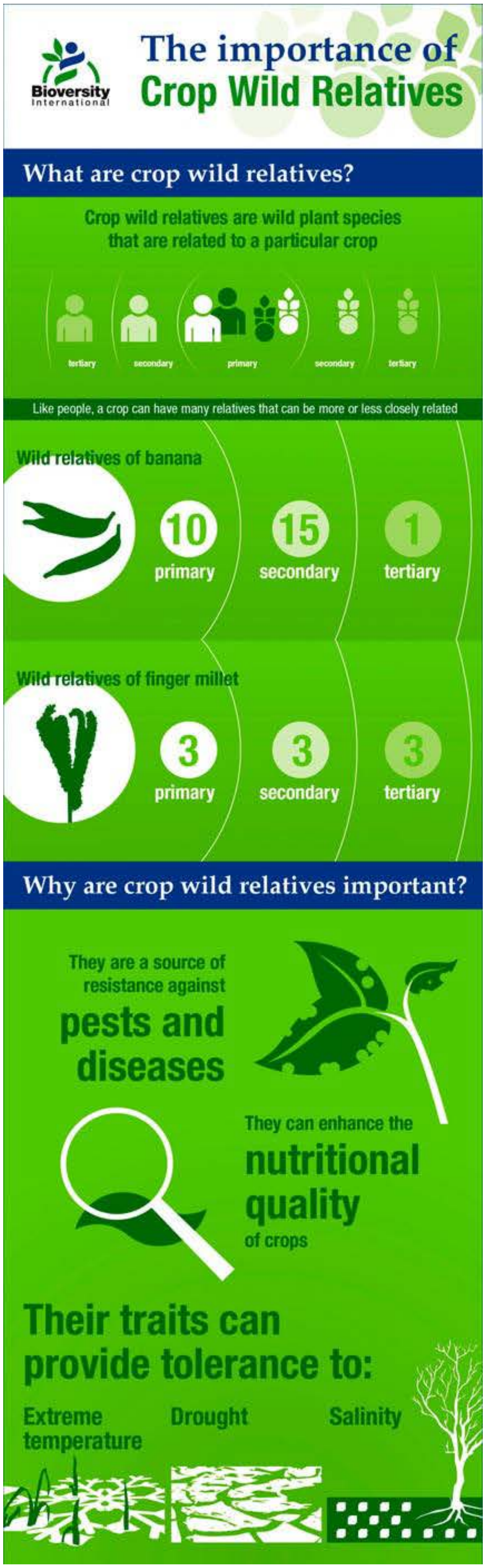
In parallel, plans and methods for systematic in situ CWR conservation are underway. Led primarily by researchers at the University of Birmingham in connection with Bioversity International, methods for systematic CWR conservation planning have been developing rapidly in recent years. Following the first-ever continent-wide inventory of CWRs ('European PGR Forum,' Kell et al. 2005), progress has been made on national strategies in Europe, the Middle East and the Americas, with momentum now shifting to southern Africa and Central America (Kell et al. 2015). At the global level, the FAO Commission on Plant Genetic Resources for Food and Agriculture commissioned Birmingham researchers to conduct a background study on the establishment of a global network for in situ conservation of CWR. This study, published in 2009, aims to provide sufficient scientific baseline information for individual countries to set up conservation areas for CWR, towards a 'systematic effort to build up national, regional or global networks of these areas' (Maxted and Kell 2009). In 2013, the FAO held a special workshop geared to developing an in situ conservation network within a broader context of PGRFA – including modern crops, landraces and wild relatives (FAO 2013).

Framing the climate and food security challenge

Yet formal recognition does not translate fluidly into practical strategies. A common refrain expressed by CWR researchers is that wild relatives fall into an institutional gap between the agricultural and conservation agendas. 'Agriculture looks at tended lands, conservation does not focus on agricultural resources' (Bioversity 2015a). Recently, however, the many stakeholders with interest in CWR – from Bioversity to the Crop Diversity Trust, from the USDA to Birmingham scientists – have received a strong wind at their backs: a confluence of crises that make conserving and using wild relatives seem not only beneficial, but imperative. They have also developed poignant narratives that propagate this belief. The literature on CWR conservation shows the active production of a crisis/salvation discourse, in which wild relatives are both threatened by climate change and vital for world food security (See Figure 6). These storylines help justify the activities of conservation science, while also legitimizing potential enclosures through the authority of a scientific lens.

The agriculture literature today is replete with data on the current and impending effects of climate change. In the Fifth Assessment report of the Intergovernmental Panel on Climate Change (IPCC), authors suggest that climate change will reduce agricultural production by 2 percent every decade until 2050. Over that time span, yields of major crops will face an average decline of 8 percent for Africa and South Asia (IPCC 2014). A study on the impacts of recent warming, meanwhile, found that major staple grains have already experienced significant climate-related yield losses – some 40 million tons per year from 1981 to 2002 (Lobell et al. 2008). Many studies on long-term climate trends do not even take into account the risk of extreme climate events: spiking temperature increases, hurricanes or rainfall-induced flooding. Up to 40 percent of the world's land surface may develop novel climates with new pest and weed complexes (Williams, Jackson, and Kutzbach 2007).

With climate change set to transform growth conditions and arable zones worldwide, climate-hardy wild relatives have never appeared so valuable. Paradoxically, the ecosystems inhabited by wild relatives are also being destabilized by global warming. By 2080, Thuiller et al. (2005) predict, climate change will result in the loss of 27-42 percent of all European plant species in such places, and the immigration or emigration of 45-63 percent of species per 50 km^2. The greatest changes are expected in transition between the Mediterranean and Euro-Siberian zones –



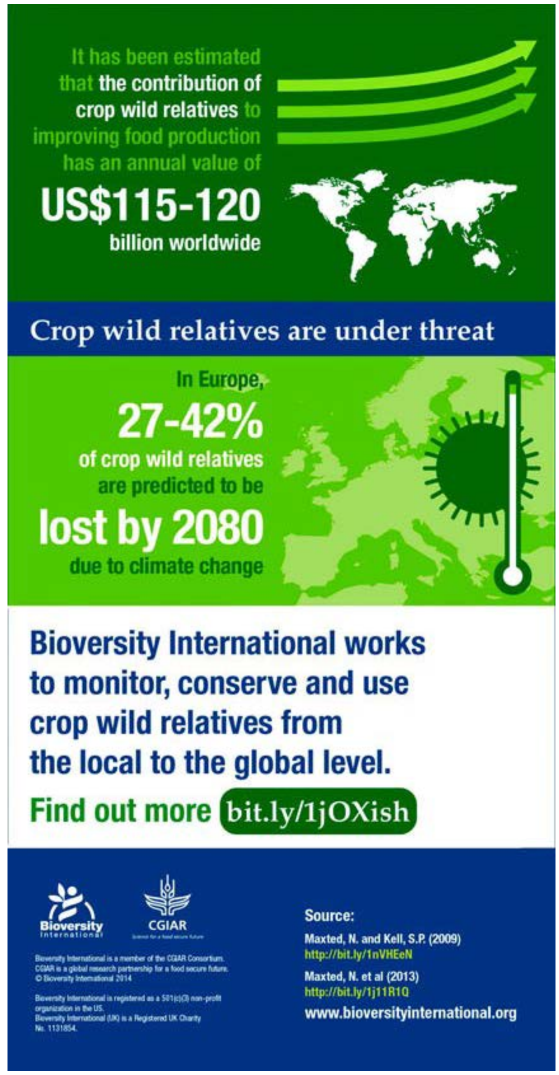


Figure 6. Why Care About Crop Wild Relatives? Bioversity's infographic illustrates the organization's efforts in promoting CWR research, conservation and public awareness. What are CWR? What threats do they face? Why are they important? According to researchers, CWR contribute USD 115-120 billion per year to improving food production worldwide (Image credit: Bioversity 2015b).

the precise region, say Maxted and Kell (2009), containing the highest proportion of agronomically important taxa. Climate change only adds to the other pervasive threats confronting wild plants: deforestation, urban expansion, invasive species, habitat fragmentation and, not least, the intensification of agriculture.

A survey of the CWR literature reveals many forms of this crisis narrative, both apocalyptic and matter of fact. Endorsing the Global Crop Diversity Trust's ex situ project, Dempewolf et al. (2014, 370) rekindle a familiar Malthusianism: 'The world's human population is predicted to reach over 9.3 billion by the year 2050 … placing ever more pressure on agricultural systems to increase production.' Meanwhile, they continue, climate change models indicate possible yield losses of 6–10 percent per 1°C of warming in a growing season: 'This means the world could see significant production losses in the future' (370). Ultimately, they suggest, 'it will be crucial to adapt agriculture to the increasingly challenging environmental conditions by breeding new crop varieties' (370).

In similar strokes, an influential essay in *Nature Climate* (Guarino and Lobell 2011, 374), frames a logic of scarcity with burgeoning population, rising temperatures and collapsing yield: 'With potentially less food to feed more people, we have no choice but to adapt agriculture to the new conditions.'

Remarkably, in situ narratives often follow similar contours. A very recent report on China's CWRs (Kell et al. 2015, 138) begins:

> The potentially devastating impacts of climate change on crop production and food security are now widely acknowledged. An important component of efforts to mitigate these impacts is the production of new varieties of crops which will be able to thrive in more extreme and changeable environmental conditions.

While in situ narratives tend to be less overtly utilitarian than their ex situ counterparts, a parallel extractive mentality pervades. Wild relatives may be conserved 'in place,' but their value is likely to be realized externally: 'Unique and particularly diverse populations of these genetic resources require effective in situ maintenance if they are to continue to meet exploitation needs of current and future stakeholders, and via them, global goods' (Maxted and Kell 2009, 7).

These examples provide a glimpse of the discourse seen across a swathe of systematic CWR literature: in which food security is generally diminished to an issue of production, and production is configured around a narrow set of variables: the crop, the trait or simply 'germplasm.' Crop improvement, in turn, is collapsed down to a particular knowledge domain (technical, grounded in a Eurocentric tradition), belonging to a select community of experts (conservation scientists, PGRFA policymakers, public and private breeders), and populating a few key institutions and donor agencies (most prominently, the CGIAR, the FAO, the Global Crop Diversity Trust, and a cluster of agricultural and plant research universities).

It is not altogether surprising that mainstream PGRFA organizations – many of which have been characterized as part of the 'neoliberal food regime' (Holt Giménez and Shattuck 2011) – would extend their productivist discourse to absorb wild relatives. More surprising, perhaps, is the degree of self-awareness reflected in many mainstream accounts. Many researchers working in

PGRFA readily acknowledge the irony of agricultural intensification as a leading cause of wild relative loss. For example, in a study of the Red List status of CWR in Europe, Kell, Maxted, and Bilz (2012) highlight the role of unsustainable farming practices, such as severe overgrazing, conversion of land to monocultures and the heavy application of fertilizers, herbicides and pesticides. Pollution from pesticide drift, habitat fragmentation from plantation-style agriculture, and the introgression of GMO genes into surrounding natural habitats have all been recognized as drivers of wild relative endangerment (Hoyt 1988; FAO 1996a, 2010, 2011; Friedman 2015).

It is similarly no mystery to these scientists that Green Revolution-style ‘crop improvement’ has eroded the genetic basis of the crop supply. Several decades of high-yield breeding have accelerated genetic erosion within domesticated species. Roughly 75 percent of crop genetic diversity, according to FAO estimates, has been lost since 1900. Just three crops – rice, wheat and maize – provide more than 50 percent of the world’s plant-derived calories. Within these crops, a few species dominate the food supply, and within those, a few homogenous varieties prevail.

Ironically, it is in the context of this crop genetic erosion that the most seductive CWR story yet is now proposed: to rewind the domestication bottleneck and reclaim the diversity that our farmer ancestors left aside.

Rewinding the domestication bottleneck

Roughly 10,000-12,000 years ago, nomadic hunter-gatherers transitioned to life in agrarian societies. Central to this transition was seed selection. Inadvertently at first, later intentionally, our ancestors began identifying and reproducing a small number of favorable traits that were readily recognizable in crops, such as seed size, plant vigor and yield. Darwin himself marveled at the meld of natural selection and ‘artificial’ (human) selection at play in domestication. An important wrinkle for natural selection within agriculture, of course, is that the farm environment is profoundly shaped by human hands: by removing competitor plants (‘weeds’), offering water when there is otherwise none, and enhancing soil fertility. Just by manipulating environments in a certain way, Murphy (2007) suggests, the earliest forms of grain agriculture likely guided the initial genetic changes that were the prerequisites to successful cultivation of those plants as crops. In the wild, for example, most seeds would be shed from reproductive structures, an adaptive trait in the conditions in which plants evolved. But in a tilled field, such seeds would fall to the ground, and not likely be saved for replanting. Thus, the shattering seed head has largely been lost in our domesticated crops. Other such ‘lost traits’ include wild relatives’ gangly growth habits and delayed seed germination (Tanksley and McCouch 1997). Compact plants that sprouted quickly from the earth would have been favored by early agriculturalists.

For millennia, most domesticated plants grew in close proximity to their wild and weedy relatives, enabling a dynamic gene flow. This was especially true in and around Vavilov centers of origin and diversity, where crops are surrounded by their close genetic kin and where complex agroecosystems encouraged mixing, both ‘natural’ and intentional. Mexican subsistence farmers, for example, would intentionally plant their maize on farm borders near wild relatives to raise the likelihood of cross-fertilization and crop enhancement (Hoyt 1988). Swidden cultivation – with ever-changing interfaces of domesticated and wild habitats – brought another potent form of genetic intermixing in African cereals and is likely to have done the same in other places (Hutchinson 1974). Where geographic proximity, landscape complexity and farmer practices aligned, CWR introgression with crops has been almost continuous, not only casting new light on the once-upon-a-time concept of domestication, but making for agroecosystem resilience.

However, agriculture has been thoroughly re-spatialized, especially following the Columbian Exchange. European explorers, traders and plunderers brought Old World crops to New World frontiers, transplanted germplasm across tropical colonial holdings and shepherded New World seed back to European fields. With this geographic distancing of many food crops away from their wild relatives, the potential for natural (and facilitated) cross-fertilization has grown increasingly slim. Destruction of natural habitat by monoculture production systems has further reduced opportunities for gene flow. Meanwhile, those cultivated crops are having diversity systematically bred out of them. As Tanksley and McCouch (1997, 1063) put it, ‘Because new varieties are usually derived from crosses among genetically related modern varieties, genetically more variable, but less productive, primitive ancestors are excluded.’ Ironically, they note, ‘it is the plant-breeding process itself that threatens the genetic base on which breeding depends.’

This contemporary fix, created by both domestication and modern breeding, has spurred papers with titillating titles such as: ‘Unlocking genetic potential from the wild’ (Tanksley and McCouch 1997) and ‘Taking a walk on the wild side’ (Guarino and Lobell 2011). Retracing the domestication bottleneck, Guarino and Lobell explain, will provide access to ‘lost’ resources – to the ‘reservoir of diversity our Neolithic ancestors left behind’ (2011, 374). Traits from CWRs have already been used to breed crops with adaptations to abiotic stresses such as salt, water and heat extremes. The more common successes have been in the biotic sphere: providing host plants with resistance to insect, fungal and viral pathogens. These stressors may seem tangential to climate change, but as plant pathogens are predicted to shift their ranges, many farmers will experience unprecedented disease pressures. The promise of rewilding the crop gene pool, then, has never looked so auspicious or necessary. As Guarino and Lobell note, ‘If there was ever a time to go back and reclaim this diversity, that time is now’ (2011, 374).

The foregoing analysis of framings and narratives in mainstream CWR discourse hints at strong epistemic similarities across in situ and ex situ researchers and institutions. Under a productivist organizing principle, in situ activities appear aligned with – even subordinated to – the purposes of ex situ extraction and use. Narratives of loss and primitiveness, as I have argued elsewhere (Montenegro de Wit 2016a), work to invisibilize peoples for whom wild relatives are very much not lost. Hardly confined to pre-history, these contemporary communities not only use CWR in breeding, they also cook, eat and market wild plants for extra nutrition and income. By framing what exists/persists as lost and unknown, these narratives work to appropriate agency and expertise; they imply that scientist-experts will be needed to regain lost diversity. More subtly, they also shift the burden of genetic diversity loss onto Neolithic farmers, rather than onto their more proximate nemeses: principally industrial agriculture. The discursive ground, then, is well prepared for scientific solutions that foreground systematic/technical planning without unduly disturbing the underlying productivist logic.

But narratives only provide a partial window into important enclosure processes in play. In the following section, I investigate material scientific practices: defining wild relatives, ranking conservation priorities, bringing inventories, mapping and making databases to construct policy-relevant science. Conservation science is seldom recognized as a site of enclosure itself. As with other S&T developments, its internal workings are generally 'black-boxed' from critical scrutiny (Latour 1999). By probing the practices, particularly of elite science institutions, we get a glimpse of how primitive accumulation germinates through knowledge production – long before it assembles as visible conservation on the ground.

Systematic CWR conservation science

More than 15 years ago, *Genes in the field*, a volume dedicated to in situ conservation, distinguished between two types of in situ. The first type, 'de facto' persistence of genetic resources in their natural habitats, refers to areas where 'everyday practices of farmers retain genetic diversity on their farms.' The second type refers to specific projects and programs 'to support and promote the maintenance of crop diversity, sponsored by national governments, international programs, and private organizations' (Brush 2000, 4). Systematic conservation for CWR falls firmly into the latter camp, consisting of scientifically informed protocols for designing and implementing conservation – both in situ and ex situ.

There are many potential approaches to the systematic planning method, and the steps are by no means sacrosanct. Maxted et al. (2007) and Heywood et al. (2007) suggest a model for developing such strategies, at the national and global levels (See Figure 7).

This model has since been taken up by studies supporting national and global networks for CWR conservation.

As can be seen in Figure 7, the protocol contains a fork, with pathways diverging to support in situ and ex situ strategies. When it comes to wild relatives, off-site strategies are comparable to those for crop plants: maintenance of germplasm in gene banks, botanical gardens and field-based reserves (Hoyt 1988). In situ strategies, however, diverge significantly from crop conservation – in fact, the latter is sometimes dubbed 'on-farm' conservation to distinguish it from the 'in situ' of wild relatives, which can range from forests to roadsides.

In situ conservation proposes the maintenance of wild relatives in their natural habitats, either by identifying wild relatives within existing protected areas and highlighting their priority management, or by establishing new protected areas. Maxted and Kell (2009) envision a strategy that ultimately creates overlapping national and global networks of such 'genetic reserves,' which would enlist individual overseers of protected areas, national land management and conservation agencies, and international bodies such as the FAO and International Plant Treaty to devise a worldwide in situ system backed up by ex situ collections. As I illustrate below, the planning for such on-the-ground work begins far upstream, in defining, counting and prioritizing wild relatives.

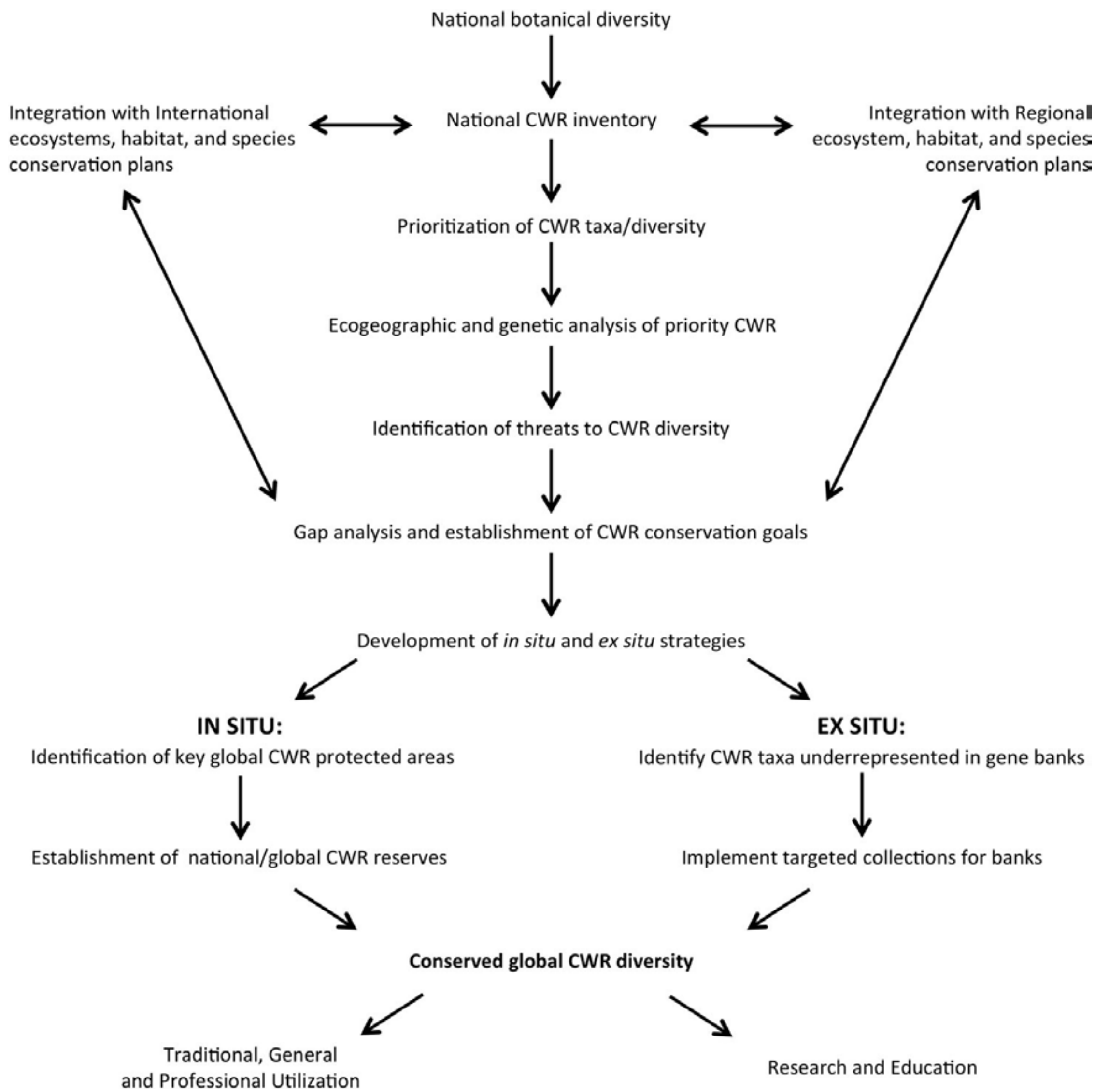


Figure 7. Systematic CWR Planning. Model for the development of systematic national and global crop wild relative (CWR) strategies (adapted from Maxted et al. 2007 and Heywood et al. 2007).

What is a wild relative?

Before any practical work can take shape, researchers must decide which plants constitute 'CWR.' A typical definition indicates that wild relatives are not only the progenitors of crops – often a wild plant of the same species – but also species 'more or less closely related' to them (Heywood et al. 2007, 245). Exactly how closely related, however, can mean the difference between identifying a few dozen species or thousands of wild and weedy kin. This definitional matter also means a great deal for crop breeding, since, biotechnology notwithstanding, genetic proximity remains a good proxy for ease in breeding.

One simple and intuitively straightforward way to define wild relatives is at the genus level. A CWR would be any taxon belonging to the same genus as a crop. Sweet potato wild relatives, for example, would include all the species and subspecies in the genus *Ipomoea*. A genus-wide definition was adopted by the European PGR forum (Kell et al. 2005) and has the advantage of easy application. The downside can be its breadth. Analyzing Mediterranean and European floras, researchers found that some 80 percent of these plant species qualified as CWRs (Kell et al. 2008). 'Gene pools' are another way of bounding wild relatives. Originally proposed by Harlan and de Wet (1971), the gene pool concept puts close relatives in the primary gene pool (GP1), more remote ones in the secondary gene pool (GP2) and very remote ones in the tertiary gene pool (GP3). Adhering to the primary gene pool generally includes taxa close enough to interbreed viably. But data about interbreeding and genetic diversity are lacking for many candidate species.

For this reason, Maxted et al. (2006) proposed an alternate strategy to supplement the gene pool concept. Based on standard taxonomic classifications, this strategy assigns different 'Taxon Group' categories beginning with the crop (Taxon Group 1a), wild relatives of the same species as the crop (Taxon Group 1b), and extending to all wild plants in the same genus as the crop (Taxon Group 4). These taxon groups, they suggest, can be used to establish the degree of relationship between a CWR and the crop when researchers have little information about reproductive compatibility.

Based on these arguments, they propose the following as a working definition of CWR:

> A crop wild relative is a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to Gene Pools 1 or 2, or taxon groups 1 to 4 of the crop. (Maxted et al. 2006, 2680)

Many authors have since taken up this definition, indicating its value as the best 'pragmatic' means available for delimiting CWR. For example, Heywood et al. (2007, 247) argue that casting a genus-wide net is not very helpful when it comes to identifying wild relatives with agronomic potential: 'There is a need to estimate the degree of CWRs relatedness to enable limited conservation resources to focus on priority species, i.e. those from which desired traits may be most easily transferred to the crop.' Similarly, Maxted and Kell (2009, 9) underscore that 'conservationists [are] competing for limited resources,' making it vital to apply an accurate definition of the relationship between a crop and its relatives.

Evident in these conceptions of CWR is both a perceived condition of scarcity – in which decision-makers must economize their resource use –and a functional view of conservation, in which ex situ extraction is the presumed objective of in situ work. In a world of numerous competing demands, they imply, rigorous metrics will provide a scientific basis for guiding rational decisions. Defining a wild relative, then, becomes imbricated in a particular strategy of appeal: to policymakers, funding organizations and governments to increase their support for wild relative research.

Yet such appeals cannot help but reshape the science itself, which develops according to foreseen policy relevant criteria. Moreover, 'accurate' definitions help streamline conservation priorities through a bottleneck that they themselves create: in which wild relatives come to be defined by their genetic proximity to crops – and, therefore, their potential for breeding purposes. Increasingly, the literature proposes that utility for crop improvement is intrinsic to the very identity of a wild relative species: 'CWR are species closely related to crops, including crop progenitors, *and are defined by their potential ability to contribute beneficial traits to crops* such as pest or disease resistance, yield improvement or stability' (Maxted and Kell 2009, 51, emphasis added by author). These discursive practices are evidence of a new accumulation frontier: where bounding nature according to its production value defines some organisms as valuable, and hitches conservation to those extractive identities.

Inventory

An initial step in systematic CWR conservation is constructing an inventory. These can be local, national, regional or global, with different methods applying to each. For example, countries in Europe and the Mediterranean can use the PGR Forum Catalogue – an inventory of this region – as the foundation for their own national inventories. For most countries, however, inventories must be built from botanical scratch. Most countries do not have databases of CWR, per se, but almost all have national checklists of their floristic diversity. These lists include all plant diversity, including cultivated and non-cultivated species.

Researchers, meanwhile, have at their disposal global lists of crops – notably, Mansfeld's World Database of Agricultural and Horticultural Crops – from which genus names can be extracted (Hanelt and Gatersleben 2001). These genus names can then be matched against the national botanical checklist to identify all genera containing cultivated plants. Assuming a genus-wide definition of CWR, all taxa (species, subspecies, etc.) within these genera can be 'extracted' as the national CWR inventory (Maxted and Kell 2009). With the ascendancy of digital biodiversity management, much of this work becomes a matter of database comparison, matching and identity extraction.

But using a genus-wide definition also tends to cull a very large set of species in the initial inventory – tens of thousands, in the case of China's wild relatives (Kell et al. 2015). For this reason, and as I explore below, researchers apply various means of whittling down the candidate conservation pool. In a process I describe as 'filtering,' these steps of selection and prioritizing CWR further shape the contours of policy prescriptions and imperatives. The use of such filters also explains an apparent contradiction: using a genus-wide definition, when researchers have devoted so much attention to precisely defining what constitutes a CWR. Various filters can also embed definitions, as we will see, moving the architecture of systematic conservation into alignment with specific norms for crop improvement.

Prioritizing

Given that the number of potential CWRs that might be conserved far exceeds institutional capacity – no matter what definition of CWR is applied – systematic conservation plans include several possible means of prioritizing. As Heywood et al. (2007) describe, priority setting may involve some form of threat assessment (e.g. based on IUCN Red List data) and consideration of the economic value of the related crops. Priorities can also take into account cultural importance for local people, the wild relatives' ecological role, and the presence of the CWR – or lack thereof – in existing protected areas. In addition, ethical and aesthetic considerations, legislation and financial costs can all be factors used to ascribe 'value' (Maxted et al. 1997b; Kell, Maxted, and Bilz 2012).

One example of how scientists apply priorities comes from a recent global inventory of CWR. Originally developed for the Global Crop Diversity Trust (principal partner in the global ex situ project), the 'Prioritized Crop Wild Relative Inventory' (Vincent et al. 2013) was designed to inform both ex- and in situ efforts. It specifies two key priority concerns: (1) socio-economic importance of the related crop; (2) potential use for crop improvement. The first filter works in an exclusive sense, by removing all CWR not considered important according to their relatedness to crops listed in the International Plant Treaty (Annex 1 crops) and a world reference of major and minor food crops (Groombridge and Jenkins 2002). The second filter works to rank CWR within these priority crop genera according to breeding value; here, researchers use a combination of gene pools and taxonomic groups to estimate breeding potential, alongside published records of successful and potential use. The global inventory concluded by identifying some 1667 taxa (1392 species and 299 subspecific taxa) of critical importance for economic and food security.

Analyzing these priority-setting steps, however, reveals the subtle (and not so subtle) ways in which systematic CWR planning could perpetuate enclosures. First is the growing reliance on only a few prioritization criteria to the neglect of myriad others. Increasingly, the literature reflects an opinion that only three priorities are 'of greatest relevance when assigning priorities to CWR species in the context of conservation planning' (Kell et al. 2015, 142): socio-economic importance of the related crop, breeding utility, and threat status (see also Vincent et al. 2013). As an example, a recent national inventory of China's CWRs began by tallying human food crops that were cultivated in China over the period 2002-2011. Crops with an *annual production value over USD 500 million* were identified and the native wild relatives of these crops became the foundational list of important CWR (Kell et al. 2015). The assumption is that wild relatives will be used to develop valuable crops, such that commodity revenues and trait value come to justify conservation of the wild species. Meanwhile, what gets filtered out and de-prioritized are values intrinsic to CWR that may be unrelated to crop improvement: stabilizing agroecosystems in situ, providing ecosystem service benefits (at multiple scales) and contributing to spiritual, agricultural and livelihood practices of local peoples. Throughout Africa, for example, people are known to eat wild cowpea species (*Vigna* spp.), while in Madagascar, wild yams (*Dioscorea* spp.) are a rich source of carbohydrates. Both are also sold in local markets, providing additional household income. CWR that do not move through the crop improvement pipe- line, or that never enter formal commodity markets, are seen as less important to address – and, thus, less important to protect.

Second is the inherent contradiction in pegging the values of CWR to the socioeconomic values of their related crops. The risks herein should be fairly obvious: the crops that are most profitable, ubiquitous and energy yielding today reflect the structure and organization of the predominant agri-food system. High-grossing crops are often those pushing out much agrobiodiversity, wild relatives included. Similarly, industrial staples such as rice, corn and wheat comprise an increasing proportion of the world diet (Khoury et al. 2014), so metrics based on current nutritional provisioning will tend to reinforce the agri-food status quo.

The discourse of CWR science seems to be moving into lockstep with a longer standing synergy between commodity production and scientized nutrition. Mudry (2009) examines how organizations such as the USDA attempt to legislate a healthy diet by mandating quantities of food based on measurable nutrients – calories, vitamins and serving sizes. This quantification has the effect of controlling how people eat, how they believe they should eat and, in turn, consumer demand for certain foods. It occludes the quality of nutrition outside of Western dietetic boundaries – and says little about how food is produced, by whom, or under what social and environmental conditions. Similarly, wild relatives are now assessed through reductive quantities such as dollar value or the caloric value of their related food crop. In the case of the China inventory (Kell et al. 2015), a novel method was employed. Using FAO statistics, researchers calculated global nutrition values for human food crops, according to average annual per capita energy supply. The intention was to consider the transnational value of local wild relatives. As the researchers put it,

> although the priority for most countries is to conserve resources that are of greatest potential socio-economic value to the nation, it is important to consider the value of genetic resources in a broader geographic sense since no country is self-sufficient in food supply (Kell et al. 2015, 7).

Latent in these priority-setting methods, then, is the potential to perpetuate many facets of the current 'socio-economy' based on their very starting points. It is through these priorities that we can see the edges of primitive accumulation being forged: signaling to industry, governments, scientists and civil society where genetic resource value is to be found (where it is not to be found) and what sort of value it represents. Wild relatives currently appear to be things we should care about because they will improve crops already central to producing our industrial food system.

Ecogeographic studies, threat assessment and 'gap analysis'

After a prioritized inventory has been compiled, researchers conduct ecogeographic studies and threat assessments to further refine the list of priority taxa, followed by 'gap analysis' to identify which wild relatives are not adequately conserved in ex situ collections and where genetic reserves could be established in situ (Heywood et al. 2007).

Considered the backbone of CWR conservation, ecogeographic work consists of an epic data trawl: researchers must collate all information available about wild relatives' ecology, geography and diversity – both taxonomic and genetic. Such information can come from existing literature or from novel field surveys and interviews, with common sources including gene banks, herbaria, museums, government ministries and plant research institutes. The 'passport information' associated with accessions in banks and herbaria specimens, for example, describes where CWR were collected, as well as their center of origin and diversity.

Increasingly, digital databases intervene both upstream and downstream of ecogeographic work. As gene banks build massive informatics platforms (DivSeek, InfoSys), much knowledge of PGRFA is coming online, including passport information and genomic, phenotypic and taxonomic data. Germplasm holdings at far-flung museums and universities are now accessible on the web, and an increasing number are being brought into centralized data management systems. On the input end, these databases have become key to gathering 'occurrence' records – information about CWR whereabouts in banks and on land. On the output end, the results of ecogeographic studies are frequently entered into regional and national databases to enable geographic information system (GIS) mapping and analysis.

For ex situ conservation, according to Maxted et al. (2008), the ultimate goal of ecogeographic studies is to identify populations of CWR thought to contain genetic diversity that is not already conserved in off-site collections. 'Gap analysis' allows researchers to fill gaps between extant gene bank collections and actual distribution on land. For in situ conservation, the goal is to locate land areas with high concentrations of priority CWR species and work to preserve them. Yet the work does not end here. Once land enters the calculus, 'threats' take on a new valence. In addition to considering threats to individual CWR taxa – a common step in creating a prioritized inventory – threats must pertain to in situ territory: to the likelihood of endangerment from habitat fragmentation, over-exploitation, expanded urbanization, unsustainable agriculture and climate change. Structured assessments can then fill the in situ gaps by showing which combinations of land sites contain the 'optimal or 'best' sample of CWR species in the minimum number of genetic reserves.[47] Ideally, Maxted and Kell (2009) suggest, it will be possible to locate and establish such genetic reserves within existing protected areas. But creating new protected areas specifically for CWR conservation should not be excluded either, as CWR species are famously cosmopolitan in their tastes, inhabiting roadsides, urban lots and other disturbed habitats that may not have been considered appropriate for protected area status.

Sociopolitical factors: where are the people?

Designers of systematic CWR science widely acknowledge that human dimensions should come into account – whether in negotiating seed collections or establishing genetic reserves. Especially in the latter case, where land is involved, decisions over access and use must involve farmers and indigenous and local communities (see e.g. Maxted 1997a; Hunter and Heywood 2010; Maxted,

[47] 'Genetic reserves' are proposed as the preferred model for conservation of CWR in situ. As defined by AEGRO, a European network that promotes in situ and on-farm management of agrobiodiversity, genetic reserves are 'areas designated for the active, long-term in situ conservation of wild populations where the primary consideration is to preserve its genetic diversity' (AEGRO 2015).

Magos, and Kell 2013).

These scientific recognitions have followed and informed discourse at the international policy level. The ITPGRFA promotes 'Farmers Rights,' and the FAO Global Plan of Action on PGRFA (FAO 2011) is replete with statements supporting the role of local peoples in conservation of agrobiodiversity, including CWRs.[48] Reflecting such policy-science conjunctures, the South African Development Community – Crops Wild Relatives (SADC-CWR) project,[49] launched in 2014, is explicitly pluralistic, aiming to include a broad group of stakeholders as 'decision-makers': from national policymakers to actors in agriculture (technical departments, plant breeders), environment agencies, conservation NGOs and farmer organizations (SADC-CWR 2015a): 'The promotion of indigenous knowledge can also be advantageous to CWR' (SADC-CWR 2015b).

But it remains unclear to what extent recognition of local knowledge on paper extends to activities on the ground (many of which are very nascent), and whether recognition will translate into authentic social empowerment. Under the scientific leadership of Ehsan Dulloo, the CWR program at Bioversity is poised to become more cognizant of local ecological expertise. In a promotional film, he notes: 'Farmers tolerate the presence of crop wild relatives on the farm because they recognize the value that these crop wild relatives bring to their cultivated plants' (Bioversity 2015a). However, at the 2014 Genepool Utilization Conference, Bioversity researchers presented on plans for a 'Community of Practice' for CWR. Sketching who would be important in such a community, they named 'FAO, CBD, UNEP, ITPGRFA, UNESCO, IUCN, CGIAR, NGOs, etc.,' – leaving aside explicit mention of peasants, indigenous peoples and public citizens (Dulloo and Drucker 2014). To include a diversity of stakeholders is also potentially misleading, since inclusion says little about the terms of inclusion, or the quality, extent and duration of participatory practice (see e.g. Sperling et al. 2001). Epistemically, different knowledges can be included on highly uneven terms: how is legitimacy granted and shared?

A large scholarship has explored lay-expert divides in environmental governance (e.g. Irwin 1995; Wynne 1996; Fischer 2000; Collins and Evans 2008). In conservation of biodiversity, as with PGRFA, recent years have seen a marked shift towards the inclusion of farmer, local and traditional knowledges. Yet implicit in this participatory turn are unresolved tensions. A strong tradition in dominant PGRFA institutions remains rooted in an 'information deficit' model, which assumes a lack of knowledge in the public. Scientists, then, should educate the public for their own good, and the wellbeing of all, in line with sustainability goals. This trend is seen, for example, in the SADC project language:

These CWR species are often neglected and thus threatened in the wild, due to ignorance

[48] Reflecting the participatory turn in 1990s sustainable development discourse, both the First (1996) and the Second (2011) FAO Global Plans of Action on PGRFA emphasize farmers and indigenous and local peoples. The latter recognizes their role as guardians and stewards of agrobiodiversity on farm and in situ (FAO 2011, 20), calls for policy supports to strengthen local conservation capacity (27) and even underscores farmer/indigenous participation in crop improvement, using 'participatory, de-centralized, and gender-sensitive approaches' (58).
[49] SADC-CWR aims to address the 'in situ conservation and use of crop wild relatives' in countries of the South African Development Community. The three-year project is a partnership of African universities and institutional partners including Bioversity and the University of Birmingham.

of their value to agriculture by policy-makers, decision-makers and ecologists. Also breeders and farmers, in particular, are unaware of these resources and often lack the skills to mine the genetic diversity from CWR for use in novel varieties (SADC-CWR 2015c).

The arguably more dominant model in PGRFA conservation today is not information deficit, but what Delgado (2008) terms 'knowledge co-production.' Exemplified by the Convention on Biological Diversity, this model recognizes indigenous, local and traditional peoples, whose knowledges are characterized as potentially 'relevant for the conservation and sustainable use of biological diversity' (UNEP/CBD 1992, art. 8). Relevant is a key word, as it implies that local knowledge becomes valuable only after it has been assessed from a scientific point of view (Agrawal 1995). Delgado shows how this expert-lay relation unfolds in Brazil, where the Landless Workers' Movement (MST) is promoting agroecology as its preferred mode of agricultural production. Technicians purport to value and validate farmer lay knowledge, but as Delgado's research reveals, legitimacy is selective. Parts of local knowledge that conform to agroecology receive 'distinctive recognition,' while the others are 'problematized' and targeted for expert remediation. In other words, the part of local knowledge that does not count as ecological expertise 'remained invisible or categorized as ignorance' (Delgado 2008, 571).

In CWR conservation, the highly obscure processes of systematic planning – the defining, priority setting and gap analyzing – are especially prone to this subtle invisiblization. Local knowledge can be, and is, included in systematic planning. But only to the extent that it conforms to pre-existing scientific principles of sustainability and conservation. Enclosure of the material seed, then, begins on this slipstream of knowledge exclusions: both the blatant information-deficit form, and the stealthier co-productive form. Scientists may not intentionally propagate enclosures, but their methodologies anticipate them in the qualified inclusion of community actors.

Conservation science is not alone, however, in making the ground fertile for epistemic and material appropriations. As we have seen, the priorities of conservation, in- and ex situ, are increasingly dictated by breeding value and the prospective caloric or dollar return from CWR-improved crops. The science of how to incorporate wild relative genes into domesticated plants thus becomes the second major hinge in our enclosures story. Plant breeding and biotechnology is initially more obvious as a site of primitive accumulation given its history with biological and legal enclosures. The very name Monsanto is something of a signpost for a dispossessive regime. Less evident (and less explored) is the making of the S&T knowledge upstream of oligopsony control. Wild relatives are not new to breeding science, but they are injecting new energy into the field. By offering the potential to re-commodify current crops with wild genes, they are pulling the frontier of primitive accumulation into a genetic space whose boundaries are pushed by the ambitions and technologies of science, and what gene-tinkerers can do.

Breeding and biotechnology

Until the 1980s, the range of CWR breeding 'successes' could be counted on one hand. Stories about wild genes preventing devastation by pests and diseases, according to Hajjar and Hodgkin

(2007), were dominated by a handful of triumphs. *Oryza nivara* provided resistance to grassy stunt virus in rice; *Solanum demissum* gave potatoes protection against late blight; and *Agropyron elongatum* and *Aegilops umbellulata*, respectively, conferred stem and leaf rust resistance in wheat (Prescott-Allen and Prescott-Allen 1986). In the past 30 years, however, the discovery and use of new resistance genes from the wild have steadily increased in these crops and others. Commercialized tomatoes now derive nearly all of their resistance genes from wild relatives (Rick and Chetelat 1995). In rice, the original *Oryza nivara* genes still fend against grassy stunt virus on millions of hectares across South and Southeast Asia (Barclay 2004), while several different wild species of rice confer resistance to at least six other diseases (Hajjar and Hodgkin 2007). Sweet potato wild relatives have been tapped for traits from protein enhancement to drought tolerance (See Figure 8).

Nonetheless, a common refrain amongst researchers for many years is the longstanding *under*-exploitation of wild relatives (Tanksley and McCouch 1997; Maxted and Kell 2009; Guarino and Lobell 2011; McCouch et al. 2013). This perceived under-utilization reflects, in part, the challenge of working with wild species. It is an everyday occurrence for breeders to hybridize two varieties of a crop species; they even cross the species or genus boundary in what is known as a 'wide cross.' Yet wild relatives, being undomesticated, are less predictable. If the plants are genetically compatible at all, the resulting embryos may not be viable without special 'rescue' techniques, and offspring of CWR hybrids are often sterile. In addition, there has been fear of yield collapse: the possibility that introducing wild relatives' genes will disrupt the high-yielding gene complexes breeders worked so hard to stabilize in the first place. Perhaps unsurprisingly, wild relatives have achieved notoriety amongst breeders for being 'difficult' (Stebbins 1958; Zeven, Knott, and Johns 1983; Sharma et al. 2013). As one breeder tells Guarino and Lobell (2011, 375): 'it's a bit like crossing a house cat with a wildcat. You don't automatically get a big docile pussycat. What you get is a lot of wildness that you probably don't want lying on your sofa.'

Weeding out this unwanted wildness demands a process known as 'pre-breeding in which modern varieties are crossed with wild relatives, followed by repeated backcrosses to the modern parent. Even then, the result is not plow-ready, but represents an intermediate product: germplasm 'enhanced' for public or private-sector use. This added step in the breeding process, in turn, has carved an institutional division of labor. Most crop-breeding programs, according to Guarino and Lobell (2011, 375), are not set up to make full use of species that require lengthy and intensive management: 'Breeders, particularly in the private sector, are rewarded for releasing new varieties quickly, and wild relatives are viewed as too unwieldy to use with sufficient ease and speed.' The public sector has therefore become the workhorse of wild relative breeding, historically at CGIAR centers[50] such as the International Center for Wheat and Maize

[50] To call the CGIAR a 'public institution' is increasingly a stretch. A restructuring process – intended to streamline the funding process and reduce transaction costs – led to the separation of the CGIAR Consortium (the research centers) from the CGIAR Fund in 2010. The latter is administered by the World Bank, as Trustee, and governed by a Fund Council. Between 2010 and 2014, top Fund contributors have been the US, the UK, the World Bank, and the Bill and Melinda Gates Foundation (BMGF). Roughly USD 175 million from BMGF (out of USD 180 million) have been window 3 gifts – i.e. targeted to specific CGIAR centers and not considered by CGIAR to be 'untied aid' (CGIAR Fund 2015). The increasing hold of philanthropy capital and private–public partnerships on the CGIAR has

Improvement (CIMMYT) and the International Rice Research Institute (IRRI), though now extending to the International Center for Agricultural Research in the Dry Areas (ICARDA; see Valkoun 2001 for examples of wheat pre-breeding using CWR) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT; see Sharma et al. 2013 for legume pre-breeding with CWR). The decline of public sector plant breeding – indeed 'emasculation' of the sector as a whole (Kloppenburg 2010) – has meant slow progress in wild relative research.

Figure 8. A Close Colombian Relative of Sweet Potato. Grown on at least 8 million hectares in 114 countries worldwide, sweet potato (*Ipomoea batatas*) is a vitally important root crop, with particular significance for the nutrition and livelihoods of smallholders in Sub-Saharan Africa, East Asia and Southeast Asia. As part of the global ex situ initiative 'Adapting Agriculture to Climate Change,' a research team led by the International Center for Tropical Agriculture (CIAT) has focused on wild relatives of sweet potato: assessing the comprehensiveness of global ex situ germplasm collections, contextualizing the results with research and breeding priorities, and identifying species with the potential to contribute desirable agronomic traits (Khoury et al. 2015). Among 14 species considered to be close wild relatives of sweet potato, its closest kin is *Ipomoea trifida*, pictured here. *I. trifida* has already contributed to breeding sweet potatoes for improved protein and starch content, and resistance to nematode and sweet potato weevil. Scientists suspect that *I. trifida* will be particularly important for future breeding, because it is adapted to climates with heat, high precipitation, drought, and temperature seasonality. (Image credit: Ornamentals of Colombia (2016), with permission).

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been criticized but is also seen as a public system vying to retain relevance at a time of private-sector dominance in agricultural and agbiotech research.

But the ground is shifting rapidly beneath wild relative breeding, transforming both the motivations for overcoming biological obstacles and the technological capacity to do so. Climate change is at the core of these recent developments: as genetic diversity is increasingly recognized as fundamental to climate-resilience, R&D and commercial attention has turned to consider the vast repository of latent diversity in wild relatives. Conventional breeding[51] seems to retain many advantages over genetic engineering (GE) for dealing with complex traits such as drought tolerance – and crossbreeding with CWR offers one such conventional approach. Yet neither breeding nor biotechnology[52] is a stable regime, and molecular science is rapidly transforming both. Calls to unleash the 'tremendous genetic potential locked up in seed banks' (Tanksley and McCouch 1997, 1063) have pulled CWR to the center of a molecular revolution: in which wild relatives are targeted for genome-wide methods of more efficient, yet 'traditional,'[53] plant breeding, alongside GE techniques touted as organic 'rewilding.' Perhaps unsurprisingly, the conjunctures of climate, science and technology, and agricultural sustainability have put wild relatives on a path with heady promise, curious contradictions and important repercussions for how, where and by whom value is created and captured. Below, I consider these elements in further detail.

Returning 'lost' diversity to the domesticated gene pool has never looked so vital, as climate change both demands such re-diversification and threatens to eradicate many wild species. A heavily politicized debate surrounds climate adaptation: on one side, agronomic and agroecological approaches target soil, water, plants, animals and other elements of the farm ecology; on the other side, breeding focuses on adapting one plant – the crop – to the changing environs. In turn, crop-centric communities are divided over conventional breeding and biotechnology. Industry pursues both tracks but is increasingly trained on the latter, in hopes of genetically engineering more 'crop per drop.'[54]

Mounting research suggests, however, that conventional breeding techniques may still eke out an

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[51] 'Conventional breeding' is a broad term depicting methods that introduce new variety to plants without reliance on genetic engineering. Conventional breeding includes 'classical' techniques – known to farmers since ancient times – of interbreeding closely or distantly related individuals to produce new crop varieties or lines with desirable properties. After WWII, 'modern' techniques added to the conventional toolkit included induced mutagenesis (chemical and irradiation) and plant tissue culture. Increasingly, conventional breeding makes use of molecular tools such as genomic sequencing, bioinformatics and marker-assisted selection.

[52] Biological technology, or biotechnology, is an ambiguous and politically loaded term. Broadly, any deliberate manipulation of biological material or systems is a kind of biotechnology, including seed hybridization using classical crossbreeding (Goodman, Sorj, and Wilkinson 1987; Kloppenburg [1988] 2004). For the purposes of this paper, I use agricultural biotechnology in the more commonly understood sense: 'as the use of DNA-based technologies for crop improvement' (Murphy 2007, 157). In turn, GE is a sub-class of agricultural biotechnology, described most simply as 'in vitro techniques for manipulating nucleic acids and introducing or reintroducing it into plants' (D. Gurian-Sherman, pers. comm.).

[53] A note on nomenclature: Many plant biologists use 'traditional' interchangeably with 'conventional' to describe a broad set of non-genetic engineering methods (see also note 12). I use 'conventional' throughout this paper, but it is important to note the discursive power of 'traditional' breeding, which carries a slate of rooted, habitual, natural and customary connotations.

[54] Speaking at the University of Nebraska's Water for Food Summit in 2010, Monsanto President Robert Fraley said: 'The widespread adoption of improved agronomic practices, advances in breeding and improvements and adoption of biotechnology will help farmers squeeze more from every ounce of water to meet the demands of a hungry, growing world … increasing the "crop per drop" is vital' (Monsanto 2010).

advantage when it comes to complex multi-genic traits such as drought resistance and nitrogen-use efficiency. Monsanto's GE DroughtGard corn seeds have been shown to provide only about 6 percent yield increase in the US, and only under moderate drought conditions (Gurian-Sherman 2012). By contrast, non-GE methods are being used to develop drought-resistant corn varieties in at least 13 African countries. In field trials, these varieties are matching or exceeding yields from nonresistant crops under good rainfall – and yielding up to 30 percent more under drought conditions (Gilbert 2014). Conventional breeding has also made important drought-resistance inroads with staple crops that are popular in the developing world such as sorghum, millet, cassava, rice and wheat.

Wild relatives enter into these crop improvement debates in a curious way, creating cross-hatching patterns of public/private, industrial/organic and traditional/modern across growers, research institutions and agri-food corporate interests. In the context of climate adaptation, industry appears to be reappraising the value of conventional plant breeding techniques, within whose reach wild species lie. Seed companies have an incentive to expand their conventional breeding pipeline to make use of wild relatives, while avoiding the taint of 'GMO.' Conventional breeding with wild relatives is also an auspicious gain for public plant breeders in the organic community, who have long focused on breeding techniques that are less capital intensive than knowledge and skill intensive (OSA 2011). At the same time, some scientists argue that new biotechnologies offer a means of GE with wild relatives in ways that could bypass GMO regulation and still qualify as 'organic.'

The conventional method of transferring genes from wild plants to crop plants is known as 'introgression breeding.' It involves crossing the crop plant with a wild relative, creating a hybrid plant, followed by multiple generations of backcrossing the hybrid to the original crop. This method, the standard in pre-breeding described above, results in a genetic background that is mostly crop, with a few 'introgressed' CWR traits. Introgression breeding can expand – and already has expanded – the available gene pool in crops, and increase overall genetic diversity (Sanchez, Wing, and Brar 2014; Warschefsky et al. 2014). It also has the distinct advantage that the genes responsible for the desired traits need not be known in advance. But there are also drawbacks of working with a 'wildcat.' A considerable amount of time – up to 10 years – can be expended in the pre-breeding stages of backcrossing to remove undesirable genes. Unwanted genes located near sought-after genes can be especially difficult to eradicate (a phenomenon known as 'linkage drag'). Finally, the method has long been considered unviable for complex traits such as yield and tolerance to cold, salt and drought (Andersen et al. 2015).

Some of these obstacles have abated with the molecular advances that introgression breeding has undergone in recent years. Still within the conventional breeding (non-GMO) realm, researchers commonly use a plant's genetic make-up to predict its agronomic potential and traits. Genetic markers, for example, can identify individual plants carrying specific genes for disease or stress tolerance, without ever exposing the plants to the relevant agents. Using such genome-wide approaches, McCouch et al. (2013, 24) suggest, breeders can 'eliminate 70-80% of individuals in any generation without having to invest in laborious multi-environment field testing.'

Even the meddlesome problem of yield has begun to give way. For obvious reasons, CWR are not generally high yielding: 'productivity' is largely a quality resulting from the process of plant domestication. Like drought tolerance, yield is also a complex trait, unlike most of the single-gene traits for pest and disease resistance. But in a much-cited paper published in 1997, Tanksley and McCouch suggested that yield potential is very likely lurking in wild relatives. The problem, they wrote, is that breeders were blinded by their own methods of search. They were looking for beneficial *traits* associated with wild relatives, instead of looking for beneficial *genes*. The standard approach to utilizing wild germplasm entails screening entries from a gene bank for a clearly defined trait, recognizable in the physical appearance (the phenotype). But while effective for single-gene traits, Tanksley and McCouch (1997, 1064) argued, 'only a small proportion of the genetic variation inherent in exotic germplasm will ever be exploited for crop improvement as a result of this strategy.' Today, breeders widely appreciate this lesson. Many plants' traits are 'quantitatively inherited'– sprinkled across the plant genome, amongst many genes that collectively contribute to the characteristic. It means that complex traits such as yield or drought cannot be enhanced by targeting a single 'locus' in a genome, as these traits result from many loci that create the behavior. Quantitative traits have now been identified in numerous CWR species, according to Hajjar and Hodgkin (2007), and 'the potential to exploit them as a breeding resource using new molecular technologies has yet to be fully realized' (Maxted and Kell 2009).

Some scientists, however, believe the future of CWR lies less with conventional breeding than with GE. They have many potential ways to introduce wild relative DNA into crop genomes. 'Transgenic' technology, usually mediated by *Agrobacterium*, is the most familiar of such approaches. Here, researchers harness the bacterium's natural gene-transfer apparatus to insert foreign DNA at a random insertion point in the host plant. A closely related method, called 'cis genesis,' involves transferring genes between organisms that could otherwise be conventionally bred. Wild relatives are therefore ripe territory for cis-genesis, given their mating compatibility with crops. But the technique likely to shake up wild relative biotech – as it has shaken the field of GE on the whole – is a powerful genomic editing tool known as CRISPR.[55] It will carry ramifications not only for how CWR genes are transferred, but also for the pool of distant wild traits that are potentially exploitable, and, therefore, for what is defined as a CWR.

CRISPR has risen to prominence since 2012, when researchers first started using it in animals and plants, and has achieved blockbuster status amongst GE scientists, praised for its relative simplicity, speed and precision. 'In the past, it was a student's entire PhD thesis to change one gene,' Bruce Conklin, a geneticist at the Gladstone Institute in San Francisco, told the *New York Times*. 'Crispr just knocked that out of the park' (Kahn 2015). More properly called CRISPR-Cas9, this 'new' technology piggybacks on a natural feature of the microbiological world: by storing snippets of viral DNA within a part of their own genomes called CRISPR, the bacteria can mobilize an enzyme called Cas9 to cut viral DNA with the same sequence.

Harnessing this adaptive immune system, researchers have created an artificial 'guide RNA' into which they can insert a few sequences corresponding to the host gene they wish to modify. They

[55] Genomic editing is a class of biotechnology that dates back roughly a decade. Techniques include zinc-finger nucleases (ZFNs) and transcription activator-like effector nucleases (TALENs) in addition to the newer CRISPR-Cas9 system (CRISPR is short for clustered regulatory interspaced short palindromic repeats). They all enable a broad range of genetic modifications by inducing DNA double-strand breaks that stimulate distinctive pathways of gene repair.

can now send the Cas9 enzyme to precise locations, in any organism of choice, directing it to snip and stitch raw DNA ends back together. 'It really opens up the genome of virtually every organism that's been sequenced to be edited and engineered,' Jill Wildonger of the University of Wisconsin-Madison told a reporter for the *Proceedings of the National Academy of Sciences*.

Less commonly emphasized in stories to date on CRISPR is a new/old double edge (Montenegro de Wit 2016d). In one of its many functions, it can control genes in crops without introducing any foreign DNA – for example, inserting or deleting single base pairs to 'knock out' gene activity. Such knockouts in crops can eliminate genes that affect food quality, divert energy away from valuable end products, and confer susceptibility to diseases (Bortesi and Fischer 2015). But CRISPR also rapidly scales up the ability to insert genetic material – and, thus, the potential to make the more familiar GMOs.[56] Donor DNA can range from synthetic oligonucleotides to genes of fish, fungi or CWRs.

In fact, a team of Copenhagen scientists has recently proposed using CRISPR to rewild crops using CWR genes. In a high-profile study published in *Plant Cell*, they explore the feasibility of genomic editing (which they call 'precision breeding') with wild relatives: 'The most efficient methods of rewilding are based on modern biotechnology techniques' (Andersen et al. 2015, 426). "…cisgenesis and precision breeding offer precise alternatives to introgression breeding that are much faster, because they are not based on crosses' (429). No rewilded crops have yet been created. But, in principle, CRISPR could offer more control and speed for rewilding as well as a route around the quagmire of complex traits. Standard GE methods generally manipulate only one or a few genes at a time, making multi-genic traits such as drought tolerance tough to engineer[57] (Goodman 2014). Harvard researchers have already used CRISPR to simultaneously alter 62 genes in pig embryos. The same capability is almost sure to hold true in plants, given CRISPR's agility across hosts.

Yet not everyone is so certain that genomic editing will offer a significant advantage over traditional cross-breeding when it comes to wild relatives. Researcher Chuck Benbrook has expressed concern over 'the precision part of precision breeding': unexpected effects on other genes can occur when a new gene is added, or when an existing one is silenced (Kolata 2015). Geneticists call this phenomenon 'pleiotropy.' In addition, even CRISPR rubs up against the old problem of agroecological diversity. Genes associated with more complex traits often perform differently in different crop types (the 'genetic background' effect) and under varying environmental conditions (the 'gene X environment' effect) (Dekkers and Hospital 2002; Cattivelli et al. 2008).

While popular discourse may pit conventional and genetic approaches against one another,

[56] Gene insertion with CRISPR-Cas9 can happen in two main ways. Very occasionally, the Cas9 enzyme leaves 'sticky end' overhangs when cutting DNA, allowing researchers to introduce a gene of interest. More frequently, Cas9 generates blunt-end cuts. By providing a donor template, researchers can facilitate a process of 'homology-directed repair,' in which the new gene insert is effectively copied into the host sequence (Bortesi and Fischer 2015).

[57] Some individual genes can affect genetically complex traits. Transcription factors are one such class of genes, now commonly targeted by researchers seeking drought resistance. However, studies suggest that genetic approaches, whether breeding or engineering, are unlikely to substantially mitigate losses from drought in the real world, where droughts vary in time and duration, and target genes unexpectedly alter more than one trait, producing undesirable (pleiotropic) effects on crop growth (Gurian-Sherman 2012).

contemporary scientific practice reveals considerable cross-traffic between the two approaches – involving both the industrial and organic agricultural communities. Interestingly, the pairings of mode and practice are not what we might think. At CIMMYT, the institutional cradle of Green Revolution research, scientists using conventional breeding have developed several promising varieties of wheat that provide higher yields in drought conditions, some already in distribution. A few of these are crosses between modern lines and wild relatives of wheat from the Middle East, where wheat originated. These lines, Marris (2008) reports, change their root architecture in drought conditions, going deeper. Meanwhile, the Copenhagen research team proposes that using CRISPR to rewild crops is an elegant marriage of organic and biotech. Rewilding has yet to be embraced by the organic movement, they argue, but the method could be used to scale up productivity in organic systems that have struggled to achieve yields comparable to those of industrial systems. Thus, while industrialized agriculture institutions employ 'old-fashioned' breeding to exploit wild relatives, some researchers in organic systems are touting GE as a way to close the 'yield gap' in organic farming.

In both cases, wild relatives are proving adept at morphing the configurations of R&D in the context of a perceived 'ancestral' or 'natural' advantage over GMO. Whether due to public skepticism over genetically engineered food, regulatory scrutiny of biotech or increasing societal concern about ownership and patenting of GMOs, wild relatives appear to offer a more natural way of doing business.

Curiously, discourses of 'nature' can usher in applications of CWR contrary to environmental sustainability. Wild relatives have already been used to confer resistance to herbicides such as the popular weedkillers imidazolinone and sulfonylurea. Wild relatives have also been mined for 'cytoplasmic male sterility' (CMS) traits that increase the efficiency of producing F1 hybrids – that is, the biologically enclosed seeds that cannot be replanted by farmers (Berlan and Lewontin 1986). The USDA is now extending this commodity-farming motif in a project focused on sunflower wild relatives. After crossing the US states to collect wild plants related to cultivated *Helianthus*, they have begun exploring cytoplasmic male sterility and herbicide tolerance, in addition to resistance to major pests and pathogens. Long-term objectives include breeding sunflower with high yield and high oil content, and 'increasing the oil per acre yield of sunflower.' The weedkiller sunflower, marketed as Clearfield, is already estimated to be 'worth millions of dollars globally' (Hajjar and Hodgkin 2007). Who will capture this market for the future breadbasket of rewilded crops?

Part of the fate of CWR, in this respect, is bound up in regulatory policy for GMOs. In the US, any food classed as non-GMO is prohibited from containing 'unnatural' genes – that is, genes that could not have occurred in nature within that plant (no fish genes in corn, in other words). But adding a gene from a wild relative of the same plant using genomic editing would be allowed, according to the Copenhagen scientists. US rules focus on product, and the product of such 'rewilding' is genetically indistinguishable from a crop interbred with CWR through conventional means. The rules are different in Europe, where GMO is defined not by the product but by the process. As long as the method involves some form of GE (transgenic, cisgenic, genomic editing), no resulting food can pass as non-GMO. Thus, a rewilded product would likely pass muster as non-GMO in the US, but not in Europe. Contingent upon their embrace by organic consumers and organic farmers, crops genetically engineered with wild relatives could pry open a large market for organic seed in the US (where 90 percent of seed for organic systems is still industrially bred). It could, of course, also foster resistance and public backlash, as Benbrook cautions, given the well-documented sociopolitical and ecological corrosions of GE. This is not to suggest that chemical agribusiness is not also poised to win big if rewilded crops manage to sidestep GMO regulations. Markets in Europe and Africa could be opened up for crops that are not GMO but are also hardly organic – such as herbicide-tolerant varieties of sunflower, for example.[58]

Until recently, the biological demands of mating two plants together have configured the definition of CWR – in terms of genetic proximity and therefore breeding utility. However, as demonstrated above, molecular advances are transforming the speed and scope of conventional breeding, while engineering tools like CRISPR are bringing the genomes of more distant wild relatives (the secondary and tertiary gene pools) into new reach. With these changes, the very identity of a 'wild relative' has been destabilized: as biotechnology shears usability away from genetic proximity, what constitutes a CWR will have to expand to reflect the wider spheres of genes newly pregnable and useful. For commercial interests, there is explicit value in reaching into foreign parts of the plant gene pool. But there are countervailing dynamics too. As more 'foreign' species become beguiling candidates for appropriation, there continues to be much material and affective value in being not so foreign – that is, in the close genetic kinship that is signature of being a wild *relative*. The terrain of CWR today is therefore shot through with both unexpected alignments and new takes on old divisions of labor: industry availing itself of 'traditional' (though increasingly molecular and capital intensive) breeding, organic researchers touting 'natural' GE, and the public sector doing the slow work of pre-breeding the foreignness out of privately exploitable genes. It is also increasingly a world in which high-tech genomic editing, digitized information databases and probabilistic modeling create the material possibilities of using CWR, while idioms of ancestry and nature shape public perception, regulatory policy and valorization in the market.

Establishing enclosures: complementarity, gene governance and big data

We have begun to see how the discourses and practices of conservation science and breeding science are reinforcing one another in engendering new values for CWRs. Plant breeders and engineers cannot mobilize value without effective conservation, and conservation gathers credibility for its activities by offering utilitarian CWR value: germplasm that might be useful for improving crops deemed valuable according to certain metrics. Conservation plans, genetic reserves, pre-breeding, CRISPR and crisis narratives are co-evolving, in ways both diffuse and readily identifiable. In itself, each discursive object (cf. Escobar 2011[1996]) is unlikely to facilitate primitive accumulation. But when these S&T elements move into synchrony with developments in information technology, legal architectures and industry moves, it becomes very likely that enclosures will occur. Knowledge production never occurs in a vacuum, and CWR science is no different. The existence and potential of its discursive and material enclosures is

[58] Agbiotech companies are already using CRISPR to develop crops, livestock, biofuels, industrial enzymes and new strains of fermentation microbes – all potentially sidestepping regulations on engineered crops (Kahn 2014; Pollack 2014). CWR could add to the crop and biofuel development pipeline.

always coproduced in historical context, with practices/processes in other knowledge domains. In the following section, I explore the following as interrelated sites of primitive accumulation:

- Institutional conservation and use policy – ‘complementarity’ between in situ and ex situ;
- Commodification and historical trends in appropriation;
- Legal architectures for genetic governance;
- Information technology – the assembly of ‘big data.’

As reviewed above, since the early 1990s, ‘complementarity’ has been widely recognized by international researchers and policymakers, suggesting that we can indeed have both in situ and ex situ strategies, coexisting and non-competing. My claim is that complementarity, enshrined now in many international policy instruments, is likely to contribute to wild relative enclosure because the character of complementarity remains highly ‘ex situ-centric.’ As Graddy-Lovelace (2015) describes it, the notion of ‘centricity’ enables us to get beyond the mere existence of in situ or ex situ. On one hand, ex situ-centric conservation values in situ cultivation insofar as it serves ex situ collections. On the other hand, in situ- centric conservation values ex situ institutions insofar as they repopulate and foster in situ renewal. Thus, ex situ-centric does not obviate the need for in situ practices – indeed, it demands them. But it configures a gravitational tug, drawing knowledge and resources into central repositories, towards sites of elite knowledge-making and classification.

The idiom of ‘complementarity,’ I argue, has made space for such an ex situ-centric epistemology to take hold within and around in situ projects, programs and studies. As plans unfold to protect natural habitats and ecosystems populated by CWR, the ex situ-centricity tends to mobilize germplasm towards off-site ‘use’ including breeding new crops and appropriating their value. It is this spatial and social patterning of germplasm flow, rather than the existence of ex situ or in situ per se, that should concern us. Ironically, in binding land-based protected habitats to bank-based repositories, ex situ appropriation becomes more ecologically sustainable. By conserving the evolutionary and ecological processes that renew diversity, and creating ‘backups’ in gene banks worldwide, the complementary system becomes more stable – and better able to fuel ongoing accumulation.

Commodification potential is a strong motive force shaping the ex situ-centric flow of resources and knowledge in mainstream complementarity. Wild relative crops promise great returns on investment, for those with the capital and technical acumen to utilize them. According to Bioversity researchers, in the United States, the desirable traits of wild sunflowers (*Helianthus* spp.) are already worth roughly USD 267 million to 384 million annually to the sunflower industry. One wild tomato variety, these experts say, has contributed to ‘a 2.4 percent increase in solids contents worth US$250 million’; and three wild peanuts have provided resistance to the root knot nematode, ‘which cost peanut growers around the world US$100 million each year’ (Hunter and Heywood 2010, 11).

In perhaps the most extensive review of CWR in public breeding programs to date, Maxted and Kell (2009) found some 234 studies reporting agronomically useful wild relative traits (for 29 food crops). Although ‘trait value identification’ does not translate neatly into actual use of traits – such data are often considered proprietary – these evaluations provide the first inkling of value recognition in the R&D pipeline. Here, the trends are clear: since 2000, there has been a significant uptick in ‘the number of attempts to improve quality, husbandry and end product commodities’ (Maxted and Kell 2009). In turn, the so-called gene giants are furthering their pursuits of CWR traits. According to journalistic reports, Monsanto has requested samples of teosinte, a wild relative of maize, from workers at Native Seed/SEARCH, a non-profit organization that works to preserve indigenous agrobiodiversity. (Bill McDorman, the former director of Native Seed/SEARCH, politely turned them down.)

Historical trends in primitive accumulation, in turn, show that circuits of dispossession are already entrenched in global seed exchanges. In 1977, teosinte was rediscovered in Mexico and brought to the US to be distributed widely to university and private breeders. One economist has estimated the traits derived to be worth about USD 6.8 billion per year (Kloppenburg 2004). Little or none of this wealth, however, has been returned to Mexican coffers. Indeed, the world political economy of genetic resources has long reflected numerous tilted planes: uneven geographic richness of biodiversity, uneven S&T capacity and uneven power relations amongst people, communities and nations. For reasons ecological and geographical, the centers of origin for agrobiodiversity tend to fall in the tropics – mostly in the ‘global south.’ Thus, historical collection of germplasm by botanists, diplomats, plant-hunters and Green Revolutionaries configured an asymmetrical, northward flow of genes. With the expansion of commercial seed production from the mid-twentieth century onward, an important stream of germplasm began flowing in the opposite direction. The reversal, however, reflected a sea change in the political economy of seed: ‘Plant genetic resources leave the periphery as the common – and costless – heritage of all mankind, and return as a commodity, private property with exchange value’ (Kloppenburg 2004, 169).

Wild relatives appear likely to deepen these circuits of dispossession yet further. The Global Priority CWR Inventory (Vincent et al. 2013) indicates that the 10 most important countries for further collecting are: China, Mexico, Brazil, USA, Iran, Turkey, Spain, Greece, Indonesia and Guatemala. The country with the most native wild relative species is Peru (at 58) followed by Mexico (39), China (35), Turkey (28) and Bolivia (23). Ford-Lloyd et al. (2011, 563) suggest that: ‘Germplasm, CWR, and the genes that they possess will therefore need to be moved around the world more than ever before in order to facilitate the process of agricultural adaptation as a response to changing climate.’ If it is from several of the world’s poorest nations that wild relatives could be extracted, the question is whether reciprocated benefits will be commensurable with the value of what was taken.

The international legal structures governing plant genetic resources will influence greatly who controls and benefits from CWR. Unfortunately, the scientific literature on CWR is scant on access to, and use and benefits of, wild relatives. Meanwhile, legal scholarship on crop genetic resources tends to overlook wild species. What can broadly be surmised, however, is that in situ, wild relatives fall under locally specific jurisdiction, frequently tied to land rights. Terms of access and use are contingent on where wild relatives set their roots: on private lands, public lands, or lands held in internationally protected areas such as those in the UNESCO Man and Biosphere program or the FAO Globally Important Agricultural Heritage sites (GIAHS). Ex situ holdings also vary according to site and scale. Germplasm in national gene banks is generally considered public property of the state, and CGIAR holdings are nominally held in the global public domain. Today, a number of regimes for germplasm governance reflect the overlapping nature of IPR and germplasm access and benefits. These frameworks include the Convention on Biological Diversity (CBD), the Trade Related Aspects of Intellectual Property (TRIPS) agreement of the WTO, UPOV (1991) and national IPR laws.

Ascendant since 2004, the International Plant Treaty attempts to address some of the logjams created by these overlapping regimes. Specifically, it responds to what critics felt were weaknesses in the CBD paradigm of treating germplasm as 'national sovereign property' and is designed to articulate fluidly with TRIPS, UPOV and patent laws (Fowler 2013; J. Kloppenburg, pers. comm.). In brief, the Plant Treaty establishes a Multilateral System (MLS) of access-and-benefit sharing for 64 crops considered the 'world's most important for food security and interdependence.'[59] Invoking a commons approach, the MLS suggests that 'everyone' is able to freely access germplasm for these 64 crops, in return for an equitable sharing of research and any commercial proceeds.

In principle, IPR is forbidden on any genetic materials (whole seeds, genetic parts or components) obtained directly from the MLS. 'Recipients shall not claim any intellectual property or other rights that limit the facilitated access to the plant genetic resources for food and agriculture, or their genetic parts or components, *in the form received* from the Multilateral System' (ITPGRFA 2004, Art. 12.3(d), my emphasis). However, *derived* materials – that is, materials changed beyond the form received – fall outside the 'commons' of the MLS. Once germplasm is transfigured by conventional breeding or biotechnology into qualitatively distinct forms, no obstacle exists to patenting or variety protection. Developers of proprietary products pledge to pay benefits back into the Multilateral Fund, but enforcement of this mechanism is weak or non-existent; moreover, the payback represents a fraction of the potential profits that could be gained through seed commoditization.

There are at least three mechanisms by which CWRs become subject to enclosure vis-à-vis the Plant Treaty. First is through the backwards pressure on both in situ and ex situ conservation plans for CWR. As previously noted, the 10-year global ex situ initiative, AACC, was developed around 29 crops considered important to global food security – all included in Annex 1 of the Plant Treaty. The Global Crop Diversity Trust, a leading partner in this initiative, then commissioned a global prioritized inventory of wild relatives (Vincent et al. 2013) to inform both land-based and gene-bank strategies. A first step in the inventory- making process was culling only CWR related to Annex 1 crops and recognized major and minor food crops (Groombridge and Jenkins 2002). In turn, research teams are now using the global inventory to create national inventories for Wales, Spain, Libya and Jordan, and a regional conservation strategy for Europe. With this growing network of inventories based on priorities established by Plant Treaty criteria, the result is a high likelihood that conserved CWR will be related to Annex 1 crops – and will be genetically related to species covered in the MLS. Via breeding or engineering of CWR traits into their related crops, these wild relatives (or at least their gene 'parts') are effectively brought

[59] Annex 1 of the Plant Treaty includes 64 food crops and forages covered under the Multilateral System. For the full list, see Annex 1 in ITPGRFA (2004).

into the MLS.

Second, and relatedly, while the Plant Treaty only governs access through the world's public ex situ repositories,[21] it supports the complementarity of in situ and ex situ approaches. CWRs are explicitly included in the Treaty's call to 'promote in situ conservation of wild crop relatives and wild plants for food production, including in protected areas, by supporting, inter alia, the efforts of indigenous and local communities' (ITPGRFA 2004, Art. 5.1(d), my emphasis). This language, however, veils a strong mandate for collections of CWR ex situ (Moore and Tymowski 2005), as well as an implicit understanding that 'sustainable use' of CWR will be achieved through ex situ control. Cooperation is needed 'to promote an efficient and sustainable system of ex situ conservation … and promote the development and transfer of appropriate technologies for this purpose with a view to improving the sustainable use of plant genetic resources for food and agriculture' (ITPGRFA 2004, Art. 5.1(e)).[60] The Treaty, then, sutures protected areas and gene banks in an ex situ-centric system, where value potentially accumulates at the downstream end of a 'use pipeline': for the benefit of researchers, private breeders and agro-industry.

Third, the Plant Treaty has been lauded for including farmers' rights, recognizing the historical and ongoing role of farmers and indigenous peoples in creating, renewing and safeguarding biodiversity. But many critics have called the recognition anemic at best, especially when the MLS does little to preclude intellectual property. The Treaty's invocation of a commons has been called but a 'trope' in this regard – accurate, perhaps, in portraying how traditional and indigenous peoples relate to their seed, but legitimizing the continued 'free appropriation' of resources from communities who would share under terms such terms (Kloppenburg 2004; Aoki 2008; De Schutter 2009). From an epistemic vantage point, it is also evident that the 'commons' denotes access by a selective community of experts with 'technical know-how.' The Multilateral System, the treaty secretariat proposes, 'sets up opportunities for developed countries with technical know-how to use their laboratories to build on what the farmers in developing countries have accomplished in their fields' (ITPGRFA 2015).

The practices of IPR governance, conservation science, and breeding science are increasingly intertwined through 'big data' and information systems. In the realm of domesticated plants, the ex situ-centric paradigm has been described as emphasizing 'data-fication' (Iles et al. 2016). CWRs are also being data-fied, I suggest, with information technology becoming as central to PGRFA work as the preservation of material seed stocks. Both conservation and breeding have shifted into this data-driven terrain. Producing conservation knowledge about CWR is now part of a highly digitized, statistically intensive project of identifying, mapping and modeling species distributions for ex situ collection and/ or in situ conservation. For example, many collection studies begin at gene banks, herbaria and botanical gardens, whose records are increasingly available as digitized databases about CWR in their possession. In turn, technologies now as commonplace as Google Maps can give researchers a quick visualization of these occurrence records (i.e. where CWR exist), while statistical modeling, combined with GIS, goes a step

[60] Access to germplasm in the MLS is configured through the world's gene banks: local repositories (e.g. in university research labs), national seed collections, and international banks, including the vast holdings of the CGIAR. The intent is to share a set of 'efficient rules of facilitated access' for all gene banks held in the public domain (ITPGRFA 2015). Germplasm held in the private domain, by corporations and other private agencies and institutions, is excluded from Plant Treaty jurisdiction.

further: to map the *potential* distribution of wild relatives on the land. Maps can then be compared with gene bank holdings to identify gaps in current ex situ holdings and prioritize land areas for collection. Online databases such as the Global Atlas of CWRs (http://www.cwrdiversity.org/distribution-map/) and the Crop Wild Relatives Global Portal (http://www.cropwildrelatives.org/) have become repositories for such information, illustrating ways that data are being compiled, analyzed, published and rendered searchable (See Figures 9 and 10).

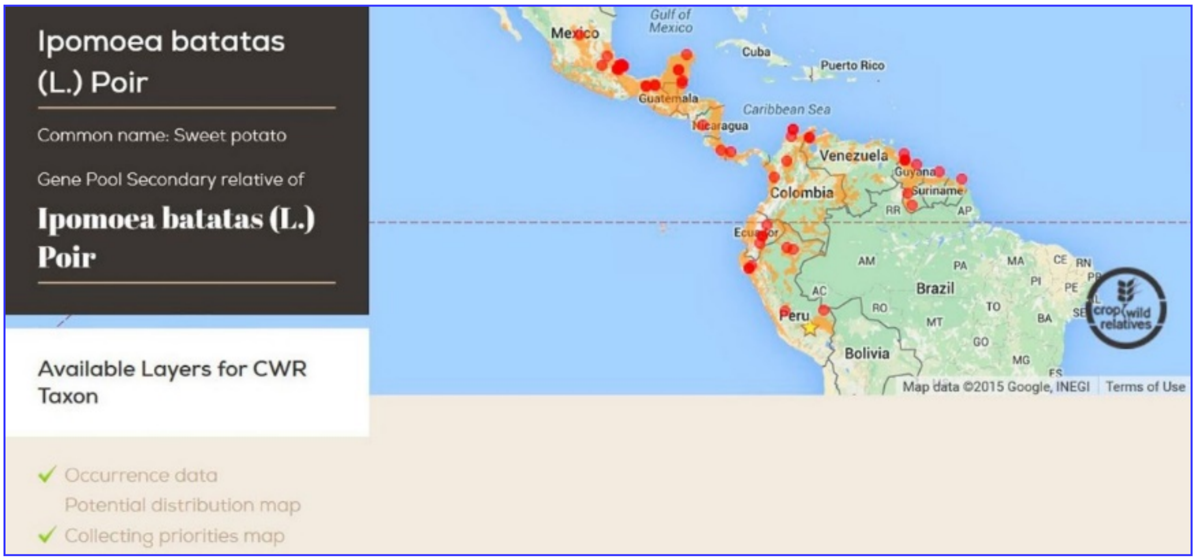

Figure 9. Mapping Collection Priorities of Sweet Potato Ancestors. Wild relatives of sweet potato are concentrated in Mexico and Central America. But their range is large, stretching from the central United States all the way down to Argentina. To determine priorities for crop wild relative (CWR) collection, researchers can conduct a 'gap analysis' that assesses current gene bank holdings for ecological and geographic comprehensiveness. It enables them to see, for example, if a species has a very wide geo- graphic range, covering numerous ecosystems, while only a few samples are held in collections. It can also tell them if the total occurrence data (herbaria, museums, botanical gardens) is very large, but the gene bank holdings are small. Usually written and performed in the programming language 'R,' the product of such gap analysis can be visualized in map layers. High-priority locales for collection of wild sweet potato, shown in orange (grey in print), include Guatemala, Nicaragua and much of southeastern Mexico. (Image credit: Crop Wild Relative Global Atlas 2013).

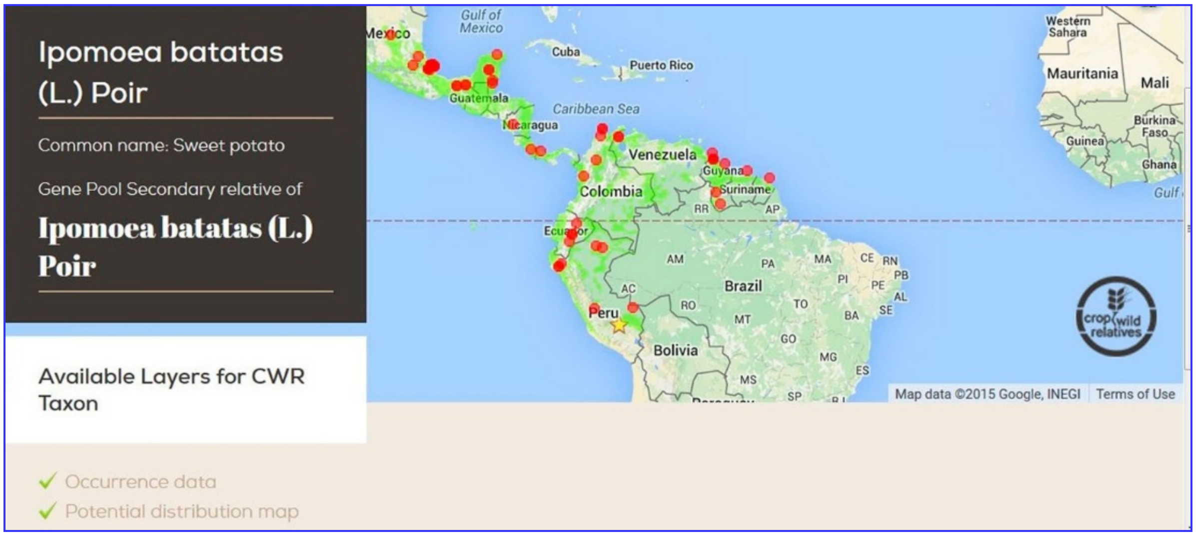

Figure 10. Where Wild Relatives of Sweet Potato live – And Might Live. Although sweet potato is a staple food across Asia and Africa, its center of origin and diversity is in the Americas – meaning wild relatives are also concentrated here. To map where crop wild relatives (CWR) exist, scientists look for 'occurrence' records in databases kept by herbaria, gene banks and museums. Occurrence of the wild form of sweet potato (wild *Ipomoea batatas*) appears as red dots on the map (black dots in print). Using environmental modeling and geographic information systems (GIS), researchers can then determine the full potential range of these CWR based on what is known about species' adaptations to temperature, elevation, precipitation and soil types. In one study, researchers modeled 27 different input variables to arrive at the potential distribution of each CWR species (Khoury et al. 2015). In this map, the possible range of wild sweet potato is shown in green (gray in print) (Image credit: Crop Wild Relative Global Atlas 2013).

On the breeding side, gathering data from gene banks is no longer the equivalent of combing through old library card catalogs. The Germplasm Resources Information Network, operated by the USDA, chronicles its seed accessions in an online genebank information management system that is now being replicated globally as DivSeek. This platform comprises a search engine through which users can access genomic, phenotypic and molecular characterizations of the world's ex situ stores of agri-food genetic resources, including wild relatives. DivSeek underscores the mobilization of plant genes into valuable food products: 'to enable breeders and researchers to mobilize a vast range of plant genetic variation to accelerate the rate of crop improvement and furnish food and agricultural products to the growing human population' (DivSeek 2016). As suggested by attendees of the 2013 Asilomar Conference, such data systems will link conservation data with breeding prospects. When biologists' genotypes and phenotypes are linked to conservationists' ecological and geographic field data, researchers will gain the ability to design more targeted ground experiments and to develop predictive models of plant performance. In the DNA fingerprints of banked exotics, the attendees offered, is nothing less than ‘a genomic “parts list”’ that ‘can guide our remodeling of cropping systems for the future’ (McCouch et al. 2013, 44).

The rise of big data, then, is injecting new potential into the respective arenas conserving and utilizing agrobiodiversity. But it is only through becoming connected that conservation and breeding/biotech establish a use pipeline and assemble the practices of enclosure. Information infrastructures provide this critical interstitial tissue, without which siloed S&T would be mostly stillborn. Intensive data-fication is particularly conducive to primitive accumulation, as it appears to provide unheralded shareability, transparency and public accessibility of information. It enables predictive modeling of landscapes and plant behavior unthinkable in an era prior to high-throughput algorithms. Simultaneously, however, it makes possible the generation and harvesting of more abstract forms of value: where tens of thousands of background data points can produce a shortlist of ‘high priorities’ for policymakers, even if the process is illegible to those outside the data-literate.

With the proliferation of online portals, information systems and databanks, several questions have emerged. Who has access to digital data? What sorts of knowledge does the digitized system include – and exclude? Is information which is ostensibly public and accessible to all enclosed in less noticeable ways? Graddy-Lovelace (2015) has out- lined some of these concerns, noting, for example, that agrobiodiversity in DivSeek is classified and standardized as open access in principle. Yet under the terms of the Plant Treaty, derivatives of plant germplasm can be enclosed through imposing patents and other IPR. Lack of internet (or even computers) can also preclude access to information in these systems. A ‘digital divide’ that already separates many low-income farmers and rural communities from their wealthier urban counterparts could well fissure access to PGRFA information, including wild relatives.

Broadband, however, may not be the most important obstacle. With the emphasis on genomic technologies, GIS and statistical modeling, these information systems embed the particular knowledges of the scientists and professionals who created them. Even if DNA fingerprints are publicly available, the question becomes, is ‘genotype’ a language that most people speak? A data-fied cosmos has difficulty capturing the many situated, affective and practical knowledges of people on the ground who have shaped the processes giving rise to CWR diversity. Although international policy regimes such as the CBD and the Plant Treaty affirm traditional ecological knowledge, such place-based wisdom can be recalcitrant to the quantitative categories of digital infrastructures. If brought into a digitized space, these knowledges are frequently reduced and simplified (from ‘rooted’ to rootless), making them amenable to exploitation and appropriation (Thrupp 1989; Rocheleau 2011; GRAIN and LVC 2015).

Conclusion

In this paper, I have argued that CWRs represent an emerging frontier in biotechnology, conservation, data science and agricultural science along which primitive accumulation may occur. Industry is poised to capture value from beneficial traits embedded in many species that are both proximately and distantly related to crops – with the more distant relatives newly appropriable through advanced GE. The climate change crisis affecting agronomic potentials worldwide has brought research, breeding and policymaker interest in wild relatives to a new height because of the climate-hardy characteristics of CWR species. 'Rewilding' the current crop gene pool is now proposed as a way to retrace the domestication bottleneck, plumping up the genetic stock of diversity eroded through more than a century of productivist breeding. None of these potentials can be realized, however, if wild relatives themselves disappear, anchoring the extractive, accumulation potential of traits in the conservation capacity of 'complementary' ex- and in situ programs.

A rich literature has explored processes of enclosure. From Marx and Luxemburg to Federici and Harvey, primitive accumulation is now recognized as an ongoing and generalized phenomenon, with diverse current manifestations. Written into the fabric of what McMichael (2008) calls the globalization project, and what Hardt and Negri dub 'Empire' (2004), enclosures rest upon a central tenet of neoliberalism: 'the appropriation of that which is shared in the "commons" or the "public domain" and its transformation into an exclusive, commodified form' (Kloppenburg 2010, 369). What I contend is that knowledge production – especially the production of scientific knowledge – is central to how frontiers of primitive accumulation/dispossession develop. Many 'ex novo separations' (cf. De Angelis 2004) will assemble through the material and discursive practices of researchers, technicians and science–educators; they will be structured into science–policy institutions, intellectual property frameworks and governing bodies for genes, data/knowledge and land. In agrobiodiversity alone, S&T developments are rapidly co-evolving and being assembled into an infrastructure of extraction. Multiple interlinked epistemic processes are impelling the appropriation of genetic commons and its transformation into a commodity form.

In this paper, I have attempted to break open the black box of systematic conservation science, scrutinizing the methods, the inclusions and exclusions of data, the metrics, the measures and the assumptions built into how wild relatives are defined and prioritized. Production of conservation value through these S&T processes influences policymaking, providing the scientific legitimation for the protection of certain wild organisms, and certain biodiverse places. Simultaneously, I have probed the technological/knowledge space inside plant breeding and biotech, which are expanding the potential scope and scale of germplasm 'use.' From conventional breeding boosted by genomics and bioinformatics to the burgeoning world of CRISPR engineering, technologies that produce new combinations of diversity are rapidly overcoming nature's old obstacles. Biological reproduction between CWR and domesticated crops has always occurred in complex agroecosystems. Pulled into an ex situ-centric use pipeline, however, this interbreeding is poised to become (systematically) commodity driven as it brings wild genes into a domesticated form. With CWR receiving little protection, as of yet, from international PGRFA governance frameworks, the motive forces of political economy, IPR and data-fication suggest the continued appropriation of germplasm along uneven lines. These scientific, legal and data practices and discourses should be recognized *as sites* of primitive accumulation.

What does this mean, in turn, for impeding dispossession? How does an STS/political economy understanding become useful for thwarting appropriation of wild relative value and enabling repossession?

To close, I will just sketch a few ideas that emerge from the preceding inquiry. First is that interdisciplinary thinking will be essential. Yes, interdisciplinarity is a term much in vogue, as much to extend colonial habits of thought as to overcome them. But I suggest that social scientists with more dexterity in diverse scientific idioms can also be a strong antidote to these trends. By investigating the methods and models in ecology, biotechnology and information sciences, it will be possible to 'see' the upstream S&T enclosure processes at work before they manifest on the ground. The constructivist angle, moreover, helps us see that these sciences are not naturally occurring. Many human agents are involved, including researchers of all kinds, policymakers, funders, international agri-food institutions and civil-society organizations. These actors busily frame and construct scientific discourses and practices. So, if we are to counteract the gravitational pull of ex situ-centricity, a promising strategy is finding ways to destabilize and reorient these active knowledge-making activities.

What might this destabilization look like? I suggest we need changes at the foundation of S&T development – that is, democratizing science and removing its scientized underpinnings:

> Scientism is when we treat decision making on a new technology as objective, value free, and best based on scientific evidence of quantifiable risks, while avoiding relevant ethical, cultural, and social dimensions. Because of scientization, we tend not to ask ourselves 'What is the purpose or end goal of this technology?' or 'What kind of world or type of agriculture do we want?' Instead, we want to know, 'Is there sufficient evidence of biological or ecological harm from this particular agricultural technology?' (Kinchy, quoted in Teller 2012)

Applied to agrobiodiversity, to disrupt the dominant tenor of S&T developments, we need to integrate science with farmer experiences and social organizing. We need to expand the criteria by which we appraise the rapidly evolving assemblage of conservation science, breeding science and data science. Agroecology provides one such modality. Insistent on the validation of farmer and indigenous knowledge, it seeks a 'diálogo de sabéres' between Western sciences and other forms of expertise (Leff 2004; Martínez-Torres and Rosset 2014). It is also a normative science, asking at the outset what kind of agriculture we want, and building the S&T architecture from there. How 'we' is configured is seldom smooth or uncontested (see Delgado 2008, 2009), but, at its best, agroecology aims for a reflexive, participatory practice that is grounded in a subversive politics: a commitment to disrupt the homogenizing forces of the globalization project with biological and cultural diversity. It offers renewal of such diversity, in situ, instead of its capture in a commodity form.

What agroecologists and others have understood is that the world is already brimming with CWR conservationists.

For millennia, farmers have 'exploited' wild relative genetics for crop improvement by intentionally moving variation across species to enhance their cultivated crops. As previously noted, Mexican indigenous farmers are known to have planted their maize on the periphery of farm fields so as to encourage introgression between CWR species and corn (Hoyt 1988). In the 1960s and 1970s, Western researchers began to take note of such farmer-led gene flow. Especially in areas under traditional agriculture, they discovered, crops are frequently enriched by genetic exchange with wild and weedy relatives – making the farming system more resilient to environmental change (Harlan 1965; de Wet and Harlan 1975; Altieri and Merrick 1987). These findings corroborated wider recognitions in agroecology and ethnobiology: that ‘wilderness’ is auspicious for agriculture (Posey 1984; Oldfield and Alcorn 1987; Toledo 2001; Nabhan 2009; Perfecto, Vandermeer, and Wright 2009; Nazarea, Rhoades, and Andrews-Swann 2013). And rather than threaten biodiversity, some forms of farming – and some farmers – seemed to actually enhance it.

Recent studies have affirmed the interdependency of wild relatives with peasant systems. A Dryland Agrobiodiversity Project in West Asia discovered that many intensively cultivated areas contain significant CWR diversity in field edges, habitat patches and roadsides (Al-Atawneh et al. 2008). In the industrially cultivated Beqaa Valley of Lebanon, rare populations of wild relatives were found inhabiting country lanes. In the Hebron area of Palestine, and in Jabal Al-Druze in Syria, modern orchards revealed very rare species of wild plants related to wheat, barley, lentils and peas (Maxted and Kell 2009). The guardians of agrobiodiversity are also not limited to growers. Local peoples across Africa, Asia, the Americas and Europe collect, cook and eat wild relative species. Wild foods provide sustenance, petty income and many other non-food uses, from medicinal and ritual to fiber and fuel (Nabhan 1989; Meilleur 1994). In their activities, these peoples may not be intensively managing farms or interbreeding crops and CWR. Nonetheless, the ‘wild’ spaces from which they harvest, through which they migrate, and on which they make their livelihoods are deeply imprinted with human knowledge and practice. Saving CWR can be found in their everyday resistances of cultivating foodways and deflecting pressures to deforest, extract and pave over.

In short, we have plenty of empirical evidence that CWRs needn’t be protected, exploited or brought to ‘improve’ crops destined for commoditization and industrial consumption. In situ conservation systems have sprouted up without planned, systematic intervention. Sciences and scientists that can navigate, with humility, through other regimes of knowledge making are well poised to democratize the practices of making and knowing nature. They may well discover that the most potent sciences for resisting enclosure are already underfoot.

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Chapter 5

Beating the Bounds:
How Does 'Open Source' Become a
Commons for Seed?

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Abbreviations

CPR	common pool resources
ETC Group	Action Group on Erosion Technology and Concentration
GRAIN	Genetic Resources Action International
IP / IPR	intellectual property / intellectual property rights
LVC	La Vía Campesina
OSSI	Open Source Seed Initiative
PVP	Plant Variety Protection
UPOV	International Union for the Protection of New Varieties of Plants

Abstract: In response to ongoing plant genetic enclosures, the Open Source Seed Initiative (OSSI) is creating a 'protected commons' for seed. It is a project, I argue, that reflects characteristics of a growing transnational commoning movement. From the Zapatistas to seed wars, such movements draw attention to commons not simply as a resource, but as a dynamic and evolving social activity: commoning. In the US, OSSI includes 38 plant breeders, 52 seed companies and more than 400 crop varieties. Yet challenges remain for OSSI to gain wider legitimacy for 'freed seed', to build trust in a moral pledge, and to establish fair guidelines for which people and which seed can participate in making the commons. Using the metaphor of 'beating the bounds' – a feudal practice of contesting enclosures – I ask how OSSI defends the commons in intersecting arenas. The first way is legal, as OSSI negotiates a move from contract law toward moral economy law. Next is epistemic, as an informal breeder network revitalizes farmer knowledge, while proving more structurally able and culturally equipped to lead commoning efforts. Finally, I reflect on the nature of boundary beating itself, aided by Global South movements. Seed sovereignty perspectives suggest room for a pluriverse of commons to grow.

Keywords: commons; seed sovereignty; open source; plant breeding; agroecology; intellectual property

Introduction

C.R. Lawn has lived the enclosures of seed. As founder of the Fedco seeds cooperative, he saw fungicide treatments become ubiquitous in the 1980s, and decided to stop selling treated seeds to protect worker health. In the 1990s, as genetically modified crops came online, he placed a moratorium on the technology out of concern for unknown consequences. Nine years later, when Monsanto bought out Seminis, Fedco's largest supplier of vegetable seeds, the co-op began boycotting the company, because, Lawn explains, 'we could not in good conscience sell their varieties' (Lawn 2016). In 2015, Fedco took a stand against intellectual property when it stopped selling any seeds covered by utility patents. The patents, Lawn says, are part of a broader phenomenon: 'We have privatized our common wealth in the hands of the few at the expense of the common good.'

C.R. Lawn and his Fedco growers and packers are not alone in these deliberate rejections of seed enclosures. They are part of a movement gaining traction in many parts of the world, Global North and South, that refuses to adopt the standard narrative: that agrobiodiversity is a natural resource best managed as private property; that innovation will not occur in the absence of patents, licenses and other intellectual property (IP) rights; that seeds are the result of individual ingenuity, rather than the collective and intergenerational knowledge that coevolves with plant genes, soils and climates. But from India to Peru, France to the Philippines, seed sovereignty movements are now advancing a radical discourse of repossession, seeking to reclaim that which has been appropriated, privatized and separated from the everyday and practical experience of farmers and farmer-breeders.

This paper traces a novel expression of seed sovereignty that emerges from something old: the concept of a 'commons.' Defined as social or natural resources not owned by anyone, but over which a community has shared and equal rights, the commons goes back many centuries in agrarian history, their enclosures marking a crucial juncture in the transition from feudalism to capitalism (Thompson 1975). Much scholarship has expanded the purview of such 'primitive accumulation,' underlining its ongoing character, and generalizing its conceptual purchase across country and city, core and periphery, and intellectual and material territory (Harvey 2003; De Angelis 2004). Reviving the commons, then, can be understood as countermovements to reclaim this vast wealth. From MST[61] land resettlers to Linux communities, worker–reclaimed companies to community gardens, sharing resources in common is making a comeback (Bollier and Helfrich 2015; Azzellini 2016). Both emerging from and informing these social movements, theory of the commons has expanded from a strong traditional base in rural and natural resources to consider urban landscapes, infrastructure, digital spaces, and sites of social and cultural reproduction. Within this 'new commons' literature, knowledge and labor have been explicitly theorized *as* commons, and – some would argue – few commons can exist without either or both.

I add to the burgeoning new commons literature by looking at commons as a biocultural form, specifically in relation to seeds. Scholarly emphasis to date has been primarily on rules and

[61] MST is the *Movimento dos Trabalhadores Sem Terra*, or Landless Workers Movement, of Brazil.

institutions of resource management, following the principles of a well–governed commons (Ostrom 1990). My argument is that seeds afford the opportunity to shed light on the politics and practices of access to biological and cultural means of reproduction. We can consider how community rules, values, and practices of making new seed varieties – or plant breeding – are at once driven by and shapers of particular geographical, ecological, and climatic landscapes. We can explore how genetic diversity is produced and/or lost through histories of legal, scientific, and biological dispossession.

Following recent contributions to commons scholarship, I emphasize commons as a living, dynamic field of practice – not simply a resource divided amongst people, but a social transformation developed in and through the practices of *commoning* (De Angelis 2004; Linebaugh 2008, 2014; Federici 2011; Bollier 2014). Moving from noun to verb, this formulation also puts greater emphasis on the people and communities intrinsic to the commons – not just on the water, but on the water protectors; not just on the seed, but on farmers, seed savers and plant breeders. These people, in community, must devise the protocols and practices intrinsic to producing, marketing and distributing resources as a collective subject. Where commons are being re–established (when they have been eroded or lost), communities must actively recruit participants, build their resources, and work to inculcate norms of cooperation, sharing and non–proprietary values. In this way, commoning helps us appreciate that commons do not just exist; they must be *produced* and *re*produced, negotiated and renegotiated, learned about and labored over.

This paper traces the origins and early development of the Open Source Seed Initiative (OSSI), which seeks to 'free the seed.' It is a project, I argue, that reflects the characteristics of a growing transnational commoning movement. Founded in 2012 by a small cohort of US-based public plant breeders, social scientists and non-governmental organization (NGO) allies, OSSI disavows traditional intellectual property rights. Instead, it proposes, plant genetic materials can be shared within a 'protected commons,' with access rights guaranteed by a simple moral pledge. In the US, OSSI now includes 38 breeders, 52 seed companies and 407 varieties.[62] Yet challenges remain for OSSI to gain wider legitimacy for 'freed seed,' to build trust in a moral pledge, and to establish fair and just guidelines for what kinds of seed – and thus, which communities – can participate in making the commons. Boundaries are central to understanding commoning processes, as lines of inclusion and exclusion delimit what constitutes the resource and what does not, who participates in community and who does not, and which beliefs and values are reified – and which are not. Using OSSI as an example, I consider boundary-making in terms of 'beating of the bounds,' a contemporary take on the feudal practice of defending common territory through uprooting any visible fences, hedgerows or other medieval technologies of enclosure (Linebaugh 2008). I ask: How are OSSI's boundaries being beaten, and by whom? What are the different practices, material and immaterial, of defining and defending its perimeters? Whose seed knowledge is included and to what effect?

[62] These numbers are current as of April 2018.

To begin, I lay out the theoretical precedents of commons theory. Taking a political ecology approach, I consider how OSSI proposes a radical solution through commoning: the annihilation of exclusive property rights to crop genetic resources.[63] I explore how participants in OSSI are beating the bounds in three related areas. First, I follow how OSSI struggled with early boundary formation, self-organizing as a community with shared principles as it transitioned from a licensing approach to a moral economy pledge. Second, I trace patterns of redefining expertise, as OSSI is reclaiming a commons around informal – not just formal – knowledge. Using Gramsci's concept of 'organic intellectuals', I consider how OSSI members are defending the commons through reaffirming subaltern vernaculars of breeding knowledge and practice. Finally, OSSI is based in the US, with a commons particular to late-stage capitalism. But it does not exist in an epistemic or resource vacuum, and I examine how Southern civil society and indigenous movements have responded to open-source models, and what implications this boundary negotiation has for unified yet differentiated movements for commoning seeds. I conclude that beating the bounds plays a central part in shaping the ability of commons to coalesce, grow, and endure.

Commons: from tragic herdsmen to cooperating commoners

For two generations, the very idea of the commons has been dismissed as a misguided way to manage resources: the so-called tragedy of the commons. It should come as no surprise, really. Affirming competition as the defining characteristic of human relations, Hardin's logic – spelled out in a 1968 essay – fit perfectly into then-congealing neoliberal designs. Yet starting in the 1970s, a young political scientist named Elinor Ostrom became interested in a heterodox question: what happens when communities cooperate to manage their resources? Gathering data on so-called 'common pool resources' (CPR) – those over which no one has private property rights – Ostrom's team surveyed the decisions and strategies that peoples around the world used to govern fisheries, forests, communal landholdings, and other CPRs vulnerable to over-

[63] Since becoming aware of the OSSI in 2013, I have done field research in Washington State and California visiting small-scale farms, extension stations, seed companies, and public seed libraries that support local plant breeding and more equitable access to seed. In 2014, I visited OSSI board member Alejandro Argumedo in Peru to learn about indigenous practices in Parque de la Papa, a coalition of five Quechua communities near Cuzco. Interviews with US-based OSSI board members and affiliated freelance breeders were conducted in 2016 and 2017, and I distributed a survey about open-source seed to key seed sovereignty informants in Venezuela, India, Mexico, the US, and Canada in late 2016. Follow-up interviews with civil-society groups deepened my understanding of peasant and indigenous concerns. Dates for primary interviews are included in the text below; all were accompanied by extensive follow-up correspondences. Document analysis was another important pillar of inquiry: I conducted a literature review on biotechnology and intellectual property laws for seed from 1930 to the present; reviewed the history of land-grant science and breeding; and studied texts on international governance frameworks for plant genetic resources. These provided a strong picture of 'enclosures' against which I could situate OSSI and its open-source pledge. In addition to the aforementioned interviews, I analyzed the language and practices of freelance and professional breeders in a variety of media: trade press books, mail-order seed catalogs, seed cooperative and company websites, gardening blogs, and popular science articles. I coded the discourses visible in all of these materials, providing the basis for a qualitative assessment of how dynamic resources, communities and social protocols configure OSSI as a commoning practice.

exploitation and free-riding. The overwhelming evidence pointed to communities working together to manage their resources sustainably. The key, Ostrom (1990, 29) wrote, was figuring out how to 'organize and govern themselves to obtain continuing joint benefits when all face temptations to free-ride, shirk, or otherwise act opportunistically.' By 1990, when *Governing the Commons* was published, Ostrom had come to some conclusions about this social organization. Known as the eight design principles for governing a long-enduring commons, they have become the cornerstone for what is now a large field of commons scholarship. Ostrom suggests, for example, that commons must have clearly defined boundaries so that participants know who has authorized rights to use a resource. Similarly, rules for using a resource must take into account local conditions and must include limits on what can be taken and how.

A next generation of scholarship has built upon Ostrom's work to apply her principles to different forms of commons, including knowledge and intellectual commons (Bollier 2005; Benkler 2006; Madison et al. 2009), digital commons (Lessig 2004; Benkler 2006), cultural and civic commons (Bollier 2003; Benkler 2011), and state trustee and global commons (Barnes 2001; Vogler 2012). Yet Ostrom still operated within a highly institutional framework that left unchallenged some basic precepts about 'rational actors' and functionalist decision-making in the design of a commons. She did not treat macro-economic structures in depth, nor did she treat the micro-scale psychological dynamics or interpersonal relationships that might animate a commons. As Bollier puts it, Ostrom's scholarship laid the groundwork for a profound reconceptualization of economic analysis and the role of the commons in it – 'without taking the next step: political engagement' (Bollier 2016, 6).

The energy of the commons today is found in an eclectic cadre of activists, organizers, peasants, and urban citizens who have embraced the commons as a paradigm for social change. The significant role of social movements in helping revitalize commons can be seen in a plethora of actions across the Global South since the late 1990s, often in response to trade liberalization and structural adjustment. Iconic examples include the Zapatista uprising in Chiapas (Federici 2011), anti-biopiracy movements in India (Shiva 1997), and Bolivian struggles against water privatization (Barlow and Clarke 2005). Demanding rights to land, water, seed, and local decision-making authority, the commons is conceptually linked to food sovereignty struggles. In Europe and North America, commons movements take on a different character, emphasizing the reclamation of public services and spaces progressively privatized by the neoliberal state. Disappearance of the urban public square is one active site, with people working to revitalize city plazas, parks, and other sites of non-commercial gathering. While the internet has certainly birthed many new commoning spaces – Wikipedia, Science Commons, and Arxiv.org – many commoners are less interested in digital hubs than in cooperative sharing of clothing, food, and work equipment. From urban gardeners to net neutrality activists, the diversity of Global North commoning reflects the cosmopolitan reach of capital, which has sought to enclose all aspects of 'industrial' life, from health, education and transportation and to science, communications and even language.

But this is not to suggest a South/North commons divide with subsistence on one hand, and urban space and infrastructure on the other. The high-profile showdown at Standing Rock attests to the persistence of territorial struggles in the North, even while civilian protests in Argentina and Brazil underscore widespread fights for public education, healthcare and freedom from foreign ‘vulture funds.’ In many cases, it is indigenous communities in both the North and South whose cosmovisions remind us of the oddity – and relative novelty – of private property. NoiseCat (2017) points out that although indigenous values, beliefs, and practices are as diverse as indigenous people themselves, one thing they share is a notion of relations to nature profoundly at odds with Western ownership rights. Thus, as Cavanagh et al. (2002, 93) suggest, for indigenous cultures, it is not really a question of commons in the European sense; ‘it is more that all creatures – human as well as plant and animal – are directly related, equal, and with equal rights to exist in a fulfilling manner.’

Increasingly, social movement revivals of commons – old and new – turn our attention to the reality of commons as a dynamic, evolving social activity. As historian Peter Linebaugh underlines, there is no commons without the commoners, no commons without *commoning*. For Linebaugh, as for other neo/Marxist commons scholars, key to understanding the power of commons is understanding the social relations inherent in them. While enclosures promote inegalitarian relations ‘among the Have Lesses and the Have Mores’ (Linebaugh 2010), commoning resists such social divisions: by actively taking back control of expropriated social wealth of all types, they help create new social norms of sharing and cooperation to counter future enclosures. By cultivating a radical re-organization of language, ideas and knowledge, they make visible how enclosures are naturalized and cast as a normative good.

In practice, such repossession is never a *fait accompli*. As with primitive accumulation, commoning is always ongoing, necessarily adapting to changing environments and social conditions. A forest could experience a regime shift under climate change; forest–dwelling communities might expand or contract with urbanization. The rules, norms and practices of humans with their trees would need to adjust. This is why, Bollier suggests, commons are best understood as a three-part relationship:

a resource + a community + a set of social protocols

Rather than consider just the forest, and beyond evaluating the community as a thing, we must consider ‘a community that manages a resource by devising its own rules, traditions, and values. All three are needed’ (Bollier 2014, 6).

A political ecology of commoning seed

In this paper, I adopt Bollier’s tripartite scheme to analyze the OSSI. The ‘resource’ is agricultural seeds, atypical in commons scholarship for straddling the ‘natural resource’/‘cultural resource’ divide. The ‘community’ is the small cadre of social scientists, plant breeders, organic farmers, and small seed companies who comprise OSSI, and who participate in various ways in producing, circulating, and advocating ‘freed seed.’ The ‘social protocols’ will be traced in the remainder of this paper, in an effort to begin exploring the nonlinear and contested nature of commoning in practice. Such protocols include the moral economy pledge underwriting the OSSI commons, the methods, and knowledge practices of informal plant breeding, and the contested rules of seed contribution, access, and use. To explore how the social protocols of a commons are (re)negotiated, I anchor this analysis in political ecology, a field which begins on the assumption that politics are inevitably ecological, and environment is intrinsically political (Robbins 2012). Central to political ecology, Watts (2000) has proposed, is 'a sensitivity to environmental politics as a process of cultural mobilization, and the ways in which such cultural practices – whether science, or traditional knowledge or discourses, or risk, or property rights – are contested, fought over and negotiated' (259). As an account of commoning centered on struggles over intellectual property, the OSSI case adds to a heterogeneous scholarship that continues to fill in gaps left by early political ecology: groundbreaking studies on soil degradation which often did not scrutinize how people fight back against the circumstances of their own marginality. 'Exogenous forces' gestured to the world economy, but lacked focus on key areas such as market politics and property rights. Natural resources were often assumed to be simply 'natural,' rather than socially and culturally produced. Not least, land managers – the fulcrum of classical analysis – were almost inevitably white males.

Political ecology has since sharpened attention to how language, power and knowledge construct nature – and stories about nature (Peet and Watts 1993; Escobar 1994/2011). It has extended from almost exclusively developing country settings into First World cases (Galt 2013); interrogated the role of women and people of color in making agrarian knowledge (Carney 2001); and underscored the primacy of locally contingent, 'non-totalizing' accounts of food system restructuring under global capitalism (Goodman and Watts 1997; Grossman 1998). If it was already understood that nature could be perceived in a variety of ways, scholars of indigenous political ecologies have folded perception into praxis, with extensive research on seed and subalternity in making agrobiodiversity (Zimmerer 1996; Graddy 2013). The OSSI commons – and my analysis of it – expands this body of work. Exploring an emergent moral economy in the US populated largely by women and first-world peasants, it is a place where informal and formal seed knowledges coalesce, hybridize, and at times conflict. I am particularly interested in commoners' negotiations and contestations – the practices which help delimit and defend a biocultural resource, as we will see below.

'*Beating the bounds*'

In medieval times, according to historian Linebaugh (2008, 74), the British monarchy and forest bureaucracy would regularly 'beat the bounds'– perform 'ceremonial walks about a territory for asserting and recoding its boundaries'. These walks were vital in mapping the complex and shifting geography of Crown holdings – and largely served to enlarge royal jurisdiction. But if perambulation was a kind of mapping, it was also an act of contestation. Peasants would walk the perimeters of a forest or piece of open field – 'If they came upon a private fence or hedge that had enclosed the commons, the commoners would knock it down, reestablishing the integrity of their land' (Bollier 2014, 138). Before physical maps (let alone Google maps) were ubiquitous, such boundary beating served several purposes: marking territory, policing borders, and serving as a public delineation of place and community identity (see Figure 11). The practice survived for centuries in Welsh and English parishes, where on special days of the year, processional parties would pass through the landscape, with men striking bounds with a stick – a willow branch known as a ‘wand’ – and even ‘bumping’ the heads of young boys against particular landmarks ‘so that they would remember’ (Khoo, Taylor, and Andreotti 2016).

To be clear, commoners in town and countryside were not at the time acting against the law, but rather in defense of it. Issued in 1217, the Charter of the Forest guaranteed the rights of commoners to use lands for farming, grazing, water, and wood. Offering legal sanction to human rights that indigenous and peasant communities worldwide had long presupposed, this lesser known twin to the Magna Carta recognized usufruct rights of people to nature; access to public resources was necessary for livelihoods.

Figure 11. ‘Beating the Bounds’ served medieval rulers as a means of ceremonially pacing grounds to map and ‘recode’ territory – and largely serving to expand the royal forest to the detriment of common fields. But walks could also be an assertion of popular right, even equality. Such was the case in 1744 when William Good urged that the annual perambulation become an anti-enclosure protest: ‘all tenants in the commonable woods in the forest have… an equal right of common with those that have houses and land of their own, and as good a right by custom, and the laws of the land, as the owners of the wood have to timber and underwoods’ (Hindle 2003, 52–53). (Illustration depicts Gerrard Winstanley and the Diggers, created for *Winstanley*, a 1975 film. Fair use rights).

Yet the next 500 years saw waves of dispossession, peasant resistance, and further dispossession in which commons were progressively separated from commoners' hands. Tens of millions of acres shifted into private ownership between the fifteenth and eighteenth centuries, displacing much of Britain's population, and feeding kilns of industrial factories with newly 'freed' labor. These annals, 'written in the letters of blood and fire', are familiar to Marxist historians (Marx 1977, 875). But sometimes glossed are the nuanced material and discursive practices of enclosing – the claims and counterclaims, the legal enforcements and re-enforcements that precipitated and shaped expropriative events. E.P. Thompson's landmark study of the Black Acts brings these into stark relief, as he builds a narrative from what Linebaugh might call boundary beating:

> Numerous acts of claiming and reclaiming forest resources across several periods of political-economic change, including the making and breaking down of physical enclosures, passing new laws or enforcing old ones, killing deer, setting up informants and spies, posting notices, organizing, making appeals, donning of costumes, and, of course, 'blacking'– the application of black paste or paint to the face as a form of disguise (Peluso 2017).

If we assume that boundary beating can apply to both commoning and enclosing, the term takes on a new valence and becomes double-edged. Beating the bounds in defense of the commons is to beat the bounds against enclosure, yet it also tends to re-activate bounds beaten *for* enclosures, sparking the antithesis of commoning pursuits. Thus, neither the privateers' nor the commoners' jobs are ever complete: against the fences, hedgerows and property laws, the unfencers, deerkillers, and head bumpers will always beat to bring a commons back. Commoners in medieval Europe variously employed boundary beating as physical mapping of space, territorial defense, and performative acts of community, collective memory and shared responsibility. It is in this multifaceted spirit that I look to how boundary beating is occurring around seed in old and new manifestations. As corporations build unprecedented oligopoly control over the formal seed supply, they are beating against anti-trust regulatory boundaries; they are erecting new IP 'hedgerows' for advanced genetic engineering; they are performing the 'feed the world' narrative to justify encroachments into informal seed. OSSI is proposing one approach to beat boundaries *for* the commoners instead of the kings. This is their story.

Case 1. From open-source licenses to a moral economy pledge: beating legal boundaries

Pacing the stage energetically, rural sociologist Jack Kloppenburg laid out the seed crisis facing many a farmer today. Despite a wide variety of farming scales, customs, and practices, he told an audience at the University of California, Berkeley, most growers – from Guatemalan campesinos to Iowa corn farmers – are experiencing one thing in common: they confront their seeds as industrial commodities. Rather than enjoy the freedom to replant from a previous season, they are structurally shackled to Monsanto or Dupont, with little choice but to purchase patented, high-priced non-renewable seed.

Well known to this academic audience as the author of *First the seed*, a landmark work on the history of biotechnology development (1492 to present), Kloppenburg has spent half a lifetime researching such problems. But this was a different, solutions-focused provocation. Seed movements worldwide are roundly condemning monopoly gene giants, the injustice of patenting, and the rapid rollout of new GMOs. A more radical stance, he offered, might be to move from a defensive posture to an offensive one: not only to impede processes of dispossession, but to open up paths for *re*possession.

OSSI was conceived as a project of repossession – a move to steal the proverbial goose back. Founded in 2012, its organizational structure includes a board of directors and a wider network of OSSI-affiliated public plant breeders, freelance breeders, small seed companies, and non-profit institutions. Many of the freelance breeders are also farmers and company-owners, blurring the conventional divisions of labor in US seed systems. In response to the past hundred years of seed enclosures, OSSI's self-stated commitment is to 'promoting and maintaining of open access to plant genetic resources worldwide.' The Pledge promoted by OSSI is an agreement by users to 'ensure that germplasm can be freely exchanged now and into the future' (Luby et al. 2015, 2485). But the Pledge at the heart of the OSSI commons – and more importantly, OSSI *commoning* – did not start out that way. It is the product of years of negotiations that illustrate the give-and-take of practical commoning, the disputes that shape a commons from inside and out, and how its boundaries can bend without breaking.

Enclosing seed and agri-food systems

The macroeconomic picture against which OSSI struggles has been detailed elsewhere (Kloppenburg 2014; Howard 2016; Luby et al. 2015; Montenegro de Wit 2017a), and need not be rehearsed again here, except in broad strokes. Hybridization, developed since the 1930s, effected biological enclosures of seed to finance the growth of a robust private seed industry. The growth and elaboration of intellectual property rights since the 1930s – through legislation, treaties and US Supreme Court rulings – has made law into the 'handmaiden of biology', creating a legal mechanism for enclosures of seed. The 1961 establishment of the Union for the Protection of New Varieties of Plants (UPOV) in Europe, followed by the 1970 Plant Variety Protection Act (PVPA) in the United States, instituted exclusive plant breeders' rights (PBR) but with important exemptions: breeders could still use protected varieties for further breeding and research, and farmers were free to save, exchange and reproduce seed. Since 1985 (*Ex Parte Hibberd*), utility patents have become especially prevalent in the US, enabling the private sector to expand ownership of genes, gene sequences, tissues, seeds, and whole plants. Unlike PVP, utility patents prohibit breeding, research and seed saving on a patented cultivar, crippling both farmers' and plant breeders' freedom to operate. Today, as Luby et al. (2015, 2482) note:

> Commercial maize cultivars are generally protected by dozens of patents on specific traits, license agreements, contracts, and trade secrets, allowing developers to own and manage the intellectual property associated with their work. 'Bag tag' licenses and

> associated 'technology use/stewardship agreements' for modern maize cultivars specify that users cannot save, replant, use as a parent, or conduct research with the seed.[64]

Intellectual property incentives, in turn, have been a dominant factor in the consolidation of the seed industry over the past 30 years, a trend documented in powerful synergies among stronger IP protections, anemic anti-trust laws, and the dominance of top firms 'at the expense of freely competitive industry' (Howard 2009, 2015). As of 2015, just six seed and chemical corporations – BASF, Bayer, Dow, DuPont, Monsanto, Syngenta – were collecting more than USD 65 billion annually from selling their seed traits, chemicals, and bio-technologies (ETC 2015). Together they controlled 75 percent of the pesticide market, 63 percent of the seed market and more than 75 percent of private-sector research in crops and pesticides. With mergers nearly completed between Monsanto-Bayer, Dow-Dupont, and Syngenta-ChemChina,[65] further consolidation appears imminent.

Such trends have had readily discernable impacts on US farmers' seed practices and habits. In what Howard (2009, 1269) dubs a seed 'treadmill', farmers have been locked into purchasing seed and associated inputs, rather than producing them endogenously. In the US, continues Howard,

> the rate of saving corn seed fell to less than 5 percent by 1960 (Fernandez-Cornejo 2004). Rates of saving soybeans decreased from 63% in 1960 to 10% in 2001 (Mascarenhas and Busch 2006). Although seed saving and replanting is currently more common among wheat growers, just one-third of those recently surveyed in Washington State stated that they engaged in this practice (Jussaume and Glenna 2009).

The additive effects of seed-, pesticide-, and fertilizer treadmills are to cultivate conditions ripe for farmer dispossession. Squeezed between, on one hand, purveyors of seeds, chemicals, machinery and fuel, and, on the other hand, traders and sellers of cheap processed food, the value accumulates elsewhere, leaving farmers little choice but to 'get big' (if they have the means) or 'get out'. Moreover, farmers attempting to switch to organic and agroecological practices are hamstrung: Even within the organic sector in the US, the vast majority of organic seed is bred conventionally – that is, selected under monoculture, high-input conditions not amenable to a diversified agroecosystem (Murphy et al. 2005; OSA 2016).

While this concentrated oligopoly structure is fully elaborated in many industrialized countries, seeds now offer the opportunity to transform agrarian political economies globally. Markets for many patented, genetically engineered crops are now saturated in the US, Canada, the European

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[64] Although the big seed companies have traditionally focused on agronomic crops such as corn, cotton, canola, and soybean, the IP regime they employ is now 'trickling down' to specialty crops – fruits, vegetables, nuts, and horticultural crops – through a complex of patents, licenses and bag tags (Goldman interview).

[65] ChemChina and SinoChem recently announced plans for a $100 billion merger in 2018. It will create the world's largest chemicals group and will follow ChemChina's $43 billion purchase of the Swiss agrochemicals leader Syngenta (Weinland 2017).

Union, and Australia, pressing agrochemical firms into the periphery for new customers. Their target is tens of millions of peasant and small-scale farmers in the Global South who still save, replant, share, exchange and sell their own seeds.[66] Toward enabling these enclosures, the UPOV convention has been a particularly influential instrument, frequently ushered in by/with free trade agreements, development aid contracts, and an assortment of certification and marketing laws. Under earlier versions of UPOV (1961, 1978), farmers' saving, using and exchanging of seeds for non-commercial purposes were not expressly restricted – and as such, were generally accepted and permitted (Yoke Ling and Adams 2016). But in 1991, UPOV was revised to dramatically expand breeders' rights. Under the new 'optional exception' farmers can only save seeds of a protected variety on their own holdings – and even then, often requiring royalty payments to the rights-holder (Moore and Tymowski 2005; GRAIN 2015). Critics say that 'breeders' rights' are now highly comparable to patents, citing numerous documented cases in which violations of UPOV have been prosecuted with criminal punishment (Aistara 2011; GRAIN and LVC 2015; Smith and Bragdon 2016). On the horizon now are the Arusha Protocol, which will apply in 19 mainly anglophone African states, and the Asia Regional Comprehensive Economic Partnership (RCEP),[67] a mega-regional trade deal being negotiated among 16 countries across the Asia-Pacific. Both agreements will require countries to join UPOV '91, pass UPOV-like legislation, or adopt laws approximating a patent regime.

As these dynamics suggest, seed enclosures tend to shift the boundaries between informal and formal seed systems. Scientists often make a distinction between formal and informal 'seed systems', or the totality of development, production, storage, and diffusion of cultivars (Tripp 1997). Formal systems are comprised of public institutions and private industry engaged in scientific plant breeding, while informal or farmers' systems depend on farmers' knowledge and customary law (Almekinders and Louwaars 1999). Legal and regulatory processes are profoundly important in delineating informal/formal boundaries (Wattnem 2016). In addition to the well-characterized functions of intellectual property law (Kloppenburg 1988/2004; Aoki 2008, 2009; Howard 2015), many non-IPR rules are weakening – or even criminalizing – informal seed markets and subordinating farmers' seed systems to industrial capital (GRAIN and LVC 2015). Keepers of knowledge in the two systems are distinct: professional biologists and geneticists are often the recognized experts in the formal sector: they 'create,' 'improve,' and 'innovate' seed. In the informal sector, it is farmers and their communities who hold expertise, and who are often 'custodians' of seeds which belong to the Earth (Tapia and Tobin 2013; African Biodiversity Network, and Gaia Foundation 2016). Cultural and affective linkages to seed vary kaleidoscopically both within and across the formal and informal divide, but because of their long history in cultivating genetic resources, many peasant and indigenous breeders speak in terms of memory, ancestry, territory, and collective 'biocultural heritage.' Researchers tend to

[66] An estimated 90 percent of the seeds that peasant farmers plant every year come from their own bins or are bartered with neighbors in local markets (McGuire and Sperling 2016).
[67] RCEP will include the 10 members of the Association of Southeast Asian Nations (ASEAN): Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. It will also include six regional partners with extant ASEAN free trade agreements: Australia, China, India, New Zealand, Japan, and South Korea. It will affect an estimated 3.5 billion people and 12 percent of world trade (GRAIN 2016).

speak instead of trait novelty and breeding lineage, their language and concerns coming to reflect the standards of 'distinct,' 'uniform,' and 'stable' (DUS) engrained in seed certification and marketing laws (Aistara 2011; Wattnem 2016).

Through the aforementioned sites and processes of enclosure, informal seed systems have undergirded the rise and expansion of modern agrifood economies, but are often displaced and undermined by them (Mooney 1983; GAFF 2016). These patterns reach far back: eighteenth- and nineteenth-century bioprospecting to build colonial collections and plantation economies; nineteenth- to twenty-first-century professionalization of plant breeding and Green Revolution crop improvement; twentieth- and twenty-first-century privatization of seed through interlinked innovations of science and law. Collectively these 'long enclosures' have differentiated 'elite' germplasm from peasant seed, redrawn global flows of germplasm value, and leveraged science and policy to inscribe enclosures within formal institutions – from the land-grant complex to UPOV – that create and govern genetic resources. OSSI represents the radical idea, then, that unenclosing seed can shift the relations of the formal to the informal, pivoting the flow of capital, power and legitimacy in the other direction.

The digital commons inspiration

As suggested by its name, the Open Source Seed Initiative drew crucial inspiration from a field often considered remote from farmers' concerns: computer science. In the early 1980s, MIT professor Richard Stallman was among the first to recognize that proprietary software could restrict people's ability to access and use software – and, thus, to innovate. Stallman's stroke of genius was inverting the copyright license, using intellectual property to make software contractually *non*-proprietary. He called his invention the General Public License, or GPL. Sometimes called 'copyleft', this innovation is today celebrated as a 'landmark 'hack' around copyright law' (Bollier 2014, 117). It ensures everyone the freedom to copy, modify, or distribute a program as they see fit, as long as they apply the same copyleft license to their creation. In this way, the free license propagates, making more and more software shareable and legally protected. It achieves a 'viral' character.

In the 1990s, GPL was combined with another breakthrough, GNU/Linux, to form the world's first free and open-source software platform, now used by millions of web servers and corporations including IBM and Oracle. The success of this digital commons was a key inspiration for OSSI's development. Frank Morton, a freelance breeder and owner of Wild Garden Seed, explains it this way:

> I first heard of 'open source' from my Linux-loving son, Taj, sometime before he created our website at age 13. That was 2003, so I guess this Open Source Seed notion has been rattling my cage for over a decade. But that is about all, because I have never been able to create the legal mechanism in my head that would allow me to share or market an original open-pollinated seed variety to others without the real possibility that some bad actor could patent it out from under me. (Morton 2014, 147)

Morton and other small-scale freelance breeders have been releasing their seed into the public domain for decades, allowing others to freely use their seed and its derivatives. Yet the reality remains that if a breeder's original varieties are not protected by a utility patent or PVP, then they can be scooped up and protected with IP by someone else (Deppe interviews #1, #2). Organic vegetable breeders like Morton have so far avoided such bioprospecting, 'sailing by,' as he puts it, with only a few varieties pirated from him. But he does not consider himself 'out of the woods,' since the imminent threat is not theft of whole varieties, but the patenting of individual traits. After the US Supreme Court declared in *JEM Ag Supply v. Pioneer Hi-Bred* in 2001 that 'novel traits' of plants could be subject to utility patenting, the gates burst wide open for enclosures at the genetic level. As a result, many naturally occurring plant traits, and traits developed in the public sector, have seen a flurry of patents filed for claims on ownership. Red lettuce colors, broccoli adapted for ease of harvest, carrots with increased lycopene content – the list goes on, says Morton. Despite this gene grab occurring beneath their feet, Morton and several like-minded farmer-breeders have found the easy solution extremely unpalatable:

> So does that mean we should hoard our beans, lock 'em up with PVP and patents? Not allow others to see, breed, or make comparisons to our stuff? That's no fun, and you can't get started in plant breeding with an attitude like that (Morton 2014, 147).

In April 2010, Morton joined Kloppenburg, University of Wisconsin breeder Irwin Goldman and a handful of others in Madison, Wisconsin, to explore prospects for developing an open-source seed (pers. comm., Kloppenburg). This meeting generated much enthusiasm, leading to a second meeting in Minneapolis in early 2011. By then, the commoners had expanded to include several more public university breeders, additional farmer-breeders, one organic seed company, representatives from Northern and Southern indigenous communities, and the institutional support of a few non-profits, including the Organic Seed Alliance, a prominent US advocacy and education network (Luby et al. 2015). They called themselves the 'Open Source Seed Initiative,' and began outlining how their commons would operate. As the members would later write, they needed to discuss principles and objectives – but more importantly, they needed a course of *action*. The priority task was determined to be creation of a legally defensible, open-source license for plant germplasm. Kloppenburg framed the objectives of the new initiative thusly:

> Modeled on the legal arrangements successfully deployed by the free and open source software movement, OSSI hopes that its licenses might undergird the creation of a 'protected commons' populated by farmers and plant breeders whose materials would be freely available and widely exchanged but would be protected from appropriation by those who would monopolize them (Kloppenburg 2014, 1226).

Limitations of licensing a commons

Looking back on 'OSSI phase 1' it is perhaps easy to see how problems emerged. Those familiar with copyright law might have predicted that roadblocks would occur when applying copyright to biological life. It is also easy to fathom how transmitting a legally defensible license on seed packets might be cumbersome. Yet these things were not immediately obvious. It took two years of active negotiating – inside and outside OSSI – for the OSSI commoners to learn several lessons about their resource, their community and their social protocols. For about 15 months, OSSI labored intensively to make the licenses work. It held lengthy meetings with OSSI's *pro bono* lawyers. It gathered feedback from seed sovereignty allies internationally. It listened to US-based small-scale farmers and breeders whom the licenses were principally intended to serve (Luby #1, Kloppenburg, and Goldman interviews). Kloppenburg appealed to other scholars with an impassioned paper arguing how the 'tools of the master'– licenses based on contract law – might ultimately be wielded against the dominant social formation and in support of seed sovereignty (Kloppenburg 2014). By 2014, however, it was evident that the licensing approach had reached an impasse. Their lawyers could – and indeed did – craft two forms of open-source seed licenses. But unlike software code, for which the code-writer automatically receives copyright protection, the creation of novel genetic sequences does not immediately grant the plant breeder an analogous right. This made the 'copylefting' of seeds a more onerous legal maneuver.

Dense and intricately worded licenses solved the problem in theory, and would have been legally defensible. But in practice they brought a bundle of contradictions. After all, a license is a contract which licensees must be enabled to read in full. For OSSI, this meant figuring out how to affix eight-page contracts onto 3 × 4-inch packets of seeds (Deppe interview #1; Kloppenburg et al. 2014). It meant devising language technical enough to make the licenses robust in court proceedings, without making them unintelligible to farmers and breeders. In the end, OSSI's farmer affiliates were put off by tactics that, from their perspective, only resembled those of 'gene giants' like Monsanto. OSSI's seed companies felt likewise: even if shorter licenses could be developed, the approach would repel rather than attract their customers. Such feedback from their core constituents told OSSI that a license would most likely fail to propagate for more than a few generations. Distrust in this particular commoning practice would undermine OSSI's entire *raison d'être* since gone would be the likelihood of going 'viral.'

With the licenses being snubbed from many directions, OSSI encountered yet another dilemma, this one within its breeding community. OSSI's plant breeders as a whole felt dedicated to a goal of 'maximally unencumbered flow of plant genetic resources' (Kloppenburg et al. 2014, 145). Yet within the group a rift had developed. In designing the licenses, some breeders had argued in favor of completely 'freed' seed, while others had felt that breeders need to be rewarded monetarily for their efforts. The result was that OSSI had opted to pursue two different open-source licenses: one for completely non-proprietary seed (a 'free seed license'), the other for payment-bearing use (a 'royalty-bearing' license). In the end, as we will see, royalties became a non-issue, but the debate revealed deep uncertainties in the OSSI project. What were its rules, traditions and values? Who would be included and excluded from this still-congealing commons?

For many public university breeders like Irwin Goldman, working in a land-grant setting has come to mean tightly restricted 'freedom to operate' (Goldman interview). It demands negotiating patent thickets in order to obtain necessary breeding materials; it requires strict adherence to university licensing arrangements; it implies that plant breeding in the public sector is increasingly disciplined by what is valuable to private-sector interests. For Goldman, commoning via OSSI represented a chance to take a radically different approach. Other public breeders, however, were less comfortable departing from the royalty system – and who could blame them? With declining levels of state support, public breeders now often rely partially on royalty revenue for maintenance of their programs (Deppe interview #1; Kloppenburg 2014). Locked into a system that produces dependency on proprietary knowledge, these breeders rejected any commons rules that would not require royalty payments.

OSSI nearly collapsed under the weight of this early dissension. The solution to the breeders' dilemma – two tracks of licenses – had produced an arcane legalese still unpalatable to the users of seed. Several breeders peeled off, leaving just five or six people in the core committee. The Organic Seed Alliance, which had been hoping to generate revenues from royalty-bearing licenses, decided to pull its support. For several months, the remaining members struggled with the disappointment of likely defeat (Kloppenburg et al. 2014).

The holdouts had, however, effectively (if not intentionally) self-selected as commoners with more aligned values and social protocols. Among themselves, they recognized that the royalty-bearing license was too similar to forms of IPR it sought to replace. Royalties aside, they appreciated problems ensconced in the licensing approach writ large: how lack of trust in the license among small-scale, local farmers, breeders, and seed companies would doom sharing from the start. If these people were to become OSSI-affiliated growers and sellers – in essence, its network of future commoners – gaining *their* trust was more important than allaying the concerns of lawyers and royalty-seekers. The solution emerged as elegant and clear: they had to terminate the pursuit of licenses.

At this impasse, OSSI was learning several things about its commons as resource, community, and social practice: first, that biological germplasm is not so easily modeled on digital software; second, that defining social protocols, in this case licenses, could reveal fracture lines between members that undermined the integrity of the commons; and, third, that one way of resolving tensions is to re-organize. Social protocols that mimicked the behaviors of seed giants could achieve legality and certainly more profit, but at the expense of social trust. OSSI took a leap and decided to abandon the anti-commons that licenses had come to represent.

The Pledge: a turn to informal seed law

The pivotal moment, says Frank Morton, was going back to first principles: 'What is the purpose of the OSSI endeavor and why are we doing this?' At a late summer meeting in 2013 in Washington state, the assembled participants decided to walk back from legal airtightness, and shifted their emphasis instead to a moral and ethical plane: 'Our most central concern,' explains Morton, 'is that the users of seed must never restrict the use of seed by others to create new varieties and adapt seed for the benefit of future generations' (Morton 2014, 148). In place of a license, the community crafted a pledge that reads:

> *You have the freedom to use these OSSI seeds in any way you choose. In return, you pledge not to restrict others' use of these seeds or their derivatives by patents or other means, and to include this Pledge with any transfer of these seeds or their derivatives.*

This Pledge is the new social protocol that propagates with every packet of OSSI seed today. It presages a reorganization of the OSSI commons into what E.P. Thompson might recognize as a 'moral economy.' In observing periodic peasant uprisings over the price of bread, Thompson understood that their revolts were less about poor people starving than about beating the bounds of a besieged way of life. The 'men and women in the crowd,' he wrote, 'were informed by the belief that they were defending traditional rights and customs; and, in general, that they were supported by the wider consensus of the community' (Thompson 1971, 78).

Similarly, the Pledge affirms a seed system structured more by the welfare of its community than by the mandates of commodity production. 'With this Pledge,' OSSI's leaders propose, 'OSSI appeals to the ethical and social norms that link plant breeders, seed companies, farmers, gardeners, and eaters' (Luby et al. 2015, 2486). These words, appearing in the peer-reviewed journal *Crop Science*, appealed to fellow plant breeders who face similar constraints on access to, and sharing of, seed in the dominant social order. A moral economic system, they suggested, involves revitalizing practices of germplasm exchange, 'unencumbered by complex legal agreements.' It involves 'recognizing and honoring the historic and collective contributions of farmers and plant breeders to the generation and maintenance of the existing pool of crop genetic material' (Luby et al. 2015, 2486). The farmer-breeders have made their own appeals in defense of the moral economy's customary rights. As Frank Morton puts it pithily, 'Farmers should always be able to replant their seed' (Morton 2014, 247).

The Pledge itself carries over the central premise envisioned with the license attempt – that is, it functions as a 'protected commons' insofar as materials are freely available and widely exchanged but are protected from appropriation by those who would monopolize them. This protection is guaranteed by a moral agreement, rather than contract law, giving it legitimacy based on the community rather than on the state. Passed along with each seed packet, the Pledge protects four basic freedoms:

1. The freedom to save or grow seed for replanting or for any other purpose.
2. The freedom to share, trade or sell seeds to others.
3. The freedom to trial and study seed and to share or publish information about it.
4. The freedom to select or adapt the seed, make crosses with it, or use it to breed new lines and varieties.

Such an agreement, of course, requires a few more specifications. Firstly, the 'freed seed' is not equivalent to *free* seed, meaning that OSSI recognizes that their farmers rely on income from seed production, that small-scale businesses can help rebuild local seed economies, and that breeders also merit some compensation for their work. For these reasons, OSSI is not out to set seed free from price, which is neither feasible in the current US political economy context nor desirable for people whose livelihoods depend, at least in part, upon its exchange value. Thus, OSSI enables farmers, breeders, and companies to sell their seed for whatever price they wish, but they cannot prevent any other person from multiplying and using the seeds on their farms or in their own breeding programs. Similarly, breeders and farmers are not restricted from entering into 'benefit sharing' arrangements with a seller; for example, they could contract with a seed producer to multiply seed of an open-source variety and both parties could share in the revenue generated from sale of those seeds. What a breeder cannot do, however, is charge a royalty that propagates through generations of that seed's reproduction, or that applies to the creation of derivative varieties (Goldman interview; see Figure 12).

Secondly, the Pledge is radically free from the vantage point of *access* to seeds within the protected commons (the only restriction being the inability to restrict others) but it implements careful and particular rules around *eligibility* – that is, how seed enters into the commons and achieves protected status in the first place. A seed variety enters the OSSI commons through being submitted (or 'pledged') by a freelance or professional breeder. This person, in turn, becomes part of the OSSI breeder community. Yet submission is contingent on certain specifications, which can be pooled into two broad categories, biological and social (Luby interview #1). Biologically, the variety, population, or propagating material must be considered 'novel', that is, recognized as unique and selected from a heterogeneous genetic background. Socially, there must be an individual breeder, co-breeder, or agent with the authority to pledge the new variety. Importantly, these rules are minimum, not sufficient, requirements, which leads to a third and related point: OSSI retains the right of refusal. If a breeder at Bayer, for example, offers to pledge a new genetically engineered variety, the commoners can refuse it – and they already have.[68] Indeed, OSSI has decided that for ethical and political reasons, it will not currently accept any genetically engineered seeds (see osseeds.org). Finally, it bears emphasizing that the moral economy underpinned by the OSSI Pledge is a commitment by all recipients of OSSI seed to *propagate* the Pledge. The freedoms, restrictions, rights, and obligations must be passed along to anyone to whom the Pledge is transferred (Luby et al. 2015).[69]

Although these eligibility guidelines have themselves raised some issues, as we will soon see, they provide defense against unauthorized pledging, biopiracy, and other unsanctioned contributions to the commons. Bound by the Pledge, the OSSI commoners have now grown to a membership of 38 plant breeders, 52 seed companies and more than 407 pledged varieties. Efforts

[68] Bayer North America has approached OSSI about pledging genetically engineered lines. Because of such proposals, OSSI has taken the following position: while it cannot discourage seed corporations from open-sourcing their own products, it can refuse their entry into the OSSI commons.

[69] These decisions concerning seed exclusion/inclusion are made by OSSI's Variety Review Committee comprising three board members who are breeders. They review each application according to OSSI's policies, which in turn have been approved by the entire board. Depending on the issue (e.g. policy on GMOs or hybrids), the Committee has long discussions over several meetings. OSSI is a 501(C)3 with formal bylaws that structure their decision-making. So far, they have made decisions entirely by consensus, reflected in unanimous votes when a formal vote is called for (Kloppenburg interview).

to extend a seed commons are ongoing in Germany, India, Ethiopia, and Kenya, where communities are adapting OSSI to their local needs. Venezuela's landmark Ley de Semillas (Seed Law) was loosely inspired by OSSI, though the Bolivarian law implements a licenses approach, known as *licensias para semilla libres* (Ley de Semillas 2015). The media has discovered OSSI too, with features in the *Virginia Quarterly*, *Ensia Magazine*, and *Civil Eats*, among others. The media has discovered OSSI too, with features in the *Virginia Quarterly*, *Ensia Magazine*, and *Civil Eats*, among others. If success is partially measured in name recognition, then OSSI is gaining ground.

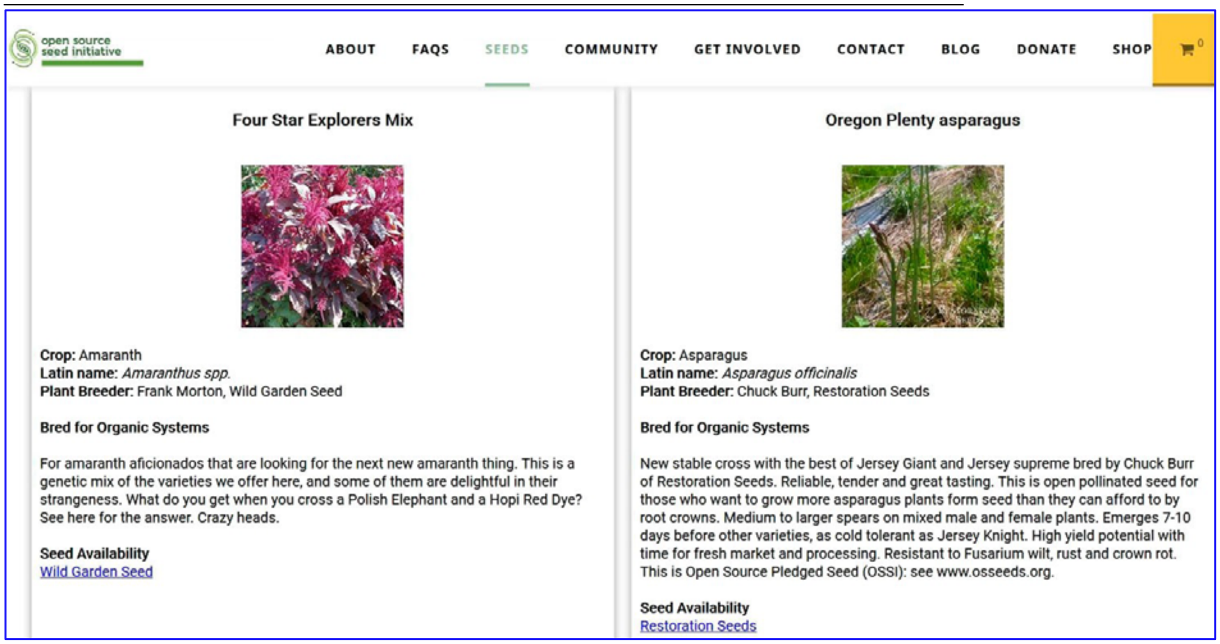

Figure 12. OSSI's Digital Commons. The OSSI website functions in several ways to 'beat the bounds' for a seed commons. First, it helps achieve visibility for the initiative, with colorful and descriptive pages for the pledged seeds (above), the breeders, and the seed company partners. Second, it affirms a chain of custody which protects OSSI seed against unauthorized use. The only way to obtain Pledged seed such as 'Four Stars Explorers Mix' is through OSSI channels. The OSSI logo (left corner, above) travels with each packet of pledged seed, such that any 'Four Stars Explorers' found without the logo or Pledge can be identified as illicitly obtained. Third, although OSSI does not sell any seed directly, the online databases enable breeders, farmers, and gardeners to recognize and access OSSI seed, supporting a decentralized network of seed commoning. Taken together, these activities help build legitimacy for the Pledge, beating the bounds against appropriation. As Kloppenburg says, even if OSSI cannot sue bad actors, 'we can shame them' (Kloppenburg interview).

Nonetheless, most scholarly and journalistic treatments of OSSI have centered on its importance as an alternative to restrictive IP. OSSI has been lucidly depicted as 'Linux for Lettuce' (Hamilton 2014) and a 'campaign' to change seed governance (Charles 2014). I contend that

OSSI foreshadows much more. In revitalizing plant breeding knowledge, reconceiving property laws, and inculcating norms and values of common rights, OSSI poses a challenge not just to patents, but to the 'long enclosures' of seed knowledge and rights dispossession. It represents, if OSSI is successful, a new ethic of commoning seed – and, perhaps, a catalytic point around which commoning social and economic life can grow.

Case 2. Redefining expertise: organic intellectuals in commoning

On 17 April 2014 – in solidarity with La Via Campesina (LVC)'s International Day of Struggle in Defense of Peasants' and Farmers' Seeds – OSSI made its first open-source seed release. Seven breeders from public universities, local seed companies, and small farms committed to releasing 37 cultivars of 14 crop species under the OSSI pledge (Luby et al. 2015). Of the seven in this original community, the majority were professional public breeders, affiliated with land-grant schools such as Washington State University and the University of Wisconsin-Madison. Soon, however, it became apparent that the center of gravity of the OSSI community was shifting: away from the formal sector of universities, labs and extension, and toward the informal sector of independent farmer- and gardener-breeders. As of February 2018, of 38 OSSI affiliated breeders, only about eight are connected to universities. The rest are 'freelancers'– self-taught and self-employed in practice if not always in name. As a group, these informal breeders have contributed all but 16 of the total 382 pledged varieties (Luby interview #3). OSSI's bounds have been 'recoded,' to use Linebaugh's terms, around an incipient paradigm of freelance expertise. For millennia – 12,000 years, give or take – farmers have been the main practitioners of plant breeding. But multiple enclosures have progressively severed this relation: after the rise of scientific plant breeding in the early twentieth century, land-grant institutions popularized and instituted top-down 'technology transfer,' while disseminating enclosed Green Revolution hybrid seed-chemical packages. As explored above, imposition of these biologically enclosed resources, coupled with the legal enclosures of IPR, further distanced farmers from the ability and rights to save, replant, and renew. Unsurprisingly, few farmers in the US today reuse seed, let alone attempt to breed. They have been structurally removed from the breeding practice, and epistemically marginalized as holders of breeding expertise.

From this perspective, it may seem surprising that farmer-breeders have led the 'commoning' in the OSSI commons. From another angle, however, it makes complete sense that they are in the vanguard. Freelance breeding networks, after all, were not born in 2014; quietly, in the shadow of the corporate food system, many subaltern seed saving, exchange, and breeding networks already have a stronger grip on the cultures and practices of commoning. This extant grassroots network has provided a very different baseline from which freelance breeders engage with OSSI. For example, in terms of IP, freelancers have long been releasing their new varieties in the public domain. Although plant variety protection (PVP) is available to small-scale breeders, it is generally too expensive to be economically worthwhile. More importantly, says Deppe, many in her circles simply do not believe in the concept of IPR. Patents are often considered 'immoral,' she says, and inconsistent with an understanding of seed as the heritage of humankind (Deppe 1993/ 2000 and interview #1). David Podoll of Prairie Road Organic Seed in North Dakota corroborates Deppe's words: 'Seeds are a sacred thing. Everything we have now is built on farmers selecting seeds for millennia. All of that genetic diversity is a great gift. Seeds should not be owned, patented, or controlled' (Podoll 2014).

But if the Pledge slid into a value system to which freelancers were already accustomed, for the professional land-grant breeders, OSSI represented a much greater departure. Encircled by patents, trade secrets, licensing arrangements, and university-negotiated material transfer agreements, it has become second nature within universities to treat seed as proprietary knowledge; each 'new' breed is valorized as a product of individual innovation, ignoring any concept of genetic heritage or breeding as a collective endeavor. Such logic, moreover, is institutionalized and dutifully leveraged: since the Bayh-Dole Act of 1980, universities have increasingly raised funds by patenting and commercially licensing publicly funded research. The irony, for public-sector breeders vis a vis OSSI, is almost too complete: threatened by austerity-shrunken investments in public education and research universities have been forced to further commodify public breeding work. Insofar as OSSI opens up these enclosures, a pledged variety represents not only a potential loss of capital for universities, but a challenge to the entire for-profit model of public-private partnerships keeping them afloat (See Figure 13).

Even OSSI did not anticipate the strength of these dynamics. In 2014, when the initiative first launched, many observers guessed rightly that private industry would ignore or impugn it. For example, a spokesperson from the Seed Industry Trade Association said they would probably avoid pledged seed, 'because then we'd … have limited potential to recoup the investment' (Charles 2014). OSSI leaders initially believed the initiative would be more significant for plant breeders, especially at universities. Goldman told NPR's Dan Charles that he expected many public-sector breeders would join the open-source effort. But as it turns out, Goldman told me, the use of OSSI germplasm poses a huge pragmatic challenge: because derivatives of OSSI seeds are also open source, the university would not be able to claim IP rights over, say, the product of a cross between university-owned germplasm and OSSI-pledged germplasm. 'This means that as a breeder, I would have to have two *separate* breeding programs: one for OSSI and a "protected" program for the university.' So while breeders from University of Wisconsin-Madison, the University of Minnesota, and Washington State have been instrumental to OSSI's formation, they have been less vital to its ongoing growth. For all the reasons sketched above – scientific culture, structural lock-ins, the challenges of managing separate breeding programs – the university system has not been a particularly fertile space for the commons to grow.

We saw previously that OSSI's early growth was marked by 'beating the bounds' around the Pledge: defending the common's perimeters with a non-IPR system of access, use, and exchange. But even the Pledge – 'the restriction to end all restrictions,' as Deppe puts it – was in a profound sense only the very beginning (Deppe interview #1). As of 2014, OSSI had begun releasing pledged varieties, a watershed moment in the IPR domain. Yet in order for the commons to flourish, it had to go further: to rekindle a knowledge of what to do with 'freed seed.' For most US farmers, this knowledge is buried under years of being out of practice; under layers of taken-for-granted wisdom about quality and expertise; under the exigencies of efficiency (it is often much cheaper to buy seed than use land to grow seed). No one in OSSI believes these issues are easy to solve, but neither are they immutable.

Figure 13. Freelance and Formal Breeders. On his farm in Oregon, freelance breeder Frank Morton (left) shows that on-farm breeding remains a vibrant practice. Here, he collects seed caps from lettuce plants with 'intensely red cap bracts.' This red cap color, he explains, corresponds well to leaf color, and 'by this state of growth, the relative health, fitness, and fecundity of the plant is easy to judge all at once' (pers. comm.). The next generation of seeds will be mostly uniform for color and fitness, with many choices remaining for lettuce shape, flavor and texture. Morton prefers breeding outdoors because gardens, he says, 'are where the knowledge lives.' Claire Luby (right), now executive director of OSSI, conducted her PhD work on carrots. Collecting seed from every commercially available cultivar she could find in the US – 142 in all – she was interested in mixing populations to explore novel combinations. In addition, she grew concerned with intellectual property rights. In 2014 alone, 15 patents were filed for carrot varieties, primarily by one company. Luby's project soon became a more ambitious endeavor to map this patent thicket and the operating space in carrot breeding. Today, she is releasing much of her work as open source, including these 'Wisconsin Open Source Composite' carrot populations, whose selection results she is documenting here. This effort, Luby hopes, will help keep carrot diversity accessible to university and freelance breeders alike. (Image credits: Karen Morton (left); Irwin Goldman (right)).

The freelance breeders

In a short two-part piece in *The Prison Notebooks*, Gramsci wrote of two kinds of intellectuals. 'Traditional intellectuals' are commonly identified by social position – learned people like religious clerics and scientists. However, he suggested, traditional intellectuals are not really a certain group of people, nor is there intrinsically intellectual activity. Rather, he recognized that 'all men are intellectuals,' potentially, but not all are intellectuals by social function (Gramsci

1971/2010, 9). What matters is how their activities take place 'within the general complex of social relations' (8). Men of letters, philosophers, and clergy function with a certain classless aura, representing their work as a historical continuity that transcends political and economic change. However, Gramsci argued, this *itself* is an ideological move. By occluding their deep attachments to various historical class formations (e.g. the clergy's attachment to the landed aristocracy), they obscure the deeply political nature of Western religious and scientific reason, naturalize existing social relations, and manufacture the consent that Gramsci considered crucial for hegemony.

Organic intellectuals, by contrast, are people such as peasants from the countryside or mechanics in factories who come out of their own class activities to become those who provide information on better ways of doing things (Nowak and Prashad 2016). Because organic intellectuals emerge within or alongside subaltern communities, they are better able to listen and learn *with* (rather than speak and teach *to*) their peoples, while articulating the relationship between their social group and society as a whole. This double fluency gives organic intellectuals a particularly salient role in helping transform popularly held 'common sense'– a contradictory and disempowering consciousness – into 'good sense,' a more sophisticated understanding of the world. Importantly for Gramsci, then, organic intellectuals are not just the opposite of traditional intellectuals; they 'think and act *elsewhere and in other ways* than the traditional intellectual' (F.T. 2017, emphasis in original). With moorings in lived experience and everyday life – and because there is no pretense of impartiality to class interests – they are suppler in moving people toward radically subversive activity.

Carol Deppe (Fertile Valley Seeds), Frank Morton (Wild Garden Seed), Jonathan Spero (Lupine Knoll), Roberta Bailey (Fedco Seeds), and Joseph Lofthouse (Lofthouse Farms) are just a few of the plant breeders who illustrate an unsung organic intellectualism in the US. They comprise a quietly expanding movement of 'freelance' organic plant breeders, a term they've coined to replace 'amateur' in recognition of their expertise (Deppe interview #1). Self-taught and fiercely Do-It-Yourself, they are generally less driven by money than curiosity, less driven by expanding patent portfolios than self-renewal. To get along, many operate small direct-to-consumer companies, earning income from selling seed breeding materials and finished varieties. They tend to specialize in open pollinated seed, or 'OPs', (free from enclosures of hybridization), and in varieties specifically adapted to low external-input organic systems (free from enclosures of chemical-gene lock-ins). Geographically, the freelancers form a diffuse network, with a notable hotspot in Washington and Oregon and single farm-company outposts in Virginia, Illinois, Maine, Michigan, New York, Utah, England, and Australia, among others. They are, of course, distinct from one another in important ways, and their entries into breeding range from subsistence farming to restaurant supplying to interests in landrace conservation. Some are lone seedsmen and seedswomen; a few participate in production commons like Fedco Seeds. Some are relative newcomers to breeding, while others have been at it for almost 50 years. Together they are developing organic, OP and locally adapted crops for resilient agriculture: local breeds for local needs.

It is this polyglot freelance community that has become, I argue, the spiritual and practical heart of the OSSI commons. Some of this informalization can be measured in numbers: the 28 freelance community members out of 38, the 96 percent of pledges, a near-balance of board seats. Other facets, however, are less quantifiable. Here, I focus on the epistemic transition: how informal breeding knowledge is being re-appropriated and re-legitimized, as this cadre of organic intellectuals beats new boundaries – epistemic and material – around who makes and remakes seed and who controls the shape of seed. I now offer two brief portraits of OSSI-affiliated freelance breeders as illustrative of the 'commoning' character that animates this freelance community.

Beating the bounds for DIY breeding knowledge

Carol Deppe, like many amateur breeders, fell into her new trade by accident. A Harvard-trained biologist with more than 20 years of working in genetics, she learned plant breeding on her own, mostly poking around in a small Oregon plot. Deppe was already accustomed to working with plants as an avid gardener, but prior to her retirement she had never experimented much beyond simple selection. Deppe warmed to the prospect of developing new grains and legumes to fortify her diet, locally adapted to her own garden's climate. More importantly, she recognized that university breeders – 'traditional intellectuals' of the plant breeding world – were simply not developing the vegetable varieties she wanted or needed. 'The U guys just try to produce whatever the biggest seed company around wants, and focus on the biggest crops, and big varieties rather than appropriate diversity,' she told me. By contrast, 'we freelance plant breeders pretty much all breed with local adaptation being first and foremost' (interview #2).

Just as Gramsci argued that organic intellectuals must transcend assimilation – 'teaching' people by installing them in dominant educational institutions often dissolves the very moorings through which their knowledge is organically held – Deppe's teachings have suffused the gardening community mostly in the form of popular writings. She is the author of *Breed Your Own Vegetable Varieties: The Gardener's and Farmer's Guide to Plant Breeding and Seed Saving*, and *The Resilient Gardener: Food Production and Self-Reliance in Uncertain Times*, among other publications. An organic articulation is visible across these works in the way Deppe shares her knowledge, navigating an expert/lay divide. She defies the common sense that farmers are not expert enough to be breeders, opening *Breed Your Own* with the simple dictum: 'Every gardener should be a plant breeder' (Deppe 1999/2000, 3). First drafted in 1993, when Deppe herself was learning how to breed, the narrative follows the contours of her own discovery process, which has the uncanny effect of leveling the playing field of expertise.

She also does not offer a polemic against corporate control of the food system. Instead, she appeals to her audience with *their* own concerns: Why can't they find seeds for their gardens? What happened to all the garden varieties that were once available? The problem, she suggests, is economies of scale. Small-scale gardeners purchase seed in small quantities compared to commercial growers, so it will rarely be in a large seed company's interests to carry local varieties – they simply cannot profit from developing smallholder breeds. Another reason melds political economy with agroecology: professional outfits develop crops for compatibility with input-intensive, monoculture regimes. They seldom focus on organic varieties that have been bred to thrive in biodiverse, low-input conditions, she explains. As Deppe unfurls her own pursuit of answers to questions about seed access, she continuously foregrounds not her individual expertise, but her *social* identity – as a gardener-educator, breeder-food grower, and member of grassroots seed networks. It is this polyvalent identity that gives her lessons purchase toward demonstrating that 'everyone is a philosopher, and that it is not a question of introducing from scratch a scientific form of thought into everyone's life, but of renovating and making '"critical" an already existing activity' (Gramsci 1971/2010, 331).

Yet in the context of a transformative movement, words should also carry through to activity and practice – the Gramscian 'philosophy of praxis.' Plant breeding, to be clear, is intrinsically practical. This characteristic has greased the subordination of 'applied' plant breeding to 'basic' plant sciences perceived as more scientifically elite. Deppe beats back against these hierarchies, with expertise that combines a Harvard PhD with soil-based knowledge and with practices that fortify the freelance breeding sector, the rabble-class of an already snubbed field. Concretely, this takes shape in praxis that minimizes the more arcane theoretical trappings of crop improvement in favor of concrete advice. On choosing a project: pick something delicious because mistakes will be many – and 'you can eat your mistakes' (Deppe 1993/2000, 3). On finding germplasm: her go-to's are mail-order catalogs, US gene banks, the Seed Savers Exchange, and personal connections. And of course, before you even start a breeding project: 'How much space do you need? How much time?' (Deppe 1993/2000, 17) Answer: Breeding can be done on any scale; intricate projects can take years of planning and follow-through, but simpler ones can yield results in just a year or two. Answer: Space requirements depend, but if your project needs exceed your property, ask your neighbors for a spare patch of backyard. Land can be commoned too! Simultaneously, for the more technically advanced or biologically curious, there is much to explore in Deppe's texts: Mendelian theory, experiments in wild relative crossing, and not least a chapter-length 60-point checklist in *Breed Your Own* for designing variety trials and conducting plot-to-plate research.

Today, Deppe sits on the board of OSSI, holding workshops and offering advice on how to begin pledging seed. Most days, however, she can be found 'out in the field' in Oregon and managing orders for her own small business, Fertile Valley Seeds (FVS). The 2017 FVS Catalog was a major achievement, as it includes one of the most extensive listings of OSSI–pledged seed, bred either by Deppe herself or by one of 10 other OSSI-associated plant breeders (Roberta Bailey, Anne Berblinger, Glenn Drowns, Hank Keogh, Craig Lehoullier, Joseph Lofthouse, Frank Morton, Dave Podoll, Jonathan Spero, and Don Tipping). Something larger than a listing is afoot here, Luby explains, which has not touched this community in several generations. 'Pledging their cultivars to the initiative results in acknowledgement of their work, formal registration of their cultivars, and a measure of protection against unauthorized and un-recompensed multiplication and sale of their material' (Luby et al. 2016, 286). That may be what the *breeders* get, but Deppe and her fellow freelancers are quick to amplify to 'we.' 'When you buy these varieties,' Deppe writes (2017, 3), 'you are helping to create and support an alternate model of control of seeds – one in which we, the people, have full rights to the seed we buy, and can save, share, replant, or sell it, and even use it to breed new varieties of our own.'

Promiscuous pollination of landrace knowledge

Joseph Lofthouse is a self-described subsistence farmer, specializing in landrace breeding. He grew up on a farm in northern Utah, gardening and milking a cow on a farm first established by his grandfather's grandfather, more than 150 years ago. Before the Green Revolution, a variety of local wheat developed by Lofthouse senior was the most widely planted wheat in northern Utah and Southern Idaho. Lofthouse junior still grows that wheat today, alongside others varieties he has coaxed back from ancient origins. Rather than 'depend on faraway distant mega-companies for seeds,' he told me, he decided to restore the age-old practice of creating his own (Lofthouse interview #1). But 'create' is an uncomfortable word for Lofthouse, who tends to defer to his ancestors when he speaks – tipping his language to their collective endeavors in contributing to the stuff of seed. For the OSSI paperwork he fills out to pledge seeds, Lofthouse admits that the individual breedership requirements are vexing. He sometimes signs '10K,' by which he means '10,000 years' worth of illiterate plant breeders who created this variety.'

For Lofthouse, who took a vow of poverty 17 years ago, there is simultaneous freedom and security in subsistence breeding. Freedom from the bland taste and nutritional vacuum of industrial food; security in the stability of harvests that may not yield maxima but are steadier over time. Freedom, in turn, from food *in*security, which also fosters emancipation from the power that corporations and the state have over farmers. As Lofthouse told me:

> I'm kind of an anarchist, and so what corporations do, or what governments do doesn't really matter to me, because I'm going to grow my seeds the same way I always grow my seeds. If some corporation comes in and says that they own my seeds or whatever, I'll still just keep growing my seeds, because I've lived in poverty for decades and I have nothing they can take from me. So, I mean, they have no power (interview #1).

For Lofthouse, the ability to renew one's means of reproduction is material, philosophical, and very practical. It is also a deeply subversive way of doing things, which is why his story is instructive for the seed commons. Gramsci noted that traditional intellectuals don't just exist: they *become* elites, gaining access to privilege precisely because their intellectual labor serves to reinforce that group's dominance (Gramsci 1932). A more robust definition of an organic intellectual, then, is not merely an 'opposite' force to the traditional thinker. It is also someone who helps us see profoundly 'elsewhere' and 'other ways' of doing things. Lofthouse's organic intellectualism emerges less as conscious politicization than in the trappings of everyday existence: through inhabiting an unusual space for intellectual work (the subsistence-smallholder slot in US society), through practicing breeding in places remote from biotech labs and university extension stations, and through making these 'de facto' normal/natural sites of intellectual work.

Traditional crops are the key to Lofthouse's breeding strategy. Continuing the legacy of peasant farmers, Lofthouse works with landrace varieties, crops with high genetic variability purposefully maintained as a diverse gene pool to enable their adaptation to harsh conditions (See Figure 14).

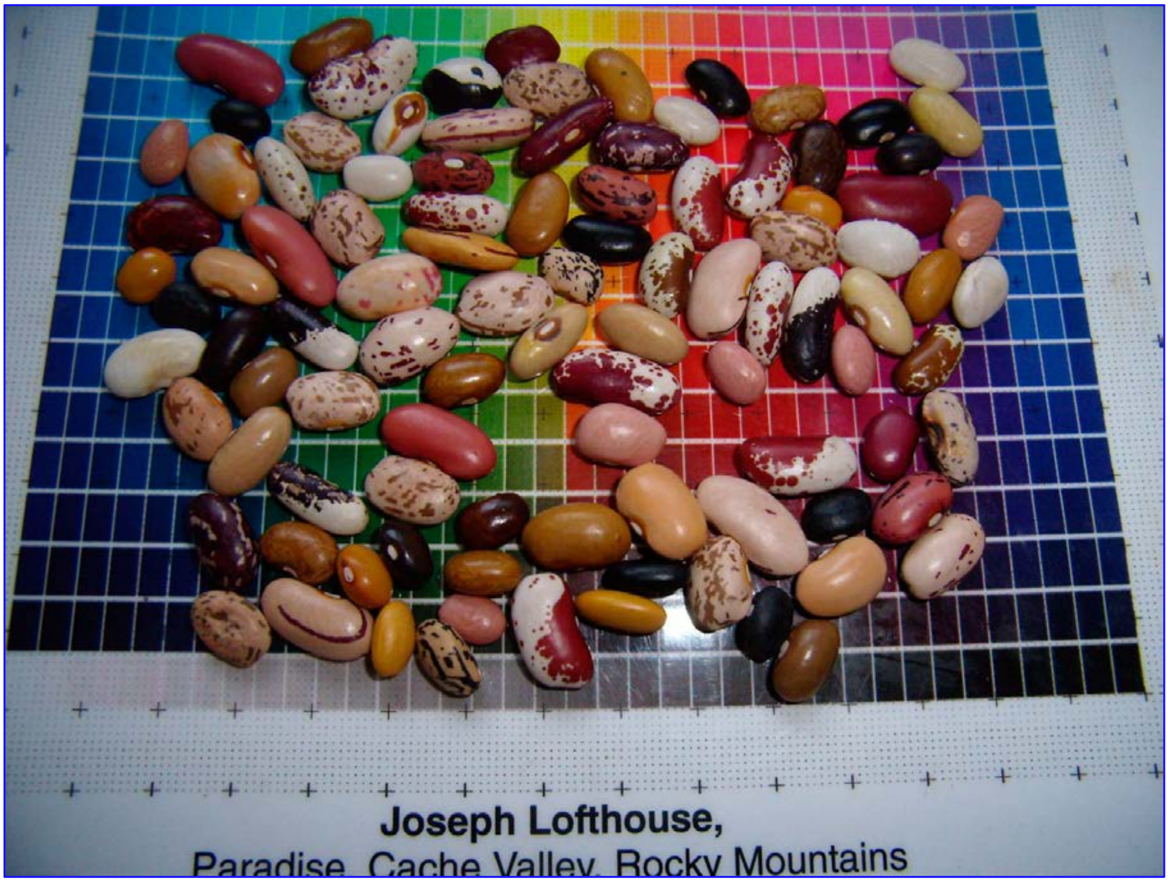

Figure 14. 'Lofthouse Landrace Dry Beans' is a landrace containing hundreds of varieties. Bred to mature quickly in a cold mountain valley, explains Lofthouse, the mixture contains old heirlooms as well as new segregating hybrids. The beans mature in 75 to 90 days, and are specially selected for non-mechanized harvest: 'human scale techniques like beating with a stick or stomping feet' (pers. comm.). They are delicious in chili, bean soup and refried beans – and when used in soups, the mixture means that some beans stay firm while others dissolve to make a rich broth. From cooks to farmers, the variety, says Lofthouse, is a marvel. 'There is so much diversity that something is likely to do well anywhere that it is grown' (Lofthouse interview #2) Lofthouse Landrace Dry Beans are OSSI Pledged and selected for subsistence-level growing without pesticides or fertilizers (Image credit: Joseph Lofthouse).

Mesopotamian wheats, Mayan maizes, and other landraces become attached to a locale over long periods of acclimatizing to territorially specific conditions: climate, soil, insects, water, people. In Lofthouse's case, Paradise, Utah, demands that seeds can thrive in a cold arid climate of 'irrigated desert, super-dry air, sunlight-drenched, cold radiant-cooled nights, short-season, and high-altitude clayish, limestone-based lake-bottom soil'– to name just a few of the ecological considerations (Lofthouse 2017a). Lofthouse is also highly discerning about characteristics he selects for – and against – on the social side:

> Home gardeners, plant breeders, and small-scale market growers who welcome diversity of shape, taste, texture, color, size, and maturity dates may love my seeds. My seeds are unsuitable for commercial farms or large operations that require uniformity, predictability, or stability (2017a).

Landrace breeding is attractive, Lofthouse says, because it means cultivating an intimate relationship between a location, a farmer, and a population of genetically diverse seed. But while landraces are still cultivated in many parts of the Global South, they are much rarer in the US and Europe, and access to landraces is limited.

This is where 'promiscuous pollination' comes in, a method that allows plants to swap pollen freely rather than restrict who mates with whom. Using this technique in 2009 to develop a new cantaloupe landrace, Lofthouse began by gathering 90 different varieties of cantaloupe over a three-year period (Lofthouse 2017b). The seeds came from his own farm, from surrounding farms, and from online mail orders. He then planted these together to make an original 'mass cross'– without, he emphasizes, keeping track of which varieties went where. The seed produced by this mass cross were the beginnings of a new melon landrace. From there, it was a practice of observation and culling. Some varieties were entirely destroyed by soil microbes before they germinated. Some grew slowly and did not produce any fruit. Others grew passably and yielded a small bit of fruit before first frost, while still others grew vigorously, producing loads of melons that ripened on the vine well before the cold came in. Importantly, a collaborator in the valley did the exact same thing. They swapped seeds over the years and produced 'Lofthouse-Oliverson Landrace Muskmelon.'

For Lofthouse, promiscuous pollination has come to mean many things: food sovereignty at a time when corporations control and constrain the food supply; the chance to collaborate with other farmers in the valley; embedding agroecology as the core of his commons practice. 'When I plant genetically diverse crops and allow them to promiscuously pollinate,' Lofthouse muses, 'they are creating lots of variation in taste, texture, color, and odor. When I save seeds from specific plants that taste best to me, I am moving the population in the direction of what tastes best to me and to my community' (Lofthouse 2016).

Of course, there are wrinkles in this story that Lofthouse is quick to point out. Unlike Deppe, for example, he is not particularly impressed by the 'restriction to end all restrictions' of the OSSI Pledge. 'It has no teeth,' he suggested to me, implying that the Pledge will be ignored by large corporations who will do what they will (interview #1). The power of OSSI, for a subsistence farmer like Lofthouse, has been less about protection against free appropriation than about the commons community. He values the social relations that come through the open-source network: where breeders can troubleshoot problems together; where one person's harvest becomes another's parent material; where word of mouth carries customers from one trusted seed supplier to another. Deppe corroborates this view, telling me that OSSI is helping bring dispersed freelance breeders into a more close-knit network, under the label, pledge and recognition of a protected commons.

Case 3. OSSI and the global seed system

Southern resistance, epistemic divides

Re-legitimizing the farmer as an expert in breeding, as explored above, could turn out to be one of OSSI's most important contributions to seed sovereignty, intellectual property notwithstanding. But the Initiative has received some pushback from civil society groups, including organizations such as the ETC Group, GRAIN, and LVC, whose research and advocacy on seed, biotechnology, and intellectual property carry much influence in global NGO and peasant networks. In 2015, for example, a report by GRAIN and LVC openly critiqued open-source licenses as 'tools of intellectual property' and 'not necessarily appropriate for seeds or for small farmers' (GRAIN and LVC 2015, 43). Meanwhile, however, other seed freedom advocates in Europe, Asia and Africa have sought OSSI's advice and partnership. These responses, coming from disparate corners of the world, illustrate that 'beating the bounds' is an inside/outside practice: continually negotiated rules within the community are never isolated from broader social forces – whether in the form of corporate gene giants or seed sovereignty allies.

From the very start, OSSI has been interested in how open source will play out globally because of ongoing geopolitical 'seed wars' (cf. Aoki 2008). To begin gauging the pulse of Global South civil society organizations, in 2011 Kloppenburg attended the fourth meeting of the International Plant Treaty in Bali, Indonesia. The elder LVC members, Kloppenburg recalls, thought the idea of open source 'was appalling'– though younger, often English-speaking colleagues were more interested. Two years later, Kloppenburg flew to Mexico City to introduce OSSI to potential allies. ETC Group and GRAIN representatives, he told me, expressed serious misgivings about the utility of an open-source approach for indigenous and peasant communities. Back in Madison, Kloppenburg reported back to his OSSI colleagues, summarizing the feedback he had received. 'We can expect to encounter these viewpoints among a wide range of NGOs both in the Global South and to some extent in Europe,' he told them. 'These perspectives will materially shape not only how we implement OSSI in the US, but also the prospects and advisability of catalyzing the emergence of an OSSI "South" initiative…We need to understand these concerns and think them through.'

According to GRAIN and ETC group, this disconnect is not only a divide between OSSI on the one hand and indigenous and peasant communities on the other. It is the more generalized problem of people who maintain the possibility of reducing social and ecological relations to *things*. Especially in agriculture, one activist told me, 'what we call seeds, as you well know, is a vast thread of social relations' (Vera-Herrera interview; see also Vera-Herrera 2016). For GRAIN, then, the point is that the attempt to codify seed reproduction is itself dangerously reductive. 'How,' he asked me, 'can we get into a contract the vast complexity of life? Seeds change with every interaction they have with humans, that is, whenever they are planted. We can envisage this relation as a never-ending conversation between peasants and seeds, so a seed variety can never be standardized.'

Several related concerns, OSSI learned, grew from this basic epistemic disjuncture: First was that the logic of digital information systems cannot be applied to living systems such as plants – and not only because plants have independent subjectivity and integrity which must be respected 'as things,' but because seeds are complex processes that entangle social and biological life. Second, much scientific manipulation disrespects the scale of transformations it imposes, and propels changes that, in nature, would likely not happen at that rate, if at all. Genetic modification of seeds is paradigmatic of this manipulation, which purports to achieve precision at the nucleotide level while still largely ignorant of genetic background effects, epigenetic factors, and how gene expression is mediated by the environment. Finally, 'positive law' as developed by Western capitalist societies tends not to respect customary law, and efforts to translate customary arrangements into positive law often undermine them. Any attempt by OSSI to build contractual licenses would therefore follow in this paradigm – likely displacing the very types of 'vernacular law' (cf. Illich, 1981) upon which commoning thrives.

Strictly speaking, the positive law approach was abandoned by OSSI in late 2013, only months after this meeting in Mexico. Responding to both US and international feedback, OSSI terminated its pursuit of contractual licenses in favor of the Pledge – a form of customary law. The objections of potential Global South allies, Kloppenburg explained to me, appear to turn not on OSSI's overall objectives, but specifically on the *method* – that is, the use of a license as a performative vehicle. OSSI had been warned that a license 'is "prima facie" a form of ownership, that no form of ownership should be used or applied to living beings and that a royalty-bearing license is simply another form of PBR' (Kloppenburg 2014).

Yet GRAIN and ETC Group insist that their objection is not simply methodological. In asymmetries wrought variously by botanical hunters, gene bankers, patenters, and free traders, peoples of the South have continuously shared 'in common' what is theirs, only to confront as patented commodities the 'improved' derivatives of stolen seed. The concerns of GRAIN and others indicate the possibility of this power inequity continuing to flourish *through* open-source practices, rather than being fundamentally challenged by them. While a subtler form of codification than a legal license, a pledge imposes a fictive and only temporary 'snapshot' of seed – epistemically if not materially alienating it from the ecological and social relations inherent in the agri-food web. Thus, despite what Vera-Herrera describes as 'laudable' moves to abandon the license, he and others remain concerned that OSSI continues to treat seeds as things, instead of social relations.

Meanwhile, the digital association of 'open source' is certainly one that OSSI will contend with, particularly among peasant and indigenous communities skeptical of technological solutions. Technically, the 'logic of information systems' Vera-Herrera spoke of fell away early on in OSSI's formation, when they learned that software copyright – and, hence, copyleft – could not be neatly applied to biological seed. As inspiration, however, the digital link persists, and 'open source' carries with it strong connotations of techno-progressive, globally linked, and radical freedoms: to use, study, share, and modify as users sees fit. To be fair, the hackers who inspired GNU/Linux, biolinux and, in turn, OSSI are a subaltern culture not to be conflated with Silicon Valley elites. Yet some optimistic assumptions are shared. One is equity in access. Chander and Sunder (2004) caution that in theory, open-source models should result in a situation where all parties reap equal benefits of a commons-based approach to informational resources. But usually ignored are the *distributional* consequences. Differing relative knowledge, power, wealth, access, and ability, they argue, may render some communities better able to exploit the 'open' resources in an open-source model.

Another assumption of open source concerns mobility and fungibility. Information should be free to move, to share, to mix and remix, untethered from any particular community, ecosystem, culture, or place. Seed sovereignty movements often apprehend seeds as rooted, culturally and territorially. Their genetic makeup reflects coevolving relationships among plants, animals, water, and earth in particular territories. Seed moves, but within certain delimited spaces whose boundaries are constructed through the sovereign rights and relations of local peoples. Such rooted 'localism' exists in an uneasy tension with the open-source 'globalism', and while these tensions also exist within food sovereignty itself (see Iles and Montenegro de Wit 2015; Schiavoni 2017), movement skepticism of unrestrained seed freedom makes full sense in light of colonial and liberal histories.

Yet in my conversations with informants, it was not even the open-source issue that seemed to elicit most concern. Rather, it was a habit of thought that Vera-Herrera described as a 'radical monopoly' embedded in the underlying structure of the Pledge. Ivan Illich depicted the radical monopoly as a process that occurs when industrial thinking manages to assume a monopoly of any formulation, notion, idea, or concept. As a result, people are cognitively boxed in: they cannot imagine changing habits of thinking or doing; they continue to reproduce an industrialized point of view even if they seek to create an alternative. With respect to OSSI, the guidelines for entering the commons – i.e. 'pledging seed'– may create a kind of cognitive box with requirements for novelty and individual authority. As a reminder, OSSI asks that a variety, population or propagating material must be 'new', and that there must be an individual breeder, co-breeder or agent with the authority to pledge it. These criteria were developed by OSSI with awareness that they constitutively exclude certain types of seed – heirloom varieties, for example, which are available from multiple resources and seldom associated with a particular breeder. They also exclude most indigenous varieties, which are rarely considered biologically 'new' by indigenous communities, nor are they subject to individual authority (Luby interview #3). Indigenous landraces and many peasant varieties have instead been adapted iteratively through farmer mass selection, with no clear delineation between today's trait novelty and generations of prior novelties. Cultivated over millennia of agrarian stewardship, they tend to be considered the product of intergenerational knowledge transfer, such that no individual agent could possibly lay claim to – let alone pledge – an indigenous or peasant seed.

Positive law does not recognize this subtlety, GRAIN and its allies argue, and the Pledge (though better than the license) continues to inscribe Western-scientific thinking. To be clear, the current OSSI guidelines do not exclude indigenous persons from pledging a crop variety. Simple selection – that is, farmers' longstanding process of saving and replanting seed – can produce a variety that biologists would recognize as 'novel' if done in a directed fashion. A farmer meticulously saving seeds with certain traits may very well isolate a distinctive variety from a heterogeneous population. In addition, indigenous farmers are fully capable of cross-breeding plants, much as professionals do, to develop progeny with previously unseen variations. Nevertheless, these qualifications – describing what native communities *could* do in order to fulfill the OSSI criteria – mostly serve to illustrate the absurdity of forcing farmers to fit commons guidelines rather than vice versa. Entering into OSSI, then, might well contravene the values, beliefs, and logics central to indigenous and peasant peoples' own experiences of seed commoning – threatening the basis through which their own seed knowledge is organically held.

Inclusions/exclusions at the commons edge

Unfortunately, this paradox is not so easily fixed by relaxing the OSSI commons rules. An argument can be made that heirlooms and indigenous varieties are particularly vulnerable to enclosure and therefore are especially in need of a 'protected commons.' But if the Pledge guidelines were amended so as to include indigenous and heirloom varieties, OSSI risks inadvertently becoming the bioprospector – since what gives OSSI the right to decide who among the countless cultivators of Brandywines or Cherokee Purples should have the authority to pledge them? And why should OSSI allow one Navajo or Pueblo farmer to pledge a corn variety that belongs not to her individually (as she herself believes) but to her territory, community and ancestry? To be seen as enabling biopiracy – which remains one of the most deeply resented expressions of colonial and imperialist 'gene grabbing'– makes evident why OSSI would hesitate to relax guidelines on pledging heirloom and native varieties. 'It has to be something novel,' Kloppenburg told me; 'Otherwise, we look like bad pirates too.'[70]

OSSI has, of course, investigated workarounds. In the case of heirlooms, they did so only to find that in addition to problems of uncertain origin, uncertain identities became an issue: heirloom varieties have many synonyms, opening up the chance for accidental duplication and inadvertent pledging of someone else's seed. With indigenous cultivars, the variables are even more complex, given communal, ancestral, and often sacred relations to seed. Importantly, OSSI did not act alone but consulted with grassroots partners, including Seed Savers Exchange who preferred that OSSI not include heirlooms, at least for the time being. Similarly, early consultations with indigenous growers in the US, Peru and Southeast Asia indicated these communities' preference for a 'wait and see' approach. For indigenous peoples especially, the concern is not only about perpetrating theft. It is also uncertainty over whether OSSI is vulnerable to being stolen *from*. Will the Pledge, as a moral economic construct, be respected by

[70] Another reason OSSI requires that seeds be 'new' is that it avoids IP infringement. As Kloppenburg describes, 'Because we get novel material, the only way you can get it is through our channels, our chain of custody. It's one of our breeders who's pledged it.' By the same rationale, the chain of custody protects OSSI seed from unauthorized use. 'If you've seen that variety out there and it doesn't have the OSSI logo on it, or it doesn't say OSSI pledge, then someone's taking it in a way that they shouldn't have taken it' (Kloppenburg interview).

seed corporations and other proprietary interests? Will Lofthouse's concerns that the Pledge 'has no teeth' sap the legitimacy through which a 'protected' commons is protected?

OSSI's hope is that Monsanto, Syngenta, and other agrichemical companies will simply steer clear of the open-source commons, because although corporations have access to OSSI materials, they cannot, under the Pledge, patent OSSI seed or any derivative product. Thus, breeding or engineering with OSSI germplasm is theoretically possible, but runs counter to these companies' core business models. Indeed, in *Plant Breeding Reviews*, a team of Monsanto researchers hinted that they have little interest in tangling with open-source seed, writing that if enforceable, OSSI represents 'one of the most restrictive forms of access' from their perspective (Butruille et al. 2015). Another possibility, of course, is that agribusiness giants will simply defy the Pledge, and proceed to illicitly privatize germplasm obtained as commons. Kloppenburg doubts that corporate piracy is likely at present, mostly because the gene giants do not need or want the resources that populate OSSI – things like organic amaranth, OP Sovereign carrots, and Purple Peacock broccoli. But the relative value of this commons for corporations could change as OSSI expands, and certainly would grow more valuable for 'trait mining' with the addition of indigenous races and varieties. Thus, from the vantage point of peasant and native communities, beating the bounds for inclusion in OSSI remains double-edged. It seems unjust to exclude the very seed varieties most susceptible to enclosure from a commons specifically designed to thwart appropriation. Yet a commons may further endanger vulnerable people's seeds if it pools them together under a Pledge that is still untested. With the legitimacy of the Pledge still largely hypothetical, a justifiable concern is that bioprospecting could occur not by exclusion from the commons but because of it.

OSSI is well aware of contradictions latent in the OSSI model. The ability to radically free seed depends upon the Pledge, which requires recognition of individual authority and scientific novelty. Western norms of property and innovation, then, remain a filter through which people and seeds must pass in order to be commoned. When asked about this paradox, Kloppenburg is quick to acknowledge the irony and move past it:

> You use the tools of the master if you can, any way you do it. We try and free the seed as much as we can. To do that, we are working within a particular regime – capitalism or US law. We are working with that as we can. Just as the people in open-source software are.

Herein lies the rub. The Pledge, by Kloppenburg's own reckoning, is still a type of master's tool, perhaps less hammer-like than the license but nonetheless a hegemon's scalpel. OSSI believes that this pragmatism is important in local context: when surrounded by US capitalism and US law, an inside strategy begins with carving out ethical markets for freed (not free) seed, and whittling seed freedoms mediated by the moral Pledge. By the same token, social movement concerns suggest that the Pledge may have difficulty slicing through the discursive formation of which it is a part. If for Escobar (1994/2011), the wiliness of 'development' was the construction of discursive fields in which 'only certain things can be said, or even imagined,' from the perspective of LVC, GRAIN, ETC Group and a broad consortium of seed sovereignty allies, open source could reproduce a radical monopoly of reductionist, liberal thinking – even while its well-intentioned advocates speak of seed freedom.

From commoning seed, to seeding many commons

These contestations have led to a realization that the Pledge inevitably reflects the social negotiation of only some types of commoners and some types of seeds. OSSI formed, at the outset, in resistance to external boundary beating: capital incessantly vying for greater imposition of intellectual property rights. But allies can also beat the bounds from the outside. In this case, social movements contested the cosmovisions underlying the Pledge, illuminating that perhaps more localized forms of OSSIs can support local sovereignty for seed.

Rather than beat its own bounds into a pulp of contradictions and possible routes to enclosure, OSSI is now taking an alternate approach to working with indigenous and peasant seed systems worldwide: it is attempting to 'seed' other local commons. The approach is simple, exemplary of what Escobar calls the 'pluriverse' of commons knowledge and practice (Escobar 2015). OSSI will share its experiences, struggles, and stories with other communities; it will offer inspiration over formulation, tested strategies and solutions rather than a body of unified theory. In this fashion, OSSI also alleviates pressure on the US initiative, nascent as it is, to incorporate a galaxy of heterogeneous seed cultures into a singular Pledge.

In India, for example, the Centre for Sustainable Agriculture (CSA) has adapted the OSSI model to the conditions of Hyderabad and its rural villages (see Figure 15). An open-source seed program helps farmers preserve seeds for traditional foods and supports participatory breeding projects to develop rice, eggplant and millets that meet local needs (CSA-India 2014). Similarly, the German organization AgriCulture and Ecology is launching an EU-appropriate open-source system. In this case, the breeders and biodynamic farmers are designing formal licenses, not unlike those abandoned by OSSI. The Germans feel the licenses are feasible in their highly legalistic culture, and may be more robust as an antidote to the onerous EU Common Catalog. (In India, CSA is coupling legal licenses with an OSSI-like pledge). Meanwhile, Ethiopian farmers and breeders recently held a four-day meeting on 'Open Source Seed Systems for Africa,' and plans are in the works for an OSSI-indigenous platform specific to native communities.

Kloppenburg emphasizes that 'OSSI is not a model. It's not even an exemplar.' What it is, he suggests, is 'a concrete enactment of certain principles that anyone else can pick up and run with in their place.' With this ethos, OSSI seeks to promote a pluriverse of seed commons rather than establish or oversee a universal archetype, which would never succeed agroecologically or politically. This approach is also congruent with what Bollier suggests is most important now: 'to form and expand a wider circle of actual functioning commons that can serve as "staging areas" for building a new vision for the future, a new cultural ethic, a political constituency’ (Bollier 2014, 170).

Figure 15. Seeding a Pluriverse of Commons. Patents and ‘bag tag’ licenses restrict farmers’ rights to save, replant, breed, and exchange. Now pervasive in corn, soybean, sugarbeet, and cottonseed in the US, similar restrictions are being aggressively promoted in developing countries. OSSI was created to counterbalance this trend. The Pledge which travels with each seed packet (left) gives farmers and breeders freedom to use seed in any way they choose, so long as they do not restrict others from the same freedoms. A group in India has recently developed their own open-source material transfer agreement (right), inspired by the OSSI Pledge. In this way, OSSI hopes to inspire a pluriverse of locally adapted and locally governed seed commons (Image credits: OSSI (left); Open Access India (right)).

Conclusion

In this contribution, I traced the efforts of one new project to resist the long colonial and capitalist enclosures of seed. ‘Beating the bounds’ is an active mode of resistance undertaken by members of the Open Source Seed Initiative in an attempt to repossess their seeds. I argued that such boundary beating moves us beyond the static ‘commons’ and into the active form of common*ing*: the living practices of making rules, negotiating protocols, and reevaluating the principles through which a commons adheres. By focusing on knowledge, I followed these social practices through three related stories, from experimenting with legal structures to affirming plant breeding knowledge to articulating with the global seed system.

Boundary beating, we discovered, has worked to reconfigure the relationship between formal and informal seed laws and structures. In turning from legal licenses to the Pledge, OSSI abandoned, on one hand, the power of legal enforcement by the state, thus gaining, on the other, the power of a moral economy defended by commoners. As a result, the commoners themselves reconstituted:

with both formal securities and constraints of licenses gone, the Pledge attracted and supported breeders, farmers, and companies committed to a more radical notion of freed seed.

We saw how this reorganization into a moral economy proved more conducive for some knowledge-makers than for others. OSSI has been populated principally by a freelance breeding community that is less constrained by institutional lock-ins, less accustomed to proprietary knowledge and more able, structurally and culturally, to participate in pledging their seed. People like Carol Deppe, Joseph Lofthouse and Frank Morton, I argued, are breathing life into plant breeding as a practice of organic intellectuals. Though their heterogeneous farms, educations, and habits defy broad generalization, in that diversity they may be infusing OSSI – and perhaps eventually the broader US food system – with epistemic resilience.

Finally, in considering the larger global seed system, we found that boundaries can be beaten from the outside as firmly as from within. Global seed sovereignty movements have expressed discomfort with some aspects of open-source seeds: the digital logic of the premise, the tendency of Western science to manipulate nature beyond its knowledge, and the positive law that underwrites an open-source model. These concerns, moreover, did not fall away with the abandonment of a license approach, contrary to what OSSI initially believed. The lingering critique was a sense that even the Pledge contains buried liberal epistemologies, that somehow this moral economy treats seeds as things rather than as social relations.

I believe (but cannot prove), however, that seed sovereignty movements of the South may find much affinity with the freelance breeders of OSSI and the US more generally. These freelancers do not appear to view seeds as rootless data, mineable genetic resources, or fungible commodities. 'Open source seed isn't inherently rootless or inherently not root-less,' Deppe suggests. 'Caring about place, about local adaptation – that's a value' (Deppe interview #2). GRAIN and LVC have been justifiably concerned that the freedom of open source becomes conflated with 'free markets' in which 'anyone, and especially large companies, can grab seeds wherever they want, and where communities lose all control' (GRAIN and LVC 2015, 42). Yet in the end, these seed sovereignty groups' affirmation that 'We need rules over seeds' is not so very different from the freelancers' convictions. 'The issue,' Deppe contends, 'is an *unregulated* commons that seed privatizers can plunder [i.e. public domain], or a *protected* commons, that they can't [i.e. open source].' Most unregulated commons fail, she believes, especially when the population is large enough and the resource is valuable enough. 'Seed sovereignty is all about a seed commons,' she told me.

Insofar as seed sovereignty movements seek to achieve common rights – to save and replant, to share and exchange seed, to breed new varieties of seed, and to participate in making policy decisions over seed – I see more alignments than frictions between OSSI and many sovereignty movements. At least the rubbings are smaller than the synergies, which could be traction for a pluriverse of commoning to grow. And this, to borrow from the essayist Rebecca Solnit, matters especially now, in times of systemic crisis. We are not slaves to Hardin's tragedy of individualism and selfish conceit. 'We're beautifully, anarchistically resourceful, communitarian, full of mutual aid, in the moments after a disaster' (Solnit 2017). So then the question becomes:

Do we understand our own power? Can commoners exercise it, build on it, make something permanent out of it, hang onto it, do the slow, painstaking work of rebuilding a society? Like the OSSI commoners, I suggest that it is not a given. It will take much boundary-beating work. But in that activity, there are real possibilities of taking dominant structures apart and watching them collapse. There are real possibilities for commoned seed to grow.

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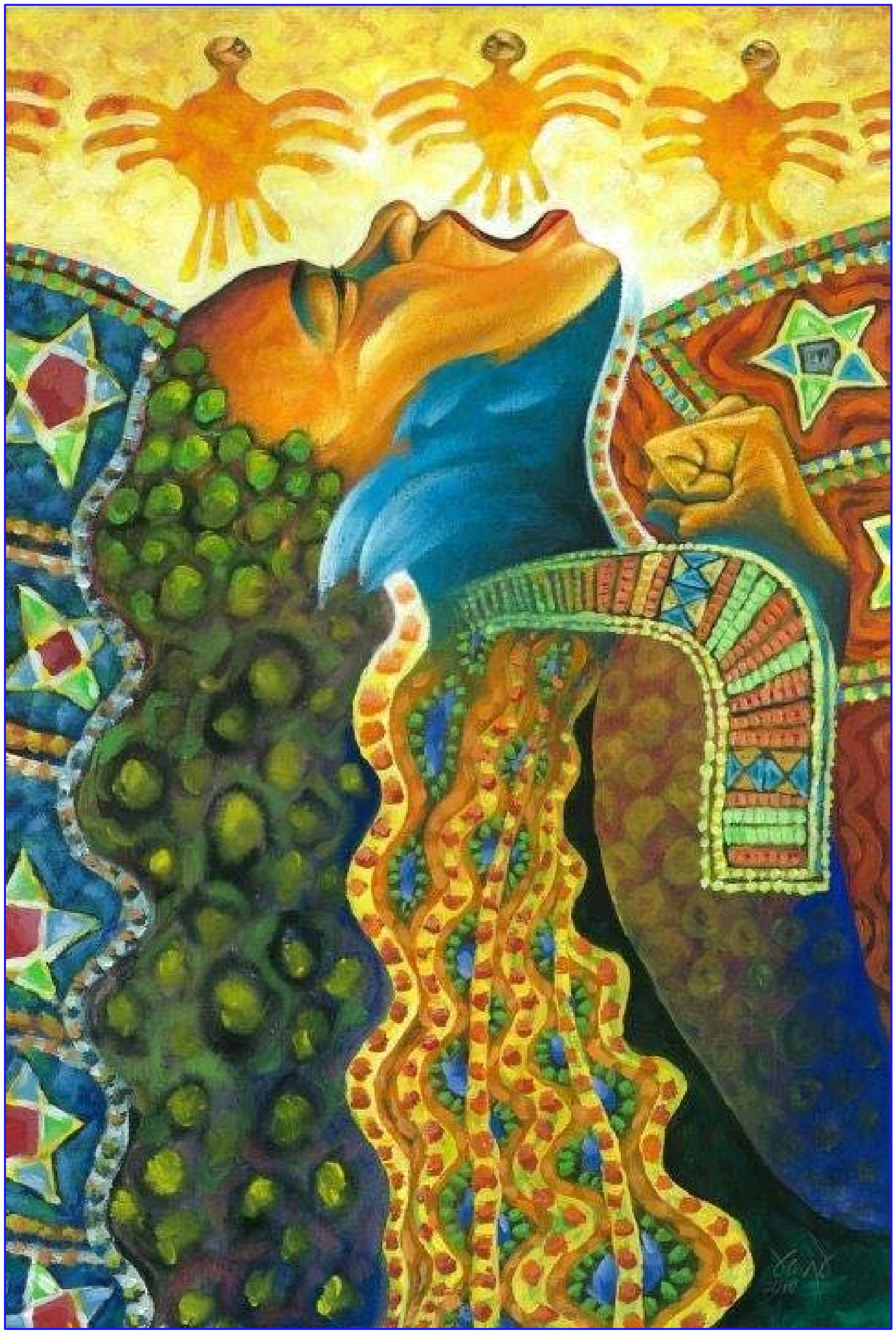

'Yalingkawas.' In the above painting,
Boy Dominguez portrays the Lumad Mandaya
term for 'freedom' or 'freed.'
(Image credit: Boyd Dominguez)

Chapter 6

Conclusions: Toward a Political Ecology of Seeds

The very first time I ever ‘did science’ it began with saving seeds. For my fourth grade Science Fair project, I wanted to know: How does a seed know which way is up? I saved the pits from three avocados, hammered nails into their sides, and suspended each over water in a peanut jar. I placed one seed right side up, another upside down, and another hovering sideways. Over the next three weeks, I watched as the first roots emerged, splitting the pit open so I could peer inside. Within the upside-down seed, I saw with amazement that the radicle turned a full 180 degrees before poking out; I took pictures every day and noted how this delayed its emergence by about a day behind the right-side-up seed. ‘This is called gravitropism,’ I explained to the Science Fair judges. ‘Tropisms help stems grow toward light and roots grow in the direction of gravitational pull.’ I remember thinking it was halfway between magic and biology, as if seeds have an inborn knowledge too.

The avocados grew in my bedroom for the next ten years, and may have been the beginning of my entwined loves for seeds, storytelling, and biology. I took these interests through high school and college, where I began more detailed work on protein folding and biochemical reactions in microbes. At the same time, I was introduced to something called ‘science journalism’ which enabled me to articulate, in everyday words, abstruse and technically intricate stories of the natural world.

Somewhere along the line, however, my view of the world also narrowed into an overly scientized perspective. Being awestruck by the dance of seeds over a peanut jar evolved into wanting to manipulate microbes that could, in turn, transform plants at the genetic level. In 2004, I nearly found myself enrolled in a PhD program at UC Berkeley where I would do just that: genetic engineering of food crops. Biofortified cassavas, bananas, and rices, I assumed, were the best prospect for feeding malnourished populations, especially in developing countries which had not benefited from Green Revolution yields. I wrote a masters’ thesis premised on a reductionist rendering of rice history and agriculture, and spent most of my seven years as a journalist continuing to promote ‘scientific thinking’ as the paradigm forward in sustainable development. Against activists’ and organic elitists’ gripes about GMOs, I believed, biotechnology could feed – and save – the world.

Fast forward to 2017, and I’m now an advocate for agroecology and food sovereignty. I take scientific thinking with a heavy dose of reflexive salt, and I am more inclined to speak against the techno-optimists than with them. So what happened? I’ve tried many times to tell the ‘conversion story’ – to answer to the inevitable questions that arise when friends or colleagues encounter regrettable readings of Maywa past. I know that a good story has notable points of inflection and watershed moments. And mine has some of those: the moment, for example, I found myself at the 2010 BIO conference in Chicago, invited by the trade industry to help the general public appreciate the benefits of engineered crops. But the fuller truth is a cascade of mundane discoveries, everyday conversations with new and challenging colleagues; the countless readings that eroded my positivist thinking into a more situated and pluralistic construction of truth. Pragmatically, it was also the influence of a Berkeley social science education: the training in development history, political ecology, geography, and STS that pulled apart my technoscientific determinism and forced me to reconstruct new patterns of thought. Not least, it was a personal and cultural return: revisiting my own indigenous heritage and embracing the biocultural and commoning perspectives that have inhabited my own 'roots' from the start.

Learning curves in agrobiodiversity

At this point in my thesis, I do not wish to reprise the Conclusions from each of my papers. I will instead comment briefly on a few salient findings, highlighting their larger implications for research and food system change. I will then turn to discuss the politics of 'centricity,' ending with a call for greater seed sovereignty founded on in situ-centric movements. In 'Are We Losing Diversity,' we learned that seed diversity is contingent, historically and spatially uneven. We saw how changes in diversity over time – or crop genetic erosion – are continually subject to different ways of knowing and recognizing diversity, as well as distinctive strategies of discursive mobilization. Discourses of 'loss' and 'persistence' can cut in many perpendicular directions, as seen prominently in how stories of rampant seed loss can be used to galvanize support for smallholders, or by contrast, to legitimate appropriation from them. Similarly, persistence narratives can celebrate farmers' de facto conservation strategies, but can also justify doing little to invest in rural livelihoods – since after all, peasants tend to persist regardless.

After publishing the first case in my dissertation, I became aware of a subtler phenomenon in play: that 'loss' discourse in general tends to remove agency from the picture. Seeds are simply 'lost' instead of being stolen, displaced, outlawed, or dispossessed – the political-economic drivers disappear into the passive language of erosion or loss. In my second paper, 'Stealing Into the Wild,' we saw how many prominent organizations ostensibly seeking to stymie erosion of crop genetic diversity are systematically advancing dispossession. These new frontiers of primitive accumulation, I argued, are materializing around the breeding and conservation science of crop wild relatives. Undomesticated biological and genetic territory like crop wild relatives represents the potential for novel commodification of 'wilderness.' But such potential cannot be realized without plant breeding and biotechnology to identify, isolate, and integrate valuable wild traits into cultivated crops. Nor can it thrive without the conservation strategies – ex situ and in situ alike – that link wild habitat preservation to 'germplasm use.' It would not happen without the formative institutional lock-ins of intellectual property that transform breeding products into commodities, data systems that render plant genetic knowledge newly fungible and appropriable, and governance regimes including the International Plant Treaty that structure and legitimate ex situ centric mobilization of agrobiodiversity knowledge and value. Rather than simply conceive of enclosures as a particular locus of dispossession (eg. seed-, water-, or forest commons) or a mechanism of expropriation (eg. patenting or land grabbing), I suggested that it is helpful to consider ongoing processes of 'coproduction' that meld epistemic and material elements into a science-policy-practice assemblage. This assemblage makes it possible for multiple enclosures to proceed: Scientific discourses, breeding practices, legal institutions, and data systems can exert their own agency, creating and reinforcing primitive accumulation of plant genetic resources, wild and cultivated landscapes, and the knowledge systems associated with each.

In 'Beating the Bounds,' we learned that movements are afoot to not only resist dispossession but enable repossession. The first important detail of the OSSI commons was the profound difference between an 'open access' regime and a protected (or governed) regime. The former lies at the heart of many a postcolonial effort to claim 'common heritage' while freely appropriating others' seed. The latter relies upon particular principles of governing the commons (a la Ostrom). But OSSI also revealed a deeper dimension to commons, which took us beyond mere resources, and beyond the static institutional governance of seed. In the stories and struggles of OSSI's members – university breeders, freelance breeders, farmers, and professors – we found a community undertaking the subversive work of common*ing*. In devising and testing social protocols for how seed can be bred, farmed, studied, and freely renewed, they embodied the practical commitments of commoners who specialize in what Bollier (2014, 5) calls 'bottom-up, do-it-yourself styles of emancipation.' But we further saw how such emancipation is far from smooth. Commoning is riven with disputes and contestations, reflecting struggles both within the commons and with outside groups. Understanding these processes in terms of 'beating the bounds,' I suggested, helps us navigate the inside/outside strategies of rule-making and resource-sharing.

In beating their bounds, the OSSI commoners engaged in learning practices, which evolved as they matured beyond the formal licenses phase and into the moral economy phase. The commons became more radical over time, as it responded to exogenous feedback from food sovereignty allies, and as self-reorganization after crisis left a commons populated by members with more subversive leanings. This notion of 'beating the bounds' has historical roots in Welsh and English traditions – 'bumping heads' so communities will *remember* their social identities – but it also points to the ability of commoning to take root in many cultures and places, adapting to particular customs, ecosystems, and political conditions.

Centricity: flow of power, knowledge, and seed

Reflecting on my papers together, a spatial theme of 'centricity' emerges as a way to understand how seed systems can function in diverging ways, with implications for who controls, uses, and benefits from seeds. As Lewontin long ago argued, seed is the linchpin of the entire agricultural system, past, present, and future. Nothing symbolizes linking historical agricultural development into future food needs quite like a seed bank. Yet we have recently learned that the failsafe genetic repository known as the Svalbard Seed Vault may not be as impervious to global environmental change as initially thought. On May 19, *The Guardian* published news that the seed bank had flooded, leading to potentially catastrophic loss of stored germplasm. It also unleashed a deluge of commentary from boosters and skeptics (Carrington 2017). Cary Fowler, director of the Vault and head of the Crop Diversity Trust, immediately took to Twitter to defuse the media claims. 'Believe me,' he said, 'no seeds have been damaged. The Vault remains safe.' For proponents of in situ conservation, it was a Vault sized, 'told you so' moment. The bank that was supposed to save seeds from climate change was now literally melting down.

The truth of this matter probably lies somewhere in the middle. Fowler was correct in arguing that *The Guardian* had softly sensationalized the narrative: small amounts of permafrost melt have been leaking into the Vault for years, and this was not quite 'breaking news' as portrayed. He was also correct that no seeds were damaged on that melty day in late May. Yet what Fowler seemed not to comprehend (or avoided acknowledging) was the larger socioecological implications of the so-called flood. The Vault *will* eventually see catastrophic water damage, if overwhelming evidence from climate science is correct (Hansen-Kuhn 2017). It will never be able to replace what is destroyed, and by concentrating the seeds together in one place, may actually heighten that extinction risk. Of course, conservation biologists are savvy to the perils of such concentration, which is why the Svalbard Vault holds only duplicates of seeds stored elsewhere in CGIAR and US national gene repositories. This global network of ex situ institutions are 'insurance,' as it were, against catastrophic loss from Svalbard. But the problem is that it was supposed to be the other way around: Svalbard was the backup, the Arctic hedge against losses from the more fragile and chronically underfunded public gene banks. With climate control, humidity gauges, security surveillance, and a location several thousand feet into permafrost, it was called the 'Doomsday' bank for good reason (See Figure 16).

That the Vault is itself doomed – it will almost certainly melt, sooner or later – brings us to larger questions of organizing our seed economies in the living world. For several decades, as we saw in Chapters 3 and 4, global conservation science has been characterized by two dominant trends. On one hand, ex situ strategies promote germplasm storage in gene banks, field banks, and other offsite, often centralized, collections. On the other hand, in situ approaches focus on conservation across the range of agrarian landscapes where crops adapt, evolve, and grow. Shifting relationships between these two paradigms goes back at least 35 years. Beginning in the 1980s, ecologists' and conservation biologists' arguments were taken more seriously, and strict ex situ gene banking was recognized as evolutionarily unsustainable (Frankel and Soulé 1981; Cohen et al. 1991; Maxted et al. 1997). As buffer zones, protected areas, and wildlife corridors were put in place, biodiversity conservation saw a distinctive turn to in situ and on-farm strategies. Towards preserving the ecosystem processes that produce diversity, researchers called attention to the contribution of indigenous peoples, smallholders, and women to 'making' diversity (Oldfield and Alcorn 1987; Altieri and Merrick 1987). This reversal in approaches – away from 'search and freeze' and towards 'recognize and renew' – was mirrored in the social sciences. Here, critiques of imperial gene hunters, coupled with greater appreciation for the coevolution of linguistic, biological, and geographical diversity, tended to support research on and advocacy for de-centralized, informal, and farmer-led initiatives for seed renewal (Zimmerer 1996; Nazarea 1998; Brush 2000).

By the late 1990s, 'complementarity' became the dominant paradigm in international science-policy, linking on-farm conservation with off-site configurations of collection, storage, and crop breeding use (FAO 1996)[71]. Most major frameworks for plant genetic resource science and

[71] Importantly, the term 'complementarity' also carries a very different meaning in conservation biology. Seen frequently in reserve design literature, complementarity refers to sites that differ from one another in terms of their species composition. Ensuring that areas chosen for inclusion in a reserve network complement those already selected, it is used widely as a quantitative indicator and guide for scientists and policymakers in the efficient accumulation of multiple species within a reserve network (Kremen pers. comm.; Groom, Meffe, and Caroll 2006).

governance – the FAO's Global Plan of Action on PGRFA,[72] the Convention on Biological Diversity, the International Treaty on PGRFA, and Bioversity's 10-Year Strategic Plans – include programs, provisions, and funding strategies for both ex situ and in situ conservation and use. Thus, while this ex situ/in situ dichotomy continues to animate popular discourse about food security, in practice, the dualism is long dead.

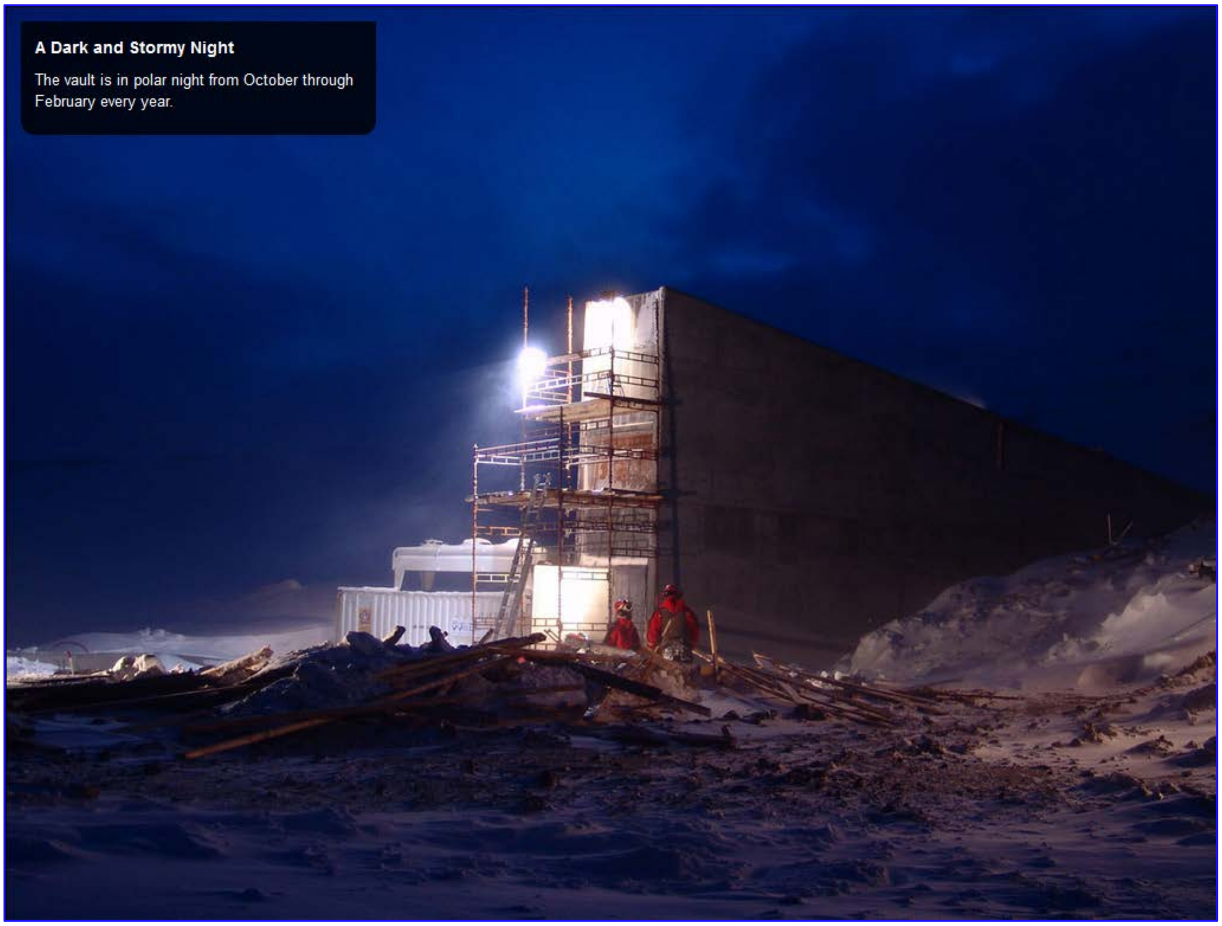

Figure 16. Is the Doomsday Vault Doomed? 'The vault is in a polar night from October through February each year.' In 2008, the time I first wrote these lines (Montenegro and Greenwood 2009), the Svalbard Seed Vault seemed buffeted from forces that imperil much of the world's crop seed: desertification, expansion of industrial agriculture, human outmigration, and shifting zones of arability under climate change. But with scientists now reporting on massive warming within the Arctic Circle, the impregnability of Svalbard is now highly uncertain [under siege?]. Indeed, many conservation biologists, ecologists, and social scientists – not to mention indigenous peoples – have long been skeptical of the ex situ approach. 'They are saving seeds that thrive in cold storage conditions,' Kloppenburg told me. A senior research official at CIRAD in France was even more blunt: 'I'm sorry, but Svalbard is just bullshit.' (Image credit: Global Crop Diversity Trust).

[72] PGRFA stands for 'plant genetic resources for food and agriculture.'

What very much continues to exist, however, is a lingering colonial[73] character of mainstream PGRFA conservation and breeding. Building upon Graddy-Lovelace, I suggest that the spatial and social orientation of germplasm flow and value – that is, the 'centricity' of circulation – demands closer attention. When complementary regimes marry in situ conservation to ex situ institutions, what is the nature of their relation? Do local farms and communities in agrobiodiverse places serve mostly to populate off-site gene banks and labs for crop improvement and commodification? Conversely, do genetic resources flow back from ex situ repositories into farmers' hands and agroecosystems? When they return, are the free from intellectual property? Free from price?

My research in Chapter 3 leads me to believe that the systematic plans to conserve and use CWR are in fact shaping up as 'ex situ centric.' By linking in situ conservation to ex situ breeding institutions and intellectual property domains, they are in effect 'saving nature' in order to populate a pipeline of offsite breeding and biotechnology. Along the way, use value becomes transformed into surplus value, and genetic materials traditionally held, used, and reproduced as commons become individuated as private property. Emerging from a spatially centralizing orientation, this ex situ centric paradigm supports a colonial epistemology that locates knowledge production in centralized, often distant sites of recognizing and classifying diversity. Expertise is conferred primarily upon those scientists and industrialists who can produce commodity-products; what is valuable is contingent, then, on certain baselines of yield-boosting, caloric, or economic growth potential. The ex situ centric regime never abolishes dependency on the land – for after all, it depends upon genetic novelty to continue working – but it subordinates local peoples, agroecologies, and knowledges to be continually exploited by traditional intellectuals and agro-industrial capital. Characteristic of post- or neocolonialism, the dynamics remain extractive, tending to support the expansion of the corporate food regime and entrenching its power Vía ongoing enclosure of seeds, knowledge, and territories previously exogenous to capital.

In contrast, the Open Source Seed Initiative is mobilizing breeder and farmer knowledge to create a protected commons for 'freed seed.' I argue that OSSI, while nascent, exemplifies an 'in situ centric' strategy: though involving both in situ and ex situ spaces and institutions, the flow of power and resources is redistributive and re-localizing. By enabling seed to adapt to local ecologies and changing social conditions, by allowing more decentralized governance of genetic resources, and by fostering diversity in who accesses, breeds, grows, and exchanges seed, the 'in situ centric' model offers potential for an emancipatory epistemology and practice. Expertise of farmer-breeders and seed savers is strengthened because these actors reappropriate not only intellectual property but also a place as legitimate makers and custodians of seed. Whereas ex situ centric systems attract investment and capital by showing that seeds can be 'unlocked' as

[73] Colonialism proper 'refers to the political-economic process of an imperial power's territorial expansion into and violent occupation of other lands to achieve primitive accumulation of and capitalization of their natural and human resources for its own economic and political enrichment. It also refers to the historical age characterized by these missions of dominance and exploitation. Though some colonies continue to exist, most successfully fought for and declared independence, ushering in a post-colonial era. Yet colonialist dynamics and disparities have persisted, even after revolutions, in what scholars and activists call post- or neocolonialism. It also smolders on within national borders as internal colonialism' (Graddy-Lovelace 2017).

data, practitioners of in situ centric demonstrate and believe that agrobiodiversity happens because of knowledge – 'and is in fact *comprised* of it' (Iles et al. 2016).

Co-producing new enclosures

Since the time that 'Stealing Into the Wild,' was published, many significant developments have taken place in this sphere – including the fact that the US Senate voted to ratify the International Plant Treaty, after more than thirteen years of willful abstention. Although seen in some sectors as a welcome move by the US to join international governance/treaties, for many seed sovereignty actors, it is a troubling move. As Hansen-Kuhn (2016) notes, the seed industry lobbied very aggressively from the US to adopt the Treaty, which is now seen as more favorable to industry than the Convention on Biological Diversity:

> At the Senate hearing, John Schoeneker, testifying on behalf of the American Seed Trade Association (ASTA, whose leadership includes representatives of Bayer, Dupont and Syngenta) and the State Department urged ratification of the Seed Treaty, which would require no changes to U.S. laws but would enable access to the seedbank. An ASTA letter to the Foreign Relations Committee signed by 80 farm and seed business groups urged ratification, saying, 'Currently, public and private sector breeders are vulnerable to the Nagoya Protocol, which was established under the auspices of the Convention on Biological Diversity and goes beyond the agriculture sector. The Nagoya Protocol is a far less favorable option [than the ITPGRFA] for germplasm exchange for U.S. agriculture researchers and the entire U.S. seed sector.'

The presence of the US as a contracting party in the Plant Treaty, many critics believe, will make it all the harder for social movements to win their protracted battles to strengthen Farmers' Rights within this international treaty. A report published by the Third World Network in 2016 described how already prior to ratification, the US delegation was participating as part of a Canadian delegation in Treaty talks, arguing against African governments' calls for a mandatory redistributive payment system.[74] A Monsanto executive also criticized countries that wanted to postpone decisions about a termination clause, which would have eliminated any requirement for benefit-sharing payments after a fixed number of years.

Such agribusiness interests in international seed law are, in turn, being coproduced by other major developments, including new advances in biotechnology and informatics. Most prominently, CRISPR-Cas9 and related genomic editing technologies has massively accelerated the interest in – and possibilities for – engineering plants, animals, microbes, and people (see supplemental data: 'CRISPR is Coming to Agriculture'). Even in the months since my last paper went to print, CRISPR has continued to make headlines. In September, 2016, the Monsanto company confirmed an agreement to license the gene editing technology from the Harvard/MIT Broad Institute for use in crop development. Since 2013, Broad has issued more than a dozen licenses for commercial research using CRISPR-Cas9 – including to GE Healthcare, Evotec, and Editas Medicine. But this was a first for agricultural use, and the Institute claims it will reduce

[74] Whereas the current Multilateral System asks for payments from any commercial development of seeds obtained from the 'commons,' this mandatory 'subscription system' would require payments based on a percentage of seed sales and license income.

the use of chemical pesticides (a plant can be modified to thwart insects), and make strains tolerant of droughts associated with climate change. Broad agreed to restrict Monsanto from using CRISPR for gene drive – a controversial technique that can spread mutations through population in the wild – but critics note that Harvard has already filed a patent application including a long list of over 50 weeds and almost 200 herbicides, laying out a strong business case for future licensing to agrichemical companies.

Meanwhile, several other companies are also in pursuit of genome-edited crops. The Calyxt subsidiary of Cellectics, based in Minnesota, is using a progenitor of CRISPR, called TALEN, to make soybeans whose oil resembles olive oil, potatoes that do not create acrylamide when fried, and wheat that produces less gluten. DuPont is collaborating with biotech firm Caribou Biosciences to CRISPR-edit corn and wheat for drought tolerance and other traits. Recombinetics and its subsidiary Acceligen both focus on engineering animals, with more than 15 patents issued and more than 170 patent filings on gene-editing methods, traits, and novel reproduction methods in cows, chickens, and pigs (See Figure 17).

This molecular revolution has both depended upon and impelled a growth in data science and technology to sequence, map, search, and store unprecedented amounts of plant genomic, phenotypic, and proteomic data. The DivSeek platform has become particularly prominent as part of global gene bank management systems, providing the IT infrastructure for molecular characterization of the world's ex situ-held seed agrobiodiversity. As noted in its mission statement, DivSeek aims 'to enable breeders and researchers to mobilize a vast range of plant genetic variation to accelerate the rate of crop improvement and furnish food and agricultural products to the growing human population.' The promise of DivSeek, InfoSys, and similar databases is remote global access and speed. Today, for example, when a new strain of influenza appears in Asia, scientists can collect a throat swab, isolate the virus, and run the strain's genetic sequence through databases where it can be characterized and re-synthesized by labs in the US and Europe in order to develop vaccines. The same could be true of agricultural crops, when CRISPR-Cas9 is used in combination with DNA fingerprints of organisms to which researchers may not have direct physical access.

Drought-resistant maize from a Zapotec community in Oaxaca has recently come into issue here. This valuable maize might conceivably be reconstructed by editing the genes of non-resistant maize varieties – in effect, CRISPR-ing one type of corn into another. For such processes to be successful, however, genetic sequences of thousands of maize varieties would be needed to serve as roadmap and resource pool for scientists to identify pertinent molecular markers and variations. Critics fear that such data mining could ultimately be used to reconstitute indigenous maize characteristics in the parents of a new Monsanto or DuPont maize hybrid. Managing access to the large genomic databases has thus become another prominent component of 21st century 'biopiracy' – the theft of virtual knowledge and virtual seed. Indeed, in an unguarded e-mail released under the US Freedom of Information Act, one of the US Department of Agriculture's top maize scientists, Edward Buckler, called such management 'the big issue of our time' for plant breeding (Yoke Ling and Hammond 2016).

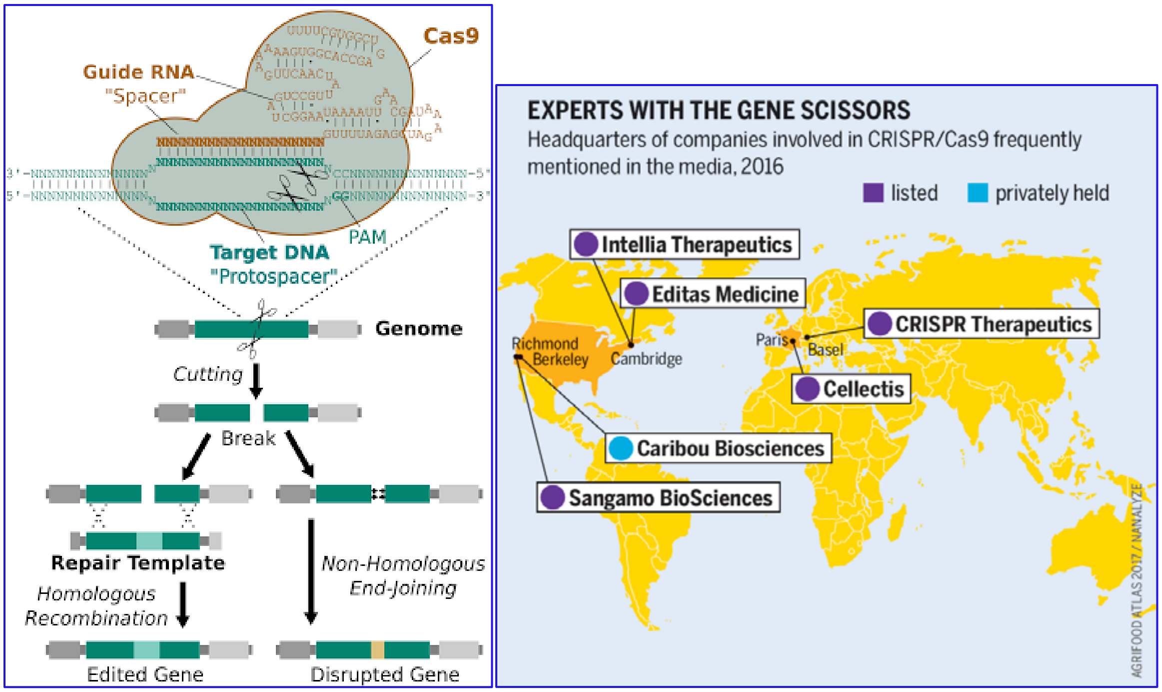

Figure 17. Two Geographies of CRISPR-Cas9. On the left, the molecular terrain of genomic editing can be seen in a graphical rendering of the CRISPR-Cas9 system. Developed by UC Berkeley's Jennifer Doudna and Emmanuelle Charpentier of the Max Planck Institute, the 'guide RNA' enables researchers to target a cutting enzyme (Cas9) to very specific locations in the genome. Depending upon the repair pathway triggered, and whether a 'repair template' is available, many different types of edits are possible – from gene deactivation to small sequence substitutions to insertion of whole new genes. On the right, the global geography of CRISPR R&D reflects an innovation and IP war. While Doudna and Charpentier's firm Caribou Biosciences has licensed the use of CRISPR in agricultural crops to DuPont, a rivalling lab at Harvard/MIT has granted a global CRISPR use rights to Monsanto. Both DuPont and Monsanto intend to bring CRISPR-edited crops to market by 2021. (Image credits: Left: Kevin Esvelt, MIT Media Lab; Right: *The Agrifood Atlas*).

Neither of these new moments of revolution in data or molecular biology would be possible were it not for redistributions of capital, infrastructure, and legitimacy characteristic of neoliberalized agricultural science. The 1980 Bayh-Dole Act was a watershed moment in hitching public plant breeding research to private sector interests. Offices of technology transfer, the 'patent oath' signed by every UC Berkeley student, the increasing pressure to generate revenue through royalties and licensing arrangements mark the creeping enclosures of a public university system. Illustrating the entanglements of co-production, this subordination of public research to capital looks set to continue thanks to biotechnologies like CRISPR-Cas9 and their legal handmaiden of IP law. In Mexico, for example, it was recently announced that DuPont Pioneer and the CGIAR's International Maize and Wheat Improvement Center (CIMMYT) have entered into a 'Master Alliance Agreement' to jointly develop improved crops using CRISPR-Cas advanced plant breeding technology 'for characteristics that address the needs of smallholder farmers around the world' (CIMMYT 2016).

Closer to home, UC Berkeley is embroiled in a patent war with the Broad Institute over rights to CRISPR-Cas9. According to UC press releases, the European Patent Office will likely recognize the UC as 'discoverer' and holder of broad rights, while the US Patent Office may split rights between Harvard and UC. It is little wonder, then, that locked-in trajectories of capital, infrastructure, pedagogy, and scientific legitimacy develop apace: a new Innovation Genome Institute is being built on the UCB and UCSF campuses to fund CRISPR-Cas9 research, several genomic conferences currently dot the university's event schedule, and 'student run-DuPont' symposia are now taken as a matter of course. Dr. Doudna, co-discoverer of CRISPR-Cas9, and co-founder of Caribou Biosciences,[75] can be seen on promotional posters across the Berkeley campus, declaring the power of genetic technology to make a better world.

This world-making is a large part of what threads my past interests in biology and storytelling with my newer development as a social scientist. As Michael Watts memorably summarizes 'discourse' to his undergrads, they are the 'names, frames, meanings, and measures' that permeate our understandings of the world. Discourses come to discipline, produce, *and reproduce* what we know and how we know it. In Escobar's words, they construct a space through which 'only certain things can be said, and even imagined' (Escobar 1994, 39).

Towards a political ecology of seeds

> *Emancipation, by definition, demands notions beyond food as being nutritional and livelihood rights. It requires the breaking down of binaries and hierarchies and asks us to reimagine food as part of the collective, community, solidarity or nature, and central to the many alternative systems we are constructing.* – Andrews and Lewis, 2017

[75] As described on the Caribou Biosciences 'Origins' page: 'At the core of Caribou's extensive CRISPR technology IP portfolio is an exclusive license to the foundational CRISPR-Cas9 work from the University of California and the University of Vienna. Caribou licenses this technology to strategic partners who are recognized leaders in our target market sectors' (Caribou Biosciences 2017).

Based on my dissertation research, I suggest we need to foster a political ecology of seeds comprised of overlapping 'in situ centric' approaches that collapse these world-making discourses and the material inequities they perpetuate.

Just as enclosures are co-produced across many sites, scales, and institutions, it is possible to conceive of the converse: that reordering towards an in situ-centric flow of seed value can be conceived as co-produced processes of repossession. Instigating one process can propel or reinforce another, beginning to undo the existing 'lock-ins' of industrialized agri-food systems, and catalyzing in their stead a series of synergistic emancipatory effects.[76] *How* is the operative question, of course, pressing us beyond abstract un-enclosures and into the realm of concrete peoples, neighborhoods, landscapes, and seeds.

The good news is that we don't have to start from scratch. Around the world, multiple experiments with repossession dot the map of an emancipatory rural politics (Scoones et al. 2017). Environmental justice struggles have brought communities of color, feminists, and climate activists to develop a suite of repossessive concepts and strategies: climate reparations, ecological debt, and body burdens, among others (Brown, Morello-Frosch, and Zavestoski 2012; Aygeman et al. 2016; Klein 2014). The importance of local control animates many initiatives, including food justice, community food security, and much (though not all) of organic farming (Gottlieb and Joshi 2010; Obach 2015). System-wide, ecological economics has spurred de-growth theory and alternative metrics for human development (Daly 2011; Costanza 2017), with Transition Towns and 'eco-villages' experimenting in their practical deployment. Solidarity economies are regenerating labor and livelihoods through cooperative production, shared and repaired consumer goods, and minimalist approaches to possession (Schor 2010; Utting 2015; Ciccariello-Maher 2016). Maker movements, time banking, seed libraries, and 'food commons' are reclaiming resource access – to credit, tools, land, water, and seed – while open source biology and open source data promise repossession of information and genes (Benkler 2006; Kloppenburg 2010; Schapiro 2017). Reminding us that such visions are hardly new, indigenous articulations of *sumaq causay* (or *Buen Vivir*) have begun to revitalize a political creed of 'good life,' in explicit contrast to capital's mandate of gain, property, and growth in itself (Gudynas 2011).

With these numerous experiments underway in terms of making emancipatory alternatives – around long-term and short-term challenges, around environment, agriculture, and urban/rural visions – I agree with Scoones et al. (2017) that such movements will be more profound and long-lasting the better they are understood and *connected together*. These authors suggest: 'In exploring resistance and the promotion of alternatives, we must not assume emancipation, but interrogate its construction' (2017, 10). To this end, in the next section I briefly explore how three major social movements might collectively generate greater momentum for in-situ centric flows of seed. The commons, agroecology, and food sovereignty, I suggest, already exist as viable movements for repossessing seed, knowledge, and farming practice. With more concerted alignment and collaboration among their constituencies, they will be better equipped to navigate

[76] This raises the legitimate question: do we want agroecological regimes to be 'locked-in'? Should we construct policies, institutions, and market structures that prevent too easily transitioning *out* of the regime we want? Possibly, yes. On the other hand, 'lock-ins' may be antithetical to ecosystem approaches to the food system, including the experimentation, adaptation, social learning, and coevolutionary dynamics that underpin it.

(and even create) what Marx called the 'epoch of social revolution', or the disruption of social relations central to confronting capitalism (Marx 1968 [1859], 161–62). To conclude my thesis, I suggest how utopian story-telling can elevate this emancipatory potential beyond class-based alliances to the wider – more colorful – politics of recognition, representation, and redistribution.

Agroecology, Food Sovereignty, and Commons: a triad for renewing and redistributing seeds

Agroecology offers principles and practices for the design and management of sustainable food systems (Altieri 1995; Francis et al. 2003; Gliessman 2015;) As a science, it understands farms as productive ecosystems, emerging from a confluence of indigenous knowledge and Western science (Bunch 1982; Vandermeer and Perfecto 2013). As a set of productive practices, it encourages local experimentation and knowledge-exchange towards developing agronomic techniques that are adaptable and resilient (Holt-Giménez 2006; McCune et al. 2011; Montenegro de Wit 2014). And as a movement, it emerges through wider social processes of people becoming involved in organizing their food systems (Altieri and Toledo 2011; Rosset et al. 2011; Brescia 2017; Yoon 2017).

Agroecology's most extensive literature rests within the natural sciences, where, reflecting its origins as a cross-pollination of ecology and agronomy, it seeks to enhance the biotic and abiotic relationships within and around a productive farm.[77] Though some trends in agroecology focus primarily on natural science – landscape ecology and biodiversity-ecosystem service management – for many researchers and practitioners, agroecology is an explicitly political project (Ferguson and Morales 2010; Mendez et al. 2013; Rosset and Altieri 2017). Going back to Russian scientist Basil Bensin in the 1930s, agroecologists have long recognized that helping farmers make decisions more appropriate to local conditions can greatly diminish their need to purchase commodity inputs – and thus to support corporate agriculture (Gliessman 1998). More recently, the socioeconomic dimensions of agroecology have themselves become an active space of scientific inquiry. New research explores contributive justice and 'meaningful labor' (Timmerman and Felix 2015); the political ecology of agroecology education (Meek 2015; Meek and Tarlau 2016); intersectional and decolonizing methods of praxis (Snipstal 2017; White 2017); and the political dimensions of 'scaling' agroecology through bridging practice, policy, and movements (McCune et al. 2017, Brescia 2017).

Despite this broadly articulated vision, however, agroecology has had curiously little to say about property rights, material or intellectual. Nor has it, with important exceptions,[78] given much attention to governance – the types of institutions, rights, and sovereignty that will realize an agroecological food system. Food sovereignty's alignment with agroecology has partly addressed these deficits. While we can find scattered references to 'soberanía alimentaria' in Latin America dating back to the 1980s in response to Northern crop dumping (Edelman et al. 2014), La Vía Campesina is largely credited with advancing food sovereignty beginning in the

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[77] Key principles include enhancing soil fertility, recycling biomass and nutrients, optimizing the use of energy, water, and genetic resources, and perhaps most importantly, increasing the beneficial interactions of organisms within and with their environments (Altieri 1995).
[78] For example, Holt-Gimenéz 2006; De Schutter 2011; Angeon et al. 2014.

mid-1990s.[79] As GATT (later, the WTO) made moves to include agriculture in free trade, food sovereignty was seeded not as an academic theory, but by those whose 'lives and livelihoods are on the frontlines of the battle for control over the land, resources and seeds necessary for food production' (Wittman et al. 2010, 11). Importantly, it was also an explicit rejection of the 'food security' framing promoted by the FAO, the CGIAR, agribusiness, and other members of the global political elite. It comes as little surprise, Fairbairn contends, that these actors would champion food security, for 'in their efforts to reduce hunger, they fail to question the political and economic structures within which they rose to power' (2010, 27).

Over the past 20 years, food sovereignty has gained prominence as a radical proposal for democratization and decentralization of the food system (Patel 2009; Wittman et al. 2010; Chappell 2018). At the VII International Conference of La Vía Campesina in July 2017, attendees representing more than 200 million peasants expressed sovereignty in two new platforms: 'peasant rights' and 'territory rights' encompassing land, water, seed, forests, oceans, and climate (See Figure 18). These calls reflect, for example, that 'We cannot claim only access to *arable* land when mother earth is threatened as a whole by large extractive projects that endanger entire ecosystems' (Moreno 2017, emphasis added). They also inform trends towards thinking about multiple sovereignties, i.e. those grounded in historical, relational, and interactive perspectives (Iles and Montenegro de Wit 2015; Schiavoni 2017), where social movements and the State interact to co-create sovereignty, where historical context matters, and where spaces of sovereignty are neither fixed nor absolute. Relational sovereignties recognize that space itself is socially produced, such that 'local' (even 'territorial') sovereign domains are constituted, in part, through translocal social ties and ecological relations.

Nonetheless, the very nature of sovereignty lends itself to approaches that are sometimes more about delineating rights than about building the communal relationships that secure these rights. Some have called for constitutional and legal changes to affirm top-down sovereignty in state institutions (Claeys 2014; Hospes 2014). Others have considered sovereignty as rooted in local governance – such as food policy councils – which could nurture local food economies (Andree et al. 2014; Trauger 2015). Agrarian movements, meanwhile, continue to emphasize rights to land for smallholders; alternatives to liberalized trade; and rights of peoples to define their own food and agriculture (LVC 1996; Nyéléni 2007; Rosset et al. 2011; Williams and Holt-Giménez 2017).

While many of these visions overlap, they raise difficult questions about contested sovereignties, especially at a time of heightened statelessness, migrancy, and mobility, when potential for local, state, and transnational sovereignties to clash has never been greater. For a paradigm based fundamentally on 'a right to have rights' (Patel 2009), it is not always clear who will be the guarantor of sovereignty. Moreover, food sovereignty – in displacing the sovereign State – is often silent on who or what can exercise sovereignty.

[79] According to Chukki Nanjundaswamy, current leader of the Indian peasant movement *Karnataka Rajya Raitha Sangha* or KRRS, it was her father that originally used the phrase 'food sovereignty' within La Vía Campesina debates leading up to the 1996 declaration (Meek, pers. comm.)

In what follows, I explore how commons can complement agroecology and food sovereignty, and vice-versa. Throughout, I emphasize how commoners are devising – and legitimating – the social protocols and communal structures that will help strengthen agroecology and guarantee sovereign rights.

Institutionally, the commons provides a pragmatic alternative to private land rights and intellectual property: two principal terrains of contestation for agroecology and food sovereignty. Understood as resources to which a community has shared access and use rights, a commons is adjudicated by community rules and customs. Such models are hardly new, and have been described in detail by political ecologists, conservationists, and peasant studies scholars for at least four decades (Robbins 2011; Hall, Li, and Hirsch 2011), as well as by indigenous and peasant communities going back further still.

Figure 18. Basque Women Welcome La Vía Campesina to their Territory. In 2017, the VII International Conference of La Vía Campesina convened in Derio, a small town in the Basque Country of Spain. The significance of this place was not lost on participants. The Basque peasantry have been in a longstanding struggle for autonomy against state-sponsored repression, agro-industrialization, and fascism. Convening in halls once used by General Franco as a seminary, peasants from around the world discussed how to confront deepening crises of capitalism – land grabbing, climate change, indebtedness, and human migration – alongside resurgences of racism and xenophobia under right-wing authoritarian regimes (Tramel 2017). (Image credit: Umut Vedat, La Vía Campesina).

In places like the Yurok forest (see Huntsinger and McCaffrey 1995), cultural norms, taboos and limited natural resources have converged to form a complicated system of usufructory rights; in these instances, community members with an intimate knowledge of their system have proven more agile than the State in delegating and putting practices into place. Reinvigorating such complex, socially negotiated rights – whether usufruct or otherwise – into land, water, and seeds would be a profoundly important first step in repossessing corporate-controlled food systems. Insofar as private property remains the cornerstone of capital, commoning begins to pull out a foundational 'brick' – replacing it with use, sharing, and access arrangements that agroecology and food sovereignty frequently invoke but haven't summoned the property 'solution' to deploy.

More specific to seeds, many prominent food and seed sovereignty advocates, including LVC, GRAIN, Navdanya, Redes Semillas, and the African Centre for Biodiversity, use terms such as 'common genetic heritage' or 'common genetic patrimony' to argue for equal rights to seed. These concepts, however, remain open to manipulation by leaving ambiguous the nature of the commons in question, as we saw in my 'Beating the Bounds' chapter. Common heritage is frequently confused or conflated with 'open access' or 'public domain' rather than the governed commons Ostrom proposed (Ostrom 1990; Aoki 2008). A governed commons or '*protected* commons' – in the vernacular of the Open Source Seed Initiative – arises through social negotiations among people with one another, and in the biological coevolution of humans with their seeds. It emerges through 'beating the bounds' to defend commons from powerful actors who would otherwise enclose them: Commoners must redefine rules of inclusion/exclusion on an ongoing basis, reshape social protocols according to communal needs and motivations, and develop appropriate sanctions for users who exploit the commons rather than renew them. Commons also coalesce through struggle within and beyond commoned spaces – the ways in which science, traditional knowledge, discourses, and property rights are 'contested, fought over, and negotiated' (Watts 2000).

To a large extent, agroecology and food sovereignty already 'get' this. Struggling over territory, defending political rights, and contesting expropriated wealth are the bread and butter of both food sovereignty (eg. Shattuck et al. 2015; Trauger 2017) and social movement articulations of agroecology (eg. Wittman 2009; Muñoz 2016; Brescia 2017). Commoning, I suggest, can learn from these grassroots expressions of territory and knowledge rights, while in turn strengthening sovereignty's call for radical equity in tractable protocols for the social management of shared resources.

Ecologically, commoning, agroecology, and food sovereignty complement each other in several ways. First is a shared emphasis on complexity. Commoning, agroecology, and food sovereignty reject the simplicity and reductionism of industrial food systems with their embrace of holistic and ecosystem-based theories of interaction, stability, and change. Self-organization and emergent properties –a 'more than the sum of its parts' reality– are described in both agroecology and commons literatures (Ostrom 1990; Bollier 2014; IPES-Food 2016; Perfecto et al. 2009)[80]. In agroecology, to understand an agroecosystem is to pay attention not only to the

[80] Within the commons literature in the Ostrom lineage, self-organization and emergent properties are strongly affiliated with socioecological resilience theory (eg. Berkes, Colding, and Folke 2003). Among other things, this field draws on complex systems theory to '[investigate] how human societies deal with change in linked social-ecological systems, and build capacity to adapt to change.' Within agroecology, invocations of nonlinearity and

components, but to the interactions between organisms within and with their environments. Does manure cycle back into the soil, where it replenishes soil fertility? Or is it washed into rivers, becoming a pollutant and demanding fertilizer inputs? Are seeds the product of farmer-breeder regeneration, or have they been developed by experts in off-site centralized locales? Similarly, self-organized commons have been documented in a wide array of cases, from foresters in Nepal to fishers in Maine. Belying analysts who argued market privatization or state regulation was necessary for overseeing resources, commoning has arisen whenever a given community decides it wishes to manage a resource in a collective manner, often with special regard for equitable access, use and sustainability.

Second is an emphasis on regeneration and renewal. Unlike classical agrarian reform, agroecology makes a specific pledge to restore the metabolic relation between communities and nature (Wittman 2009). Food sovereignty movements propose to 'exploit neither land nor people' in opposition to monoculture which exploits 'both land and people' (LVC 2017). Thus, to practice agroecology *as* food sovereignty is to take a stance against all forms of exploitation – of soils, bodies, water, ecosystems, and climate. Commoning similarly presumes renewability of shared resources as a matter of principle. Third and relatedly is affirming justice as part of a social-ecological metabolism (Allen and Sachs 1991).

Within these ecological kinships, there remains room for mutual improvement. For example, while commons principles tout resource renewal, they frequently lack specific environmental management practices, let alone theories to explain how ecosystem services are regenerated in time and space (Vandermeer 2011; Kremen and Miles 2012). On the social side, commoning affirms justice, but has not grappled deeply with structural racism, patriarchy, and nationalism, despite their evident entanglements with class power in seeding and accelerating enclosure. Agroecology and food sovereignty could therefore strengthen the ecological science basis of renewing a commons resource. They could also complement commons' non-hierarchical idylls with sharper analyses of resource-sharing through the emancipatory lenses of 'People's Agroecologies.' The ideological '*formación*' increasingly spoken of by black, brown, indigenous, immigrant, and women agroecologists have justice lessons for all here: They clarify that formación is about not just about the self-transformation of the individual, but about the ability to convene a diversity of expertises within a common movement. As Ana Elisa Pérez of La Finca Consciencia de Puerto Rico, de Boricua puts it, 'While agroecology produces diversity, biodiversity; we should also cultivate a diversity of perspectives, people, and genders in order for it [agroecology] to be successful as a movement' (Snipstal 2017). These intersectional alliances, one Canadian farmer at the LVC Women's assembly explained, is fundamentally a non-

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emergent properties draw directly upon understandings, emergent since the 1920s, of complex systems dynamics associated with predator and prey networks – including oscillations that are to be expected and generally observed in nature (Vandermeer and Perfecto 2013). The 'chaos revolution' (Hastings et al. 1993) has also greatly informed modern ecology, and with it, agroecology. Emphasizing inherent unpredictability, chaos theory posits that we might start with two different almost identical starting conditions - say, two apple orchards almost, but not quite free of apple maggots - and the information will be completely unrelated to later conditions (how many pests those apples have three years on). As Vandermeer and Perfecto put it '…this knowledge should invoke a bit of humility into any research program that seeks precise prediction of almost anything about an agroecosystem.'

exploitive engagement with ecosystems and people: a way to avoid the tendency to reproduce power over and instead embrace the concept of power *with* (LVC 2017b).[81]

Discursively, commons is a touchstone for revealing the historical anomaly of enclosed life. Among the most insidious aspects of the 'Capitalocene' (c.f. Moore 2017) is the degree to which the language and workings of capital remains relatively anonymous in popular understanding. Agroecology, food sovereignty, and commoning movements have a role to play in making terms like 'enclosure' familiar – and in so doing, to make them strange. They can remind us that it was never enough for primitive accumulation to be hatched in the minds of elite intellectuals, nor even to be embraced by political leaders from Walpole to Trump. Constructing common sense around the normalcy of dispossession has required numerous and diverse channels across the ages: monarchs, churches, universities, professional associations, think tanks, philanthropies, NGOs, and mass media, among others. Especially since the 1970s, marketing and advertising campaigns have saturated people in hyper-consumption – from fast food to fast fashion –and the taken-for-granted truth that competition is the defining characteristic of human relations. Young learners come up through school systems that do little to disrupt this commodity fetish, or to disturb an ideological posture other than one in which dispossession is cast as a normative good: 'fiscal responsibility, 'debt management,' etc. Enclosures, then, have become not only about taking resources away from people, but about creating capitalist identities – 'the first step towards attempting to define new subjects normalized to the capitalist market' (De Angelis 2000, 25). If capitalist subjects increasingly do the work of dispossessing themselves, a philosophy of praxis would begin here – where agroecologists, food sovereignty movements, and commoners construct a shared analysis and practice of repossession.

Systemically, commoning provides a roadmap toward a larger food commons. Agroecology is by definition agricultural and is currently strongest where it addresses farm-level production. Commoning, by contrast, spans agrarian and non-agrarian pursuits, including food production/consumption, materials manufacturing, social services, science & technology, and policy/governance. It is possible, then, that commoning helps agroecology 'scale' from the farm system to the food system – a move agroecology declares in theory (Francis et al. 2003) but has not yet realized or formulated in practice.

On the input side, commons could be developed for land, water, seed, technical training and education, farming equipment, and credit. On the output side, commons could support value-added production, transportation, marketing, distribution, and retail. Food sovereignty clearly affirms such systemic application, as seen, for example, in Venezuela's nearly 1,500 'comuneros' that organize direct democratic self-government and social production enterprises (Ciccariello-Maher 2016). So too does the European commoning movement, as seen in recent meetings to discuss how people might benefit from multiple types of commons, in so-called

[81] The Vth Women's Assembly of La Vía Campesina hosted an historically unprecedented discussion of what feminism means in the context of peasant struggle. Emerging from this assembly, the 2017 Euskal Herria Declaration promotes a move beyond gender parity and towards radical equity. Understanding the role of violence and power in the movement's struggles is key, as explained by a farmer from Canada at the Women's Assembly: 'In a patriarchal system, power means power over. Women don't want that – they are afraid of it, and for good reasons. When we as women speak of power, we mean power with, so we see struggles not as violence but as a way to reconstruct the map together. We have to advance power with, and our struggle needs to be for the living, beautiful, just, and solidary world. That is a huge political project, but it is doable' (LVC 2017b).

‘commons guilds’ or ‘a common of commons.’ Towards revitalizing agrarian livelihoods in country and city, we might envision such guilds as including ‘science commons’ for research and publishing; ‘material commons’ for access to tools, vehicles, and food/clothing/fuel markets; ‘digital commons’ for internet and media; and ‘service commons’ for cooperative housing, affordable healthcare, and childcare. These possibilities underline, as farmer-scholar Caitlin Hachmyer (2017) recently put it, that land commons are not enough: ‘We may be able to put land into a trust, but we still have to have *the conditions that enable farmers to work it*: public services, childcare, and housing – all the incentives for farmers to stay in agriculture.’ Along these lines, early work is being done to establish the theoretical and practical grounds of food commons (see Vivero-Pol 2017; Cochran and Yee 2011).

Political-economically, the more radical invocations of agroecology and food sovereignty tend to converge on this: an argument that agri-food transformation hinges upon an upending of the dominant political economy, capitalism itself (Shattuck et al. 2015; Rosset and Altieri 2017). Reporting back from the Youth retreat of the National Farmers’ Union of Canada, Ayla Fenton (2017) wrote:

> We also discussed the idea that a productive critique of capitalism is essential to the struggle for food sovereignty and agroecology. The pillars of the capitalist food system – concentration of market power, vertical integration, exploitation of labour, and increasing corporate control of the resources required for food production – are completely at odds with the pillars of food sovereignty. The farm income crisis, food insecurity, diet-related disease epidemics, and the externalization of environmental destruction are all just symptoms of a deeper root problem.

For the most part, however, social movements lack a coherent proposal for what comes in capitalism’s stead. Neither agroecology nor food sovereignty are in themselves economic systems, though they comprise important components. Commons contributes a stronger structural alternative, with principles and practices for re-organizing social and economic life. As depicted above, the material aspects – associated with the production, use, and management of resources – come through a redistributive system of treating all resources as shared in common, sans private property, and without competition as a disciplining force. Ethically, the moral economic frameworks of Thompson (1971) and Scott (1977) come closest to expressing the commitments underlying a commons economy, wherein logics of accumulation are subordinated to communal norms of economic activity. Organizationally, commoning favors de-centralized strategies of decision-making, supporting redistribution of wealth, authority, and power.

At this point, the critical reader will likely be thinking: these are very nice, these alternative moral-economic proposals. It’s a good idea to dissolve private property, to emphasize ecology, to create discourses that make enclosures strange. But really, how much impact can small, decentralized experiments have? When the foes are Monsanto-Bayer, Syngenta-ChemChina, Dow-Dupont, et al., what are the prospects of winning intellectual property wars? When set against Washington and Wall Street, how realistic is the realization of a post-capitalist regime?

Such questions inevitable gravitate towards issues of scaling. In order to pose a tractable alternative to the status quo, something must be scaled out, across, or up. Transitions literatures (eg. the Dutch School of Transitions) put forward a highly technical template for how systemic change might occur. Ascending from niche level, through regime level, and ultimately to landscape level transformations, small innovations garner greater visibility, acceptance, and take-up within entrenched sociotechnical systems. But agroecologists, commoners, and food sovereignty proponents tend to be as wary of overly technocratic proposals as they are of blatant co-optations by industrial capital. While the latter move to make alternatives larger, faster, more efficient, and more competitive, the former tend to squash the organic vitality through which counter-hegemonic ideas are produced and held. Evidence is already near at hand: In the rush to scale, putative commons have already morphed into 'share economies' – Uber, Lyft, and Airbnb – that casualize labor and imperil unionized work (Brooks 2016; Schor 2017). Agroecologists likewise worry about the intrinsic risks of scaling: As the concept has become 'institutionalized' – widely recognized, used, and advocated by organizations such as FAO – a prominent concern is that agroecology is being co-opted, and that science itself is propertized *through* agroecology rather than in spite of it (Giraldo and Rosset 2017).

To focus on scaling (out, across, or up) is in a sense to play on capital's own turf. Thus, I agree with Bollier, who suggests, 'It is precisely the de-centralized, self-organized, and practice-based approach of the commons that makes it so hardy as a political strategy' (2014, 170). I see the promise/hope/value of commons, then, as more than a governance framework, a socio-ecological ethic, or even an alternative political-economy. It is the durability of common*ing* as a strategy for radical change. Understood less as 'transitions' guided from the top down by technocrats and elites than as relational, sometimes unruly decentralized experiments (Scoones et al. 2017), the approach suggests movement towards a 'pluriverse' social order (Escobar 2015). It hints at interconnected commons and sovereign territories rather than attempts to establish or oversee a universal 'sovereignty' or 'commons' or 'agroecology' archetype, which would never succeed agroecologically or politically.

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I began my dissertation by asking: How can seed diversity – and access to it – be expanded once more? What is seed diversity in the first place, and whose diversity matters? Which forms and relations of science, governance, and politics engender democratic access to seeds, and which forms preclude it? My short answer is that linking commoning, agroecology, and food sovereignty together can provide the in situ centric system needed to create the diversity reflective of multiple ecologies and cultures; to govern access to seed as a function of negotiated social protocols and human rights; and to give voice to communities now often excluded from the science, governance, and political management of their own means of production.

My longer answer is that this trifecta is still mostly aspirational and unconsolidated. Many commonalities – but also tensions – exist between the three. Social movements such as LVC insist that agroecology and food sovereignty are intimately bonded: 'Agroecology without food sovereignty runs the risk of being a purely technical solution... At the same time, food sovereignty without agroecology is an abstract framework that provides working people with little in terms of tangible strategies for developing alternatives' (LVC 2017a, 14). The commons are yet to figure into this two-pronged framework, partly due to a European center of origin and Western intellectual traditions, and partly due to unsettled articulations with indigeneity and indigenous peoples (as we saw in Chapter 5). Getting commons into agroecology and food sovereignty, and vice versa, will need to confront these geographical, cultural, and cosmovision issues. It will also need to contend with frictions where strongly territorial conceptions of sovereignty may run at odds with versions of commons that emphasize viral openness, fungibility, and radically limited restrictions on movement, re-mixing, and re-use. Tech-inspired commons – biohacking, open source biology, myriad digital P2P networks – will foreseeably encounter significant agrarian skepticism, just as traditional indigenous concerns about remixing 'their' seeds may find internal and external pressures to embrace more fluid *criollos* and *mestizajes*.

Equally important, agroecology, food sovereignty, and commons will need to contend with localisms that can feed reactionary politics and discriminatory sentiments. As seen in food sovereignty cases from Poland to Maine (De Master 2013; Anderson 2013), local movements can inadvertently – or, worse, purposefully – exacerbate racism, sexism, nativism, and other social inequalities. In contesting globalization, alternatives easily slip into sovereignties with underlying fascist stripes: erecting rigid boundaries around places, reviving strong nationalisms, and re-energizing latent xenophobic, cultural, and ethnic chauvinisms. Following Dupuis and Goodman (2005), Hinrichs (2000), and the critical scholars upon whom they build, I argue that the triad of agroecology, food sovereignty, and commons will need to aggressively fend against this possibility, in part vis à vis a reflexive localism. Less shackled to a politics of place (based on proximity and particularity) than attuned to a politics *in* place, social movements and scholars might apprehend places 'as the sites which juxtapose the varied politics—the local, national, and global—that we find today. What matters is this juxtaposition' (Amin 2002, 397).

Geographers including Brenner, Harvey, Watts, and Massey have challenged absolute conceptions of place as discrete bounded units. Rather than 'enclos[ing] peoples, resources or knowledges within a 'local domain' (Castree, 2004, 135), this scholarship suggests, we might consider 'place' as relational – constituted through both internal and outward-looking connectivities (Massey 1994).[82] Such relational understandings of place could help reconcile the strongly territorial affinities of sovereignty movements with commoners' penchant for open-source sharing. Understood less as absolute space and more in terms of relational interactions, a sovereign 'territory' becomes untenable as a projection of discrete identities or ideological purities. Instead it takes shape in and through commoning, food sovereignty, and agroecology, which by necessity bring in diverse organisms, practices, and knowledges to sustain a social-ecological metabolism. This diversity within and across places can then be celebrated through kaleidoscopic ways of knowing, believing, learning, breeding, and laboring in the world. In this, we come closer to affirming the equal rights and mutual obligations of all living things (Wittman 2009; Wittman et al. 2010).

[82] As indicated above (p.88), food sovereignty literature is slowly gravitating in this direction. Work by Schiavoni (2017), for example, situates sovereignty in social – not just spatial – relations.

Epilogue

Time for Utopian Storytelling – Because 'No' is Not Enough

'Poets and beggars, musicians and prophets, warriors and scoundrels, all creatures of that unbridled reality, we have had to ask but little of imagination. For our crucial problem has been a lack of conventional means to render our lives believable.' – Gabriel García Marquez, 1982

To end this thesis, I'd like to finish with a story. Or not *a* story in particular, but a story of stories – why the accounts we relate, who tells the stories (who does not), and which narratives are produced and propagated are so important to seeds, and to bringing about the larger structural changes needed for their repossession. As a biologist turned journalist, turned social scientist, I've discovered that whether in the lab or out in the world, the channels through which knowledge runs are often mediated by storytellers: be it the professional world of newspapers, magazines, and radio, or the increasingly 'unmediated' world of blogs, podcasts, Twitter, and Facebook in which elites and the 'everyman' quixotically converge. In story, there is not only great potential to consolidate 'common sense' and trap us within narrow frames of neoliberal consent. There is also an emancipatory potential – a means for critical re-evaluations of history, nature, and society, inspiring cogent visions of what might be.

I discovered in my first paper that stories of 'loss' can drive very divergent strategies of conservation, nominally ex situ and in situ, but also representing differing paradigms of industrial versus agroecological reproduction and control. I found in my second paper that storytelling can take us back in time: to early plant domestication and the allure of 'rewilding' crops with ancestral genes. Threaded with Malthusianism – we must feed nine billion on a smaller, hotter planet – these narratives helped obscure the drivers of agrobiodiversity loss while legitimating new enclosures of intellectual property, data, and seeds. In my third paper, stories helped freelance breeders express and circulate their knowledge. Revitalizing practices of farmer-breeding, they transmitted the how-to and why-to tales of commoning within the community and into wider social spaces.

We need stories because, as Gramsci suggests, hegemony is organized not only through relations of force, but also consent. Stories help structure our individual and collective thinking: they document events, transmit ideas, foment both 'wars of maneuver' and 'wars of position.' Stories construct and reconstruct histories, educate future generations, and constantly articulate the now.

Yet in so doing, stories have a double edge. As part of common sense, stories can maintain the contradictory form of consciousness that stabilizes a dominant social order. In agriculture, we're surrounded by common sensibilities: that globalized food is more efficient, that intensifying production spares the environment, that we must double global crop yields by 2050. By the same token, storytelling can make common sense critical, helping pierce the bubble of discourses people perceive to be real. Some of my favorite storytellers are incredible men and women – organic intellectuals all – who deeply understand this power. Naomi Klein, Amy Goodman, Juan

Gonzalez, Rebecca Solnit, George Monbiot, and Glenn Greenwald have taught me as much, if not more, than academic texts about the expansion of capitalism during times of war, natural disaster, and economic crises. Gabriel García Marquez, Bertolt Brecht, Pablo Neruda, Nadine Gordimer, Arundhati Roy, Edwidge Danticat, Toni Morrison, Isabel Allende, Jose Saramago, and Teju Cole, among others, have let the real and imaginary converge: opening my eyes to vicious dictators and romantic revolutionaries; bringing legacies of *desaparecidos*, Jim Crow, and apartheid into stark relief; and helping me imagine how children of these unbridled Imperial realities – 'poets and beggars, musicians and prophets, warriors and scoundrels' – make their hungry, violent, and gnarled lives liveable.

For Hannah Arendt, the idea of thinking and speaking as a form of action were important as a defense against totalitarianism. She understood, perhaps better than most, that you can toss around facts – you can blanket the news in fact-checking – and understanding will not stick. Weimer Germany was a stunning example of this phenomenon, as were the 2016 US elections. Trump catapulted to power not just in spite of, but also *because of* the liberal media. Around January 2017, CNN, NPR, the New York Times, and other mainstream outlets declaimed their New Years' resolutions: a resounding assault on 'fake news.' This year, journalism would fight authoritarianism with Truth-finding – 'we'll tell you the facts.' Of course, this response fed all too perfectly into a festering knowledge politics, casting the dominant elite as knowledgeable truth-holders: pitting educated (mostly coastal urban) liberals against backwards (largely Farm Belt and Rust Belt) conservatives. While elites outside of right-wing circles aggressively unified across ideological lines in opposition to both Brexit and Trump, supporters were continually maligned by dominant media narratives (validly or otherwise) as primitive, racist, xenophobic, and irrational. Yet, 'the indisputable fact,' notes Greenwald (2016):

> is that prevailing institutions of authority in the West, for decades, have relentlessly and with complete indifference stomped on the economic welfare and social security of hundreds of millions of people. While elite circles gorged themselves on globalism, free trade, Wall Street casino gambling, and endless wars (wars that enriched the perpetrators and sent the poorest and most marginalized to bear all their burdens), they completely ignored the victims of their gluttony, except when those victims piped up a bit too much — when they caused a ruckus — and were then scornfully condemned as troglodytes who were the deserved losers in the glorious, global game of meritocracy.

Arendt said what is needed instead of screaming facts at people until we are blue in the face is thinking through 'communal discourse.' To make truth meaningful in the world, she suggested, knowledge must be produced *between people*. Lyndsey Stonebridge is a professor of philosophy at the University of East Anglia. She indicates that Arendt's intervention in the current moment would be not saying we are just making up our own reality, either as fact, or its converse, 'fake news.' What is needed instead is testimony – telling the human experience around fact and knowledge. This is why, she indicates, history and sense of myth were so important to Arendt. These are what make truth meaningful to people in a community. If we want a culture that is armed against false news and political lies, she would argue, what we need most is a culture of arts and humanities. What we need is more storytelling. What we need is more critical discourse, more imagination. Storytelling is *social organization* in this sense: a way to assemble what is, what we believe, and what ties us through language to another (Tippett 2017).

Yet one of the sharpest paradoxes at a time of arch privatization is that many of our public platforms for telling stories have also become enclosed. Copyright over most published matter is commonplace, and the infrastructure of digital media is the battleground of telecom giant property wars. Journalism has had a long-shifting history in navigating for-profit models with ‘speaking truth to power’ – the paradoxes are nothing new. But post 2009 financial crisis and amidst competition from free online content providers, the media struggle is palpable. Advertorials are now tough to distinguish from reported stories, journalists attend corporate-funded conventions and training camps, and foundations are sponsoring everything from poverty blogs to ‘specialty’ food content. While small-town papers go belly-up, the remaining voices of authority – *The New York Times*, *The Guardian* – constantly straddle the unforgiving line between ‘Church’ (advertising/revenue) and ‘State’ (editorial). In this environment, conflicts of interest have become less about ‘pay for play’ than about corporate consolidation, and the institutional suturing of public to private interests. How do we tell adequate stories of injustice and neoliberal crises, when our vehicles for doing so are ever-more enclosed?

Part of the answer is continued support for a rich and variegated landscape of independent media. These include progressive outlets like the Nation, Mother Jones, and Democracy Now, as well as conservative outlets like the National Review and the American Conservative. Another solution lies in creating spaces for academics to dialogue more directly with people. The platform ‘The Conversation,’ launched in 2014 to be an ‘independent source of news and views from the academic and research community, delivered direct to the public’ is one example of new media that could foster greater communal discourse. Yet another avenue comes through building up participatory storytelling practices and forms. Recently published volumes such as *Fertile Ground* (Brescia 2017), *Against Colonization & Dispossession* (Kapoor 2017), and *Chasing the Harvest* (Thompson 2017) illustrate that peasants and farmworkers don’t just have a place in the news (although that too is welcome). They have a place in *making* the news. In case studies and oral histories, rural communities, researchers, and civil society groups have joined together in co-creating stories: ‘regenerating trees, landscapes, and livelihoods in rural Mali,’ ‘resisting dispossession and neoliberal disaster reconstruction’ in Tamil Naidu fisheries and organizing ‘recommoning in response to agribusiness dispossession in Kenya.’

For audiences of critical academics, the privations of capital expressed in these accounts will not be novel. Some of our journals exist primarily to chronicle the surfeit of dispossessions and repossessions that make capitalism tick. But making that claim and making that claim *felt* are two very different things. For all the empirical heft of peer-review journals and academic treatises, they often do not reach the masses whose ears should be all important, whose common senses have more political potential than traditional intellectuals can muster alone.

I am excited, then, when ‘mass media’ papers begin telling neoliberal stories – as the Guardian has done in the past 16 months with long features on the Mont Pelerin School, on Thatcherism, and on Elsevier’s monopoly control of science publishing. I am even more energized by participatory ways of making media together. The Delicious Revolution podcast, similarly to the texts mentioned above, experiments in new ways of co-producing knowledge in story form (See Figure 19).

In speaking with people whose expertise comes through working with food – farmers, fishers, artists, activists, scholars, and journalists – the podcast makers aim to ask what food means, how to change the food system, and how, then, to change society. To me, such storytelling inches closer to the organic intellectual activities Gramsci felt could sharpen common sense into coherent and powerful *buon senso* (good sense). They are closer to the *diálogo de saberes* (dialogue of knowledges) that inspire agroecology movements from Latin America to Asia. They come closer, I reckon, to recognizing that truth is forged in social relationships between people – a practice more emancipatory in premise and promise.

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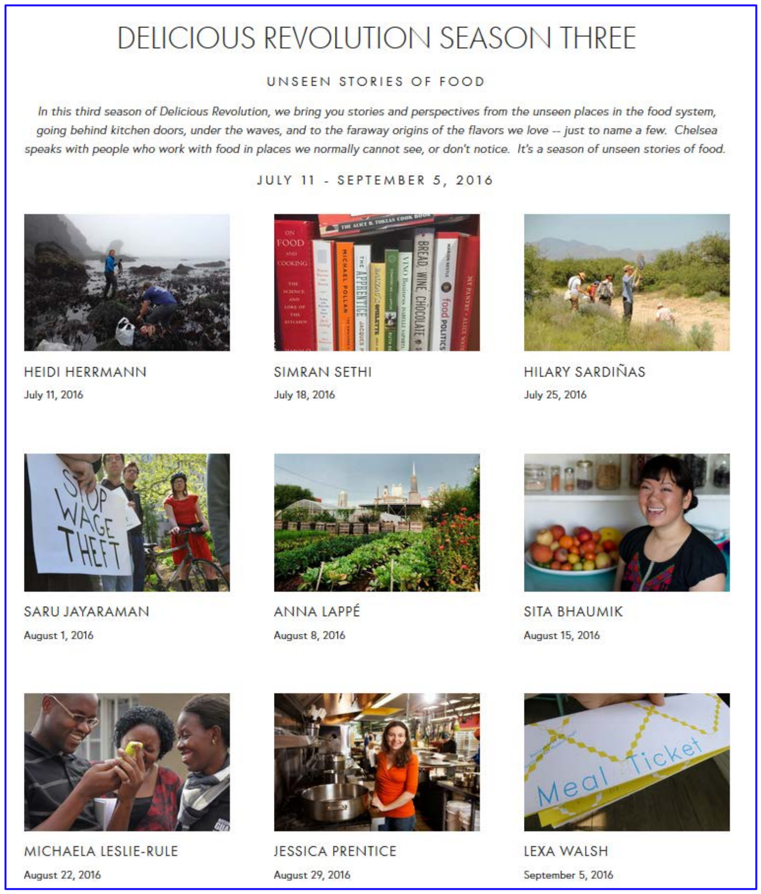

Figure 19. Delicious Revolution. At a time when farmers comprise less than 2% of the US population, the remaining 98% are often far removed from 'the agrarian experience.' Podcasts like Delicious Revolution are rekindling an old form – storytelling – to bring to life the complex, intersectional, and decolonizing trends inflecting US agrarianism today: via people whose expertise comes from working as farmers, fishers, artists, cooks, activists, scholars, and journalists.

With this in mind, can storytelling help us unwind the creation myths upon which neoliberalism – and capitalism more generally – rests and depends? Can storytelling help expand more room for agroecology, food sovereignty, and the commons? I think yes, but it will require careful opening of siloed scholarly and activist spaces, to be both more inclusive of myriad theories, and more receptive to various wielders of wisdom in vernacular and formal fora. For example, it appears undeniable that post-Brexit and intra-Trump, we are met with the predictable counter-movements to free market excess. But how to understand the current moment is far from linear or simple. Some storytellers, following in the Marxian tradition, have offered lucid parallel analyses of Brexit, Trump, and class warfare; rekindling agrarian questions, they've wondered about peasants as reactionary or revolutionary force at a time of neoliberal dysfunction. Others, inspired by Polanyi, have reminded us that society protects itself against the free market, but in so doing can give rise to fascist impulses – 'thus endanger[ing] society in yet another way.' Still others have focused attention to racism, xenophobia, and misogyny as latent forces in the American electorate propelling an authoritarian regime into power.

So did Trump win because of bigotry in America – end of discussion? Or because of the elitism of corporate Democrats – and white supremacy is just a sideshow? Following Fraser (2000; 2017), hooks (2013) and Crenshaw (1991),[83] I consider it vital in this climate that we tell stories that do at least two things: go beyond analyzing revolutionary moments as erupting only from shifts in class-based alliances; and go beyond just understanding struggles for *recognition* as simple 'identity politics.' The brilliance of Trump (if it can be so called) was in the ability to capitalize on neoliberal catastrophe, and therein to pit identity politics against class politics within a fractured Left. His showboating authoritarian populism unleashed a contempt for liberal elites alongside hatred towards vulnerable citizens of color – towards Muslims, immigrants, blacks, Mexicans, Jews, and women.

But while diverse strands of the Left have united to condemn such xenophobia, many see a return to progressive neoliberalism as a palatable (even desirable) solution in this climate of hatred and fear. 'Progressive neoliberalism' per Fraser, refers to a turn in the late 1990s in which liberals enthusiastically embraced 'diversity,' 'multiculturalism,' and 'inclusion,' while continuing to enact policies that increase inequality and produce racial polarization. In strokes that created an alliance between mainstream currents of social movements on one hand (feminism, civil rights, LGBTQ rights) and business sectors on the other (Silicon Valley, Hollywood, Wall Street), putatively liberatory forces were effectively joined with finance capital. Progress became based meritocracy instead of equality, and 'emancipation' was distorted as the rise of a few talented women, people of color, and gays in a cutthroat corporate hierarchy. Gone was the notion that we might abolish hierarchies altogether (Fraser 2017). Lost was the possibility of conversation about *all* inequalities – structural, cultural, epistemic, ecological – and the ways they are imbricated together.

Reclaiming emancipation, away from liberal-individualist understandings of 'progress' and towards an expansive egalitarian vision seems a necessary and urgent goal. The anti-hierarchical, anti-racist, class-sensitive, and feminist understandings of emancipation that flourished in the 1960s and 1970s are ripe for return. We can begin to write a richer story for food and farming that threads politics of recognition (race, gender, identity) into politics of redistribution (class, social difference, and inequality) and into politics of representation (democracy, community, belonging, and citizenship). Rather than see multiple 'identities' – gender, ethnicity, race, class, religion – as a cluster or amalgamation of IDs, we can probe their ideological and material construction, their emergence in systems, institutions, and structures that produce and entrench inequalities of all types.

[83] Fraser draws a stark difference between politics of representation and the better-known 'identity politics.' In a long essay for *New Left Review* in 2000, she explains that her notion of representation is based on status, rather than identity. Identity politics has a displacement problem (displaces attention from structural inequality) she argues, and a reifying problem, in that it reifies group differences, ironically inflaming separatism, conformism, and intolerance. By contrast, a status-based notion of recognition affirms race, gender, ethnicity without severing recognition from its institutional matrix, and without decoupling identity from political economy (Fraser 2000).

Such a foundation helps us respond to displays of white nationalism like those in Charlottesville, Virginia[84] with appropriate condemnation, yet without exaggerating the novelty of 'now'. It helps us see the punishing legacy of US colonialism, imperialism, and capitalism on African-Americans, Latin Americans, Native Americans, and countless other peoples for whom oppression 'ain't nothing new.' It helps us link arms against neo-Nazis while recognizing that as repugnant as they may be, such groups are not the ones now incarcerating one-third of black men under thirty; evicting poor families from gentrifying neighborhoods; exploiting (im)migrant farmworkers and foodworkers; or grabbing lands from indigenous peoples worldwide. The 'alt right' isn't to blame for launching trillion-dollar wars, for massively expanding covert military and civilian surveillance, or for seeding regime changes that fracture sovereign states, invite privatization, and often impel refugees towards countries where nationalism and xenophobia are newly powerful. Racism, sexism, and ethnic prejudices are vastly more widespread and endemic, arguably, in the everyday power apparatus that we generally equivocate to: as we invest in mutual funds, acquiesce to 'Big Food', and move around in ecosystems whose minerals, oils, and genes are continuously mined by industry without recompense. We accede quietly wherever we fail to see that seed companies now 'too big to fail' are but the expected upshot of the rankest inequality: in which banks, multinationals, and the billionaire class allow just 8 people (mostly white, all men) to hold more than half of the planet's wealth (Oxfam 2017).[85]

The hegemonic sources of our unjust global order are not hard to find. So, yes, we can fight authoritarian populism without blaming white working class and rural folks from Appalachia to Detroit who are also victims of dispossession. We can talk about structural racism, colonial habits of thought, and elitist disdain for the uneducated, the poor. To explode neoliberal common sense, we can insist that Utopian ideas occupy space in the storytelling of now.

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'Our thesis is that the idea of a self-adjusting market implied a stark utopia…' – Karl Polanyi, 1944

We are grounded in the belief that 'Another world is not only possible, she is on her way.' – Arundhati Roy

When we cast our minds back to the 2008 financial crisis and the first waves of emancipatory resistance, such as Occupy Wall Street, M16, and allied movements in Europe, it was possible to think the spell of neoliberalism was breaking. People were garnering the courage for the first time in a generation to say, 'We do not want this model.' Yet somehow, Naomi Klein (2017, 209) observes, they somehow lacked the courage to say '*This* is what we want instead. *This* is the

[84] On Saturday, August 12, at a 'Unite the Right' rally in Charlottesville, Virginia a car plowed into a group of counter-protesters, killing Heather Heyer, age 32. With neo-fascist, white supremacist, and other factions of the 'alt-right' blaming counter-protesters and the police for violence that erupted, the White House responded by tepidly condemning the 'egregious displays of hatred, bigotry and violence on many sides.' In the days and weeks that followed, the national conversation pulsed around the rights of extremists who seemed newly energized, and the scope, meaning, and perils of 'free speech.'

[85] Oxfam's 'An Economy for the 99 percent' report (2017) finds that eight men own the same wealth as the 3.6 billion people who make up the poorest half of the global population. This figure was based on better data on the distribution of global wealth, particularly in India in China. Previous reports had shown that 62 billionaires owned the same wealth as half of the planet. With the exception of Carlos Slim (the Mexican owner of Grupo Carso, with an estimated net worth of 50 USD billion) all of the top eight are white men.

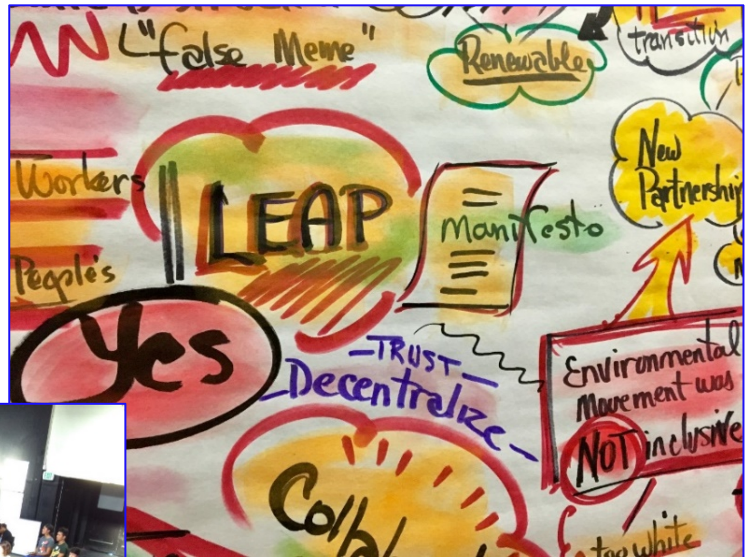
economy we believe is workable.' They did not argue that we have abundant resources in this time of unprecedented private wealth to provide the basics to everyone – quality healthcare, quality education, housing for all. They did not proactively state that war is making us less safe, and that we want to be a society that welcomes refugees, or that we want a 100% renewable energy economy with reparations for the historically exploited. People, Klein suggests, were not quite there yet, as if stumbling in a hangover of neoliberalism.

She believes we are ever closer now, and I cautiously agree. Commoning, if not always explicitly invoked, has made a difference. The past year since Trump's election have seen social mobilization in the US unlike the country has seen since Vietnam. Black Lives Matter has organized an anti-oppression platform that is uncomfortable to many White ears: that slavery, Jim Crow, and mass incarceration cannot remain silent terms in a world that speaks so casually of justice and equality. '*Black Lives Matter*.' In Europe, a group called DIEM25 is taking the lessons of Greece to counter brutal austerity politics with a manifesto and policy plans for rebuilding a social-democratic Europe. DIEM rejects the misanthropy, xenophobia, and toxic nationalism wrought by decades of Utopian markets and asks for deliberate action on the part of multiple extant progressive movements – because 'only one prospect truly terrifies the Powers of Europe: Democracy!' In Canada and the US, the Leap Manifesto is a similar example of movements coming together. Endorsed by 220 organizations – from small grassroots groups to the largest trade union in Canada – Leap loudly pronounces, Yes, another way is possible. What is a progressive trade policy, it asks? How do we put indigenous rights and racial justice at the center of an energy and economic transition? How do we connect human migrations to correctives for climate change, war, and unjust finance? Leap is not a perfect document, Klein (2017, 254) indicates, but it stands antithetical to neoliberal common sense, as a 'reawakening of the utopian imagination' (See Figure 20).

Utopianism applies equally to perceptions of commons, agroecology, and food sovereignty. They sound to many, many people like something naïve. Romantic. Impossible. But we can peel away this common sense. Making stories can help reveal that agroecology and food sovereignty is already underway – though not without struggles – in many parts of the world. We can be reminded that commoning has a long legacy in human cultures, organized by numerous indigenous societies and the civilizations of Rome, Greece, and the Inca whose descendants are my Peruvian kin. We can be kept from fetishizing any of these as idyllic – recognizing, for example, that Incan agrarian communism was at once patriarchal *and* more redistributive than the modern US state.[86]

[86] In *Country and the City*, Raymond Williams reminds us that people in every historical era have tended to romanticize a 'before', suggesting that the idyll is an always-receding horizon, and never in fact real. Rather than imagining a fictional 'space (or time) apart' from social and ecological changes we don't like – as seen in many back-to-the-land utopian movements of the 1960s – we could envision commoning as a struggle against the political economy processes traversing urban and rural spaces, past and present. Historically material, without being deterministic, this view allows scholars and social movements to see themselves as making history in the present moment – continually (if nonlinearly) producing a better tomorrow, in the here and now.

Figure 20. **'No is Not Enough.'** Initiated in the Spring of 2015, the 'Leap Manifesto' is a plan for moving Canada to a clean energy economy in a way that addresses systemic racism and economic inequality. Spearheaded in part by public intellectual Naomi Klein, Leap is formed by an ensemble of Canada's Indigenous rights, social and food justice, environmental, faith-based, and labor movements.



Inspired by the exigencies of neoliberal crisis — and the mantra 'No is Not Enough' – they have come together 'to dream together about the country we actually want and how to get there.' The Manifesto, now available in twelve languages, charts a systemic revolution, including energy democracy, ecologically based food systems, and rights to a universal basic healthcare, childcare, and income (Leap Manifesto 2017).

Telling – and enacting – stories can help divulge the oddity and relative novelty of capitalism itself. It can help cityfolk learn, for instance, that the metabolic rift is not normal or 'natural': animals needn't be raised separately from crops, nor food separately from humans (indeed, many peasants would never dream of such a thing). Similarly, stories can bring to life processes of primitive accumulation that have patterned the transition from feudalism to capitalism, lurching toward the world we have today: water bottles instead of public drinking fountains, giant seed oligopolies instead of seed-saving farmers, copyrighted songs instead of free books. Stories can narrate big arc trends like food regimes and little arc trends like freelance breeders. They can link different realms of capitalism together, bringing experiences of labor movements (focused on wages and the economic depredations of capital) with social movements (focused on primitive accumulation and extra-economic enclosures). Above all, they can help to shake up common sensibilities not by blaring facts at people, but by creating communal discourse, revealing that what is utopian is not really commons at all, but the notion that capitalism can really be sustained.

The case of seeds suggests we have a tough project ahead. Commoning requires ongoing work to define, negotiate, and assert socially agreed upon boundaries. Food sovereignty has many potential synergies, but also many friction points with commons. Agroecology begs questions about diversity – how much difference a commons needs versus how much difference it can contain. But I am committed to this work because, seeds affirm life. Wendell Berry, the poet and ecologist, has put it this way: 'Only the purpose of a coherent community, fully alive both in the world and in the minds of its members, can carry us beyond fragmentation, contradiction, and negativity, teaching us to preserve, not in opposition but in affirmation and affection, all things needful to make us glad to live.' ∞

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APPENDIX 1. Methods: Planting a Seed in 'Restructuring'

My mixed methods approach in studying seeds is inspired by the continuing attempt by social scientists to reconcile a number of long-running frictions and tensions in agri-food studies: Debates over structure versus agency, universalizing tendencies versus heterogeneity, the contested meanings and effects of economic globalization. At the turn of the 21st century, a boom in agri-food scholarship sought to make sense of these questions as part of 'restructuring' – changes to systems of production and consumption amidst geopolitical, institutional, and political economy transitions characteristic of the post-Bretton Woods regime.

How could agri-food restructuring be understood and explained? Globalists' stories of the 'world car' and the 'world steer,' suggested that restructuring would forge a homogeneous system of centralized global intra-firm divisions of labor, where global outsourcing of components streamed into specialized sites for final assembly (Bonnano 1994). Post-Fordist stories, meanwhile, posited a relative conformity to processes of industry, albeit with 'just-in-time' inventory management and 'flexible specialization' to reduce inventory costs, foster growth via subcontracting, and therein better exploit labor time (Grossman 1998; Boyd and Watts 1997). Across both genres, restructuring came to be associated with a relative retraction of state power and the ascendant regulatory control of free trade regimes, transnational corporations, and international finance (Friedmann 1993)– 'food from somewhere' seemed to transform into 'food from nowhere' (McMichael 2009). But scholars including Goodman and Watts (1997) pushed firmly back against these renderings, arguing that 'globalization' must move beyond totalizing, deterministic conceptualizations of agri-food restructuring. As evidence, they pointed to heterogeneous food supply chains that did not conform to a 'world factory'; constitutively uneven emergences of high-value agriculture in developing countries; and multiple trajectories of 'agrarian internationalization' (including sub-contracting) in which the state continues to play a central role. [87] Challenging the homogenizing, a-historical, and de-territorializing dynamics often affixed to the concept of globalization, they call instead for polyvalent, contingent, and rooted accounts.

The 'restructuring' debates also provoked important questions about the methods and scales of analysis that can be adopted to analyze food systems in the context of predictable contradictions of capital yet mediated by locally inherited structures, histories, and institutions. Writing in 1991, Bill Friedland made a remark that has stuck with me: theorists who employ micro-analytic approaches (eg. ethnography) have tended to emphasize 'the continuing persistence, adaptability, and flexibility' of smallholder systems, while those who employ macro-analytic approaches have tended to see their continuing differentiation and eventual demise (Friedland 1991, 18). For example, did observational scale, I wondered, come to produce different accounts of peasant – and thus seed – persistence?

In my dissertation, I take a methodological approach modeled on Goodman and Watts' focus on connecting complex global structures with their contingent and territorial manifestations. Across

[87] Although some scholars have suggested that transnational corporations employ contract farming to increase flexibility, Grossman argues that many contract schemes have considerable state involvement (this is certainly the case in East Caribbean bananas). Where vertical dis-integration has been found, it is often in response to political pressures or fear of land expropriation – not as a means of increasing flexibility, per se.

my three papers (‘cases’), I attempt to move between larger institutional systems and their localized developments. I consider how activities across levels are coproduced, shaping one another through complex and interconnected processes across scales. While recognizing the value of world-scale analyses (like food regimes) for linking global relations of food production and consumption to periods of capital accumulation, my engagement with seeds is motivated by processes that must be taken ‘down to earth’ (c.f. Rocheleau 2011) and rooted in farmers’, scientists’, and social movements’ practices at local and community scales. This approach is also congruent with studying patterns of homogenization and diversification in seeds: How do we study seed ‘loss’ not simply as the stageist progression of modernity (on one hand) or the homogenizing tendencies of globalization (on the other), but instead as spatially and temporally uneven losses and persistences? Can we confront questions of access not just through the lens of structural (‘big’) forces driving accumulation by dispossession, but also via the particular (‘small’) struggles, where endogenous frictions from people and nature create complex patterns of dispossession and repossession?

With this in mind, my three cases utilize a mixed methods approach, incorporating a variety of scales, texts, and subjects for inquiry and observation. These studies only begin to sketch the political ecology of seeds envisioned in Chapter 1 – from a broad mosaic, they represent a few peculiar and colorful tessellations. The methods are matched to the relevant scales and actors. My first paper (Are We Losing Diversity?) is a historical survey of agrobiodiversity narratives in international science and policy, contrasting global portrayals with local names, meanings, and measures. My second paper (Stealing Into the Wild), is a national and transnational study of science practices and discourses, where my subjects are mostly institutional. Finally, my third paper (Beating the Bounds) is a decentralized local, interrogation of contemporary seed commoning in the United States, where my subjects are individual farmers, breeders, scientists, and activists, and to a lesser extent, seed sovereignty movements of the Global South with whom they are beginning to articulate.

For all cases, when coding, I manually organized my materials into data libraries that I reviewed, organized, and within which I highlighted relevant parts. I determined themes and keywords based on my initial literature reconnaissance and theorizing for each case; in case 3, preliminary fieldwork also guided this step. As I worked through my data collection, I added further themes and keywords based on what I was learning. I then developed a rough theoretical scheme that allowed me to map and analyze the discourses, scientific and technological practices, institutional policies, and other elements for each case. Discourse analysis (e.g. Wood and Kroger (2000); Wetherell, Taylor, and Yates (2001)) and interpretive STS methods (e.g. Jasanoff and Wynne 1998) provided an intellectual framework for my coding and analytical work.

Are We Losing Diversity?

In broad strokes, this case is situated in historical texts, contemporary scientific research, and narratives old and new about crop genetic diversity. Searching in scientific and policy literature databases from roughly 1970 to 2016, I began a ‘snowball sample’ with key literature review papers and reports from international agrobiodiversity organizations and leading experts in this field (eg. Bioversity International’s 10-Year Strategy Plan; FAO’s State of the World’s Plant Genetic Resources for Food and Agriculture; Brush et al. 1998 and 2000; Jarvis et al. 2008 and

2011). Extracting those references, I included edited agrobiodiversity volumes, Global Crop Diversity Trust reports, and papers from journals including *PNAS, Nature, Conservation Biology, Annual Reviews of Anthropology, Culture and Agriculture, and Economic Botany*. This review helped me devise an analytical approach to questions of 'loss' which unfolded in three parts, each requiring a sample of a different literature base.

First, I considered evolution and migration of seeds in time and across space, looking to historical accounts of crop domestication and landmark studies of artificial and natural selection (eg. Darwin's *The variation of animals and plants under domestication*). Next, I looked at diversity's structure, asking how agrobiodiversity is distributed within and across geographic sites. This took me to ecology literature, where metrics of richness, evenness, and divergence have enabled deeper understandings of diversity's patterning in wild and agricultural systems. In turn, I considered social practices for naming and recognizing diversity, involving both scientific and 'folk' methods – the former included a survey of new methods on genotyping and molecular marking, while the latter involved a closer look at ethnobotanical and anthropological studies, including folk soil taxonomies and farmer naming systems. Each of the above perspectives brought into view a locally specific name/place/number of species to juxtapose with larger patterns in agrobiodiversity change. Finally, I considered narratives of loss and persistence, drawing on the past 25 years of scientific and civil society accounts. The contemporary mobilizers of these narratives are dominant institutions that become important in my subsequent papers as well: the Consultative Group of International Agricultural Research (CGIAR), the UN Food and Agriculture Organization (FAO), the Global Crop Diversity Trust (GCDT), and the International Treaty of Plant Genetic Resources for Food and Agriculture (ITPGRFA). I also conducted a limited analysis of the funding structure of the GCDT to better understand the broad coalition – including philanthropy capital, sovereign states, and corporations – that is now supporting the material and epistemic formation of an ex situ pipeline of seed conservation and use.

In order to code these materials, I took notes on a number of key dimensions. First, I considered the meanings of 'diversity' and 'crop diversity' in the discourses that natural scientists, social scientists, and civil society organizations employ in characterizing agrobiodiversity change. I then looked at the techniques by which particular actor groups recognize, identify, and parse 'difference' among seeds and crops, such as farmer naming, taxonomic categorization, genetic sequencing, and functional and phenotypic recognition. I noted what types of crops were being referred to in texts ('traditional varieties,' 'landraces,' 'peasant varieties', 'HYVs', 'modern varieties'), and what kinds of agricultural system(s) were implicitly or explicitly referenced (industrial, agroecological, diversified). Importantly, each appearance of keyword, phrase, or term was studied for context. Descriptions of landraces in some accounts, for example, frequently stressed farmer knowledge and genetic heterozygosity. In other accounts, the same keyword, 'landrace,' might be (and was) associated with backwardness, 'primitive' agriculture, and 'unimproved' genetic material. These codings provided insight on whether farmers were recognized as having a central role in the making of agrobiodiversity and seed knowledge.

Centrally, I tracked *narratives* of loss and persistence produced and invoked by specific actors and institutions. As I was principally interested in the purpose those strategic invocations might serve, I loosely classified narratives into a 'nature first' stance (treating farmers and their practices as pragmatic means to achieve biodiversity-saving ends); a ‘farmer first’ position (agrobiodiversity is valuable insofar as it supports rural livelihoods and development); and a ‘gene first’ concept in which agrobiodiversity is reduced to ‘genes’ or ‘genetic resources,’ often (though not always) for the purposes of exploitation and accumulation of value.

Across these groups, I asked whether loss is seen as a homogeneous or heterogeneous phenomenon; and according to whom seeds are said to be ‘lost’ (eg. so-called ‘orphan’ varieties are often well known to, and widely used by, indigenous communities). I noted the scales and rates of loss or persistence being observed: local, regional, national, global (to understand unevenness in spatial distribution); rapid or slow loss and stable or expanding diversity (to target unevenness in temporal distribution). Finally, I tracked types of policies being advocated to conserve crop diversity, by whom and in association with which narratives. These included in situ or ex situ conservation or both; seed banking or preservation of farmlands or both. I noted whether the actor argued that the proposed policy is the only solution to loss of diversity (eg., salvational framing = there is only one solution; we can provide it), or whether multiple alternative policies were being advanced (eg., empowerment framing = solutions are pluralistic; communities should define their needs). The policies were linked to classical productionist and neo-Malthusian framings and affiliated concepts, for eg: ‘rational,’ ‘cost-effective,’ ‘feeding the world,’ ‘efficient,’ and other scarcity-based logics.

Stealing Into the Wild

To investigate how science and technology research is enabling seed enclosures now and in future, I looked again to the institutions of the CGIAR, the FAO, the Global Crop Diversity Trust, and the Gates Foundation who are currently undertaking and funding this research. Now focusing specifically on a new frontier of accumulation – *undomesticated* relatives of crops – I surveyed the scientific literature on conservation science, breeding science and biotechnology relating to CWR for the last 30 years. Using Web of Science and Google Scholar, I conducted a comprehensive search of scientific and technical databases. In particular, I identified a number of significant review articles and edited books from Bioversity International, the crop diversity hub of the CGIAR (within Bioversity a fairly small community is focused on CWR conservation in situ and ex situ, so their work over time can be readily traced). In addition, I studied policy documents (e.g. the aforementioned FAO ‘State of the World’ and FAO ‘Global Plan of Action’ reports), news, briefings, and webpages that the international agencies and affiliated university scientists have issued on conservation and use of crop relatives over that time. For popular narratives, I used Lexis-Nexis and RSS feeds to review journalism and media coverage of emerging biotechnologies; specialty blogs like the ‘agrobiodiversity weblog’ helped filter the wide universe of data sources into topical foci, including genetic engineering and crop wild relatives. To understand the history and politics of germplasm flows, I looked at the primary ITPGRFA text and secondary analyses of its history and impacts. Finally, I sampled extant business and biotechnology industry news to determine whether and how companies are beginning to exploit CWR resources.

Following an approach similar to that in Case 1, I developed a scheme that allowed me to chart discourses visible in technical and popular literature, and to analyze the kinds of practices being developed in conservation planning and plant breeding science. Technical literature included both peer-review and non-peer review sources, mostly gleaned from university databases and holdings of CGIAR, FAO, and subsidiary agencies; popular literature included media articles, blogs, videos, and education/advocacy materials produced by the aforementioned institutions for public outreach. I noted the definitions of CWR that particular actor groups were making or relying upon: (1) in scientific, breeding, genomic, and policy terms; (2) as gene, trait, plant, or crop; (3) as ability to be bred with existing crops (usually determined by biological proximity to existing crops – and therefore with important implications for defining a 'relative') and ability to contribute beneficial traits to new crops. I classified the attributes and traits being imputed to CWR (e.g. climate-hardy; resistance to diseases, pests, drought; nutrition and cultural taste; and other phenotypic outcomes). I tracked the reasons cited for studying, conserving, or using CWR: adaptation to climate change; protection of global food security; meeting rapid population growth. In particular, I recorded descriptions of what CWR are 'good for.' I discovered, for example, that the metaphor of 'mining' genes/traits was frequently invoked to describe the benefits of crop wild relatives. Another metaphor, of 'rewilding,' was sometimes used to imply reviving 'lost' traits or traits 'lost' with domestication and breeding. I used such phrases to further organize my notes, identifying agricultural discourses within which the future role of CWR was being understood, such as sustainable intensification or agroecological production and consumption.

This paper, moreso than the first, stressed both scientific discourses *and practices*. I followed in particular 2 approaches to conserving CWR: 1) systematic collection and banking *ex situ*; 2) systematic surveying, inventorying, and conservation *in situ*. In both, I delineated the recognized or projected users of CWR: farmers, scientists, breeders, or biotechnology companies. I coded for different types of included knowledge about CWR: scientific knowledge (ecological, genetic, breeding); farmer knowledge (agronomic, breeding, cultural); and policy knowledge (primarily in international conservation, hunger/food security, agricultural science agencies). I noted the values being imputed to CWR (economic/market, environmental, agricultural, food security), and which use values and/or exchange values should be protected as a matter of priority. For this, I looked for Red List indices (threat assessment), protected area status, ecological roles, cultural importance, ethical considerations, financial/cost considerations, and breeding value. Coding for these enabled me to begin seeing the difference between the breadth of possible ways to prioritize conservation and the fewer criteria shaping scientific practice. As a final step, I coded more explicitly for CWR policies: in situ or ex situ conservation or both (complementarity); protection of genetic reserves or collection for seed banks. This strategy brought me to recognize many more likenesses than differences in mainstream PGRFA practice. Although leading to different ex- and in situ final sites of conservation, the projected use values, the included knowledges and indeed many of the upstream conservation practices (eg. prioritized inventory lists and 'gap analyses') were shared across both systems.

Beating the Bounds

Initial fieldwork. My methods for investigating OSSI developed out of – and later informed – my theoretical understanding of OSSI as comprising resources + community + social protocols. Preliminary fieldwork in 2013 introduced me to the community: Jack Kloppenburg, Irwin Goldman, Claire Luby, Frank Morton, Steve Jones, Kevin Murphy, Bill Tracey, Adrienne Shelton, Julie Dawson, and several other plant breeders associated with the Organic Seed

Alliance. OSSI was then in a primordial state, figuring out if and how the licenses would be feasible. I engaged in participant observation, informal conversations, and careful recording of presentations and dialogues at the Student Organic Seed Symposium in Port Townsend, Washington State in July 2013. Site visits to 8 organic farms and one seed processing facility helped me better understand the supply chain of seed production. I met with Kloppenburg in March 2014 to discuss getting involved with OSSI and to review with him possible methodological approaches for studying OSSI. In July 2014, I traveled to Peru, where I met with indigenous leader Alejandro Argumedo (on the OSSI board) and visited 3 of the 5 communities that comprise the Parque de la Papa, or Potato Park. We were accompanied by interpreters, as I am not Quechua speaking. I gained insight into seed sovereignty views circulating in some parts of the Global South.

Document analysis. I conducted a literature review on biotechnology and intellectual property laws for seed from 1930 to the present; reviewed the history of land grant science and breeding; and studied texts on international governance frameworks for plant genetic resources. These provided a strong picture of 'enclosures' against which I could situate OSSI and its open-source pledge. In addition to interviews (see below), I analyzed the language and practices of freelance and professional breeders in a variety of media: OSSI's own website resources, trade press books, mail order seed catalogs, seed cooperative and company websites, gardening blogs, and popular science articles. I reviewed all of the then-37 breeders' websites and blogs where available. I coded the discourses visible in all of these materials, providing the basis for a qualitative assessment of how dynamic resources, communities, and social protocols configure OSSI as a commoning practice.

Fieldwork and interviews. Between 2016 and 2017, after OSSI was already established under the Pledge, I did my semi-structured interviews. My semi-stratified sample was designed to gather information from three core groups: *(1) Founders' perspective:* the history of OSSI, its philosophical and ideological commitments, its decision-making structure, and the detailed "nuts and bolts" of how the OSSI Pledge works. I interviewed four OSSI board members (Jack Kloppenburg, Claire Luby, Jahi Chappell, Alejandro Argumedo). *(2) Breeder-farmers' perspective:* the experiences and views of breeders who pledge seeds into OSSI. After reviewing the OSSI list of breeders (see above), I chose a sample of five. I included both formal and informal breeders, sought to achieve a representative sample in gender and geographical location (e.g. Pacific Northwest, Utah, Northeast), and distinguished between breeders who are highly involved with OSSI (e.g. Frank Morton, Carol Deppe, Irwin Goldman,) and those who are more on the periphery (e.g. Joseph Lofthouse). The latter was an intentional choice to glean data from breeders who are *not* part of the central group and possibly freer to be more critical of it. *(3) Global South perspective:* views from Southern seed sovereignty movements, especially those concentrating on the Global South level (e.g. La Via Campesina; GRAIN; ETC Group). My initial intention, as described below, was a larger-scale survey. But I moved instead to a more tractable set of interviews with 4 key informants from Mexico, France, Venezuela, and Canada. I coded all these interviews similarly to the documents.

Most interviews were conducted via phone or skype, though several in the Pacific Northwest were in person. Especially with Carol Deppe and Claire Luby, ongoing email communication helped me fill in many gaps in knowledge over roughly 16 months between summer 2016 and winter 2017. My interview protocol was reviewed by my OSSI partners for clarity, and my journal manuscript was similarly revised with feedback from Kloppenburg, Goldman, and Luby, reflecting my commitment to co-production of knowledge. My interview protocol (see Appendix 2) was designed with the two aforementioned population clusters in mind: 'Founders' and 'Breeder-farmers.' I formulated open-ended questions to elicit, from the former group, an unfiltered history of OSSI's formation, evolution, and licensing struggles, which I would later characterize in terms of 'beating the bounds.' From the latter group, I tailor-made interview questions according to whether the informant was a public university breeder or an informal "freelance" breeder. Both sets were asked questions about why OSSI is appealing to them, what opportunities it affords, and what problems they see with the seed/breeding/IP system as it currently exists. For public breeders, I added questions specific to university institutional contexts. For the freelancers – a community that I discovered in the process of this research – I developed questions more attuned to practicing farmers and gardeners.

Following an approach similar to that in Cases 1 and 2, I determined themes and topics based on my preliminary fieldwork and literature review, while also adding themes as I worked through my data collection. First, I developed a scheme to map the resource, community, and social protocols being forged through OSSI's commoning. Next, I examined how informants and materials verbally and textually construed the dominant formal seed system, the role of agri-food corporations and intellectual property rights (e.g. attitudes towards patents, bag tags, and trade secrets), the nature and inspirations of 'open source', and what 'freed seed' might mean. I looked at how informants and materials defined 'expertise' and 'seed knowledge' in terms of university, freelancer, and industry settings, respectively. To understand how informants might explain their activities, I filtered keywords including 'rights,' 'seed freedom,' 'seed sovereignty,' and 'corporate power,' within the context of political claims; keywords like 'agroecology,' 'diversified farming,' 'landrace,' 'heirloom,' 'traditional variety,' 'heritage,' within the context of agronomical and cultural claims; and keywords like 'local food systems,''relocalization,' 'food sovereignty,' and 'community-based' within the context of economic/structural claims. Finally, I cross-mapped these themes and keywords to identify the resource, community, and social protocols constituting OSSI.

Towards building onto this work, further interviews were conducted in October 2017, after my final dissertation paper had been submitted for journal review. These interviews came by way of an invitation to an international open source workshop in Montpellier, France. 'Open Source for Seeds and Digital Sequence Information' deepened my understanding of new challenges and opportunities with so-called 'de-materialization' of agrobiodiversity. I presented my research on OSSI and conducted several interviews with OSSI's nascent international partners: Selim Louafi of the Center for Agricultural Research and Development (CIRAD), France; Gloria Otenio of Bioversity International, Uganda; Sophie Steigerwald of Agroecol, Germany; Willy Douma of HIVOS in the Netherlands. In the workshops, I engaged via interpreter with Guy Kastler of La Via Campesina, France. Kastler is a member of LVC's biodiversity commission; as its leading expert in seed IP affairs, he was a prominent critic of open source in its licensing phase. Kastler's concerns about open source corroborated my Case 3 findings regarding the politics surrounding open source within LVC, GRAIN, ETC, and other civil society organizations that have a 'shared analysis' of genetic resource concerns (Kuyek, Vera-Herrera, Felicien, Ribeiro, all pers. comm.).

Mining the OSSI data. Another key way I characterized OSSI's community and seeds was through reviewing their database of Pledged varieties. (See Figure 21). I conducted this work primarily to ground myself in the OSSI 'territory.' I asked questions such as:

<u>*Seed characteristics*</u>
- What kinds of crops and varieties of crops are being pledged?
- What kinds of traits (breeding, growing, processing, cooking, eating)?
- How many are bred for organic systems?
- Quantity of breeding materials versus finished varieties?

<u>*Community Characteristics*</u>
- How many breeders?
- Are they public sector or freelance breeder?
- Where are they located?
- Gender, age, race, ethnicity?
- How do they describe their seeds? (Studied Variety Description for language framing, tone, motivations, use values)

	B	C	D	E	F	G	H	I	J	K
1	**Crop**	**Latin name**	**Plant Breeder**	**Breeder Affiliat**	**Seed Img**	**Variety Description**	**Seed Company Partn**	**Bred for Organic**	**Commercial Avai**	**Finished Varieties**
2	Hidden	Hidden	Hidden	Hidden	Hidden	Hidden	csvFilter - Hidden	csvFilter - Hidde	csvFilter - Hidde	csvFilter - Hidden
3	Amaranth	*Amaranthus spp.*	Frank Morton	Wild Garden Se	http://osseeds.or	For amaranth aficionados that are looki	Wild Garden Seed	**Bred for Organic**	Commercially Ava	Finished Variety
4	Asparagus	*Asparagus officin*	Chuck Burr	Restoration See	http://osseeds.or	New stable cross with the best of Jers	Restoration Seeds	**Bred for Organic**	Commercially Ava	Finished Variety
5	Barley	*Hordeum vulgare*	Pat Hayes	Oregon State U	http://osseeds.or	A semi-dwarf, 2-row, awned, hulled, sp	Resilient Seeds		Commercially Ava	Finished Variety
6	Bean	*Phaseolus vulgar*	Anne Berblinger	Gales Meadow I	http://osseeds.or	This bean was given to me by my neighbor, Torchy Oberg. Tor		**Bred for Organic Systems**		Finished Variety
7	Bean	*Phaseolus ssp.*	Carol Deppe	Fertile Valley Se	http://osseeds.or	Bred for organics. Determinate bush dr	Fertile Valley Seeds	**Bred for Organic Systems**		Finished Variety
8	Bean	*Phaseolus ssp.*	Carol Deppe	Fertile Valley Se	http://osseeds.or	Early productive dry bean with rich mea	Fertile Valley Seeds	**Bred for Organic**	Commercially Ava	Finished Variety
9	Bean	*Phaseolus vulgar*	Carol Deppe	Fertile Valley Se	http://osseeds.or	'Beef-Bush Gold Resilient' dry bean. Br	Fertile Valley Seeds	**Bred for Organic**	Commercially Ava	Finished Variety
10	Bean	*Phaseolus vulgar*	Carol Deppe	Fertile Valley Se	http://osseeds.or	Bred for organic systems. The most int	Fertile Valley Seeds, F	**Bred for Organic**	Commercially Ava	Finished Variety
11	Bean	*Vigna unguiculat*	Carol Deppe	Fertile Valley Se	http://osseeds.or	Bred for organic systems. Early maritin	Fertile Valley Seeds, S	**Bred for Organic**	Commercially Ava	Finished Variety
12	Bean	*Cicer arietinum*	Carol Deppe	Fertile Valley Se	http://osseeds.or	Bred for organic systems. Productive 2	Fertile Valley Seeds, F	**Bred for Organic**	Commercially Ava	Finished Variety
13	Bean	*Phaseolus vulgar*	Carol Deppe	Fertile Valley Se	http://osseeds.or	85 days. Sister** to Golden Gaucho. B	Fertile Valley Seeds	**Bred for Organic**	Commercially Ava	Finished Variety
14	Bean	*Phaseolus vulgar*	David Podoll	Prairie Road Or	http://osseeds.or	(90 days) The bumblebee did it! Transf	Prairie Road Organic S	**Bred for Organic**	Commercially Ava	Finished Variety
15	Bean	*Phaseolus vulgar*	Joseph Lofthouse		http://osseeds.or	A landrace containing hundreds of varie	Joseph Lofthouse	**Bred for Organic**	Commercially Ava	Finished Variety
16	Beet	*Beta vulgaris*	David Podoll	Prairie Road Or	http://osseeds.or	(55 days) Sweet, deep burgundy beets	Prairie Road Organic S	**Bred for Organic**	Commercially Ava	Finished Variety
17	Broccoli	*Brassica olerace*	Frank Morton	Wild Garden Seed		(92 days) Open-pollinated. A gourmet (	Fedco Seeds, Hawtho	**Bred for Organic**	Commercially Ava	Finished Variety
18	Broccoli	*Brassica olerace*	Jonathan Spero	Lupine Knoll Far	http://osseeds.or	New, Open pollinated, early, anthocyan	Lupine Knoll Farm, Re	**Bred for Organic**	Commercially Ava	Finished Variety
19	Brussels Sprouts	*Brassica olerace*	Heike-Marie Eubanks		http://osseeds.or	An open pollinated variety bred from an expired hybrid and sev		**Bred for Organic Systems**		Finished Variety
20	Calendula	*Calendula officin*	Frank Morton	Wild Garden Se	http://osseeds.or	An extract from the Flashback gene po	Wild Garden Seed	**Bred for Organic**	Commercially Ava	Finished Variety
21	Calendula	*Calendula officin*	Frank Morton	Wild Garden Se	http://osseeds.or	A bright new mix of pastel orange and I	Wild Garden Seed	**Bred for Organic**	Commercially Ava	Finished Variety

Figure 21. **The Open Source Seed Initiative master database** includes each pledged variety by crop type, Latin name, and whether or not the germplasm is "finished" or available as breeding material. It also includes each OSSI plant breeder and his or her affiliation. New information in the database includes "bred for organic," also offered as a searchable filter in the online database (https://osseeds.org/seeds/).

A subset of this data became important for two things: (1) verifying the continued growth and diversification of OSSI, in terms of breeders, companies, and varieties; (2) tracking the number of *informal* sector breeders as opposed to *formal* sector breeders participating in the commons. This unevenness could be counted both in terms of seeds and breeders, as illustrated in the figure below.

(1) *Changes in OSSI 'by the numbers'*

December 2016: 34 breeders, 38 seed companies, and ~300 varieties (Kloppenburg, pers. comm.)
April 2017: 36 breeders, 42 seed companies, and 372 varieties (database; Luby pers. comm.)
July 2017: 36 plant breeders, 42 seed companies, and 373 crop varieties (ibid)
October 2017: 38 plant breeders, 48 seed companies and 377 crop varieties (ibid)
December 2017: 38 plant breeders, 52 seed companies and 382 crop varieties (ibid)
April 2018: 38 plant breeders, 58 seed companies and 407 crop varieties (ibid)

(2) Freelance v. Formal Breeder. As seen in Figure 22, the total number of Pledged seed varieties is disproportionately skewed between informal and formal breeders: roughly 96% of total OSSI pledges have been bred and contributed by informal 'freelancers.' I followed this division of labor over time, between December 2016 and April 2018. Over this period, the number of varieties contributed by formal sector breeders remained constant at 16, while the number of informally bred varieties continued to steadily climb: from roughly 280 at the end of 2016 to 361 in October 2017 (the data reported in my paper) to 391 by April 2018. Triangulating this simple quantitative analysis with data gleaned from interviews, it became evident that public university structures were dramatically limiting breeder contributions. This finding guided my subsequent methodological focus on the freelance community.

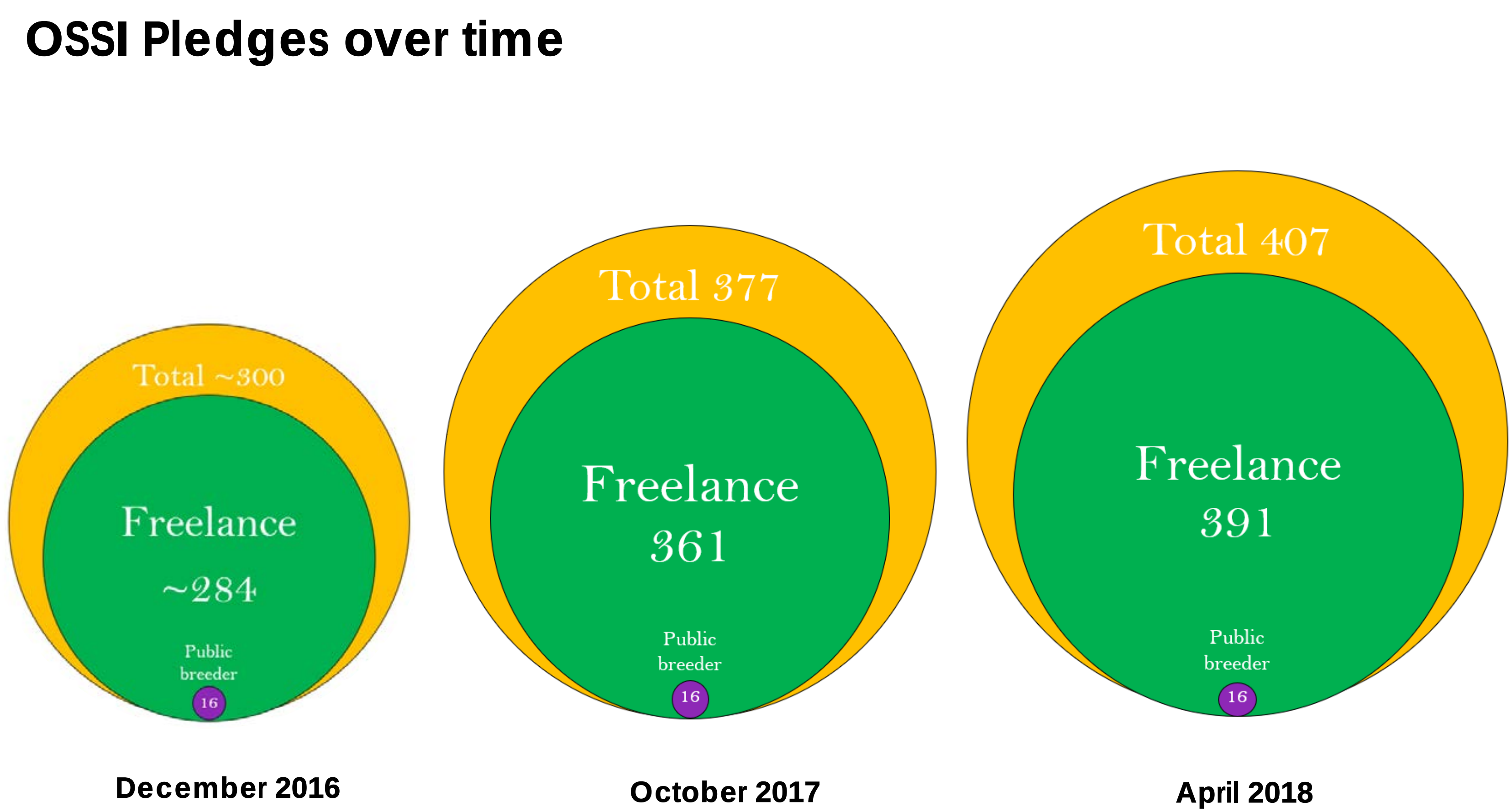

Figure 22. Freelance v. Formal. The number of seed varieties pledged into OSSI broken down by formal sector versus informal sector, or 'freelance,' breeders.

Mapping 'Where the Breeders Are'

Using the OSSI membership database, I created a very basic map to get a sense of their geographical distribution in the US (a few members in UK and Australia). This Google map (last updated in October 2017), can be found online here:

https://www.google.com/maps/@39.6466161,-93.0674342,4z/data=!4m2!6m1!1s1amgIq-p7A4UjnJWKnDXdLne11wA?hl=en&authuser=0

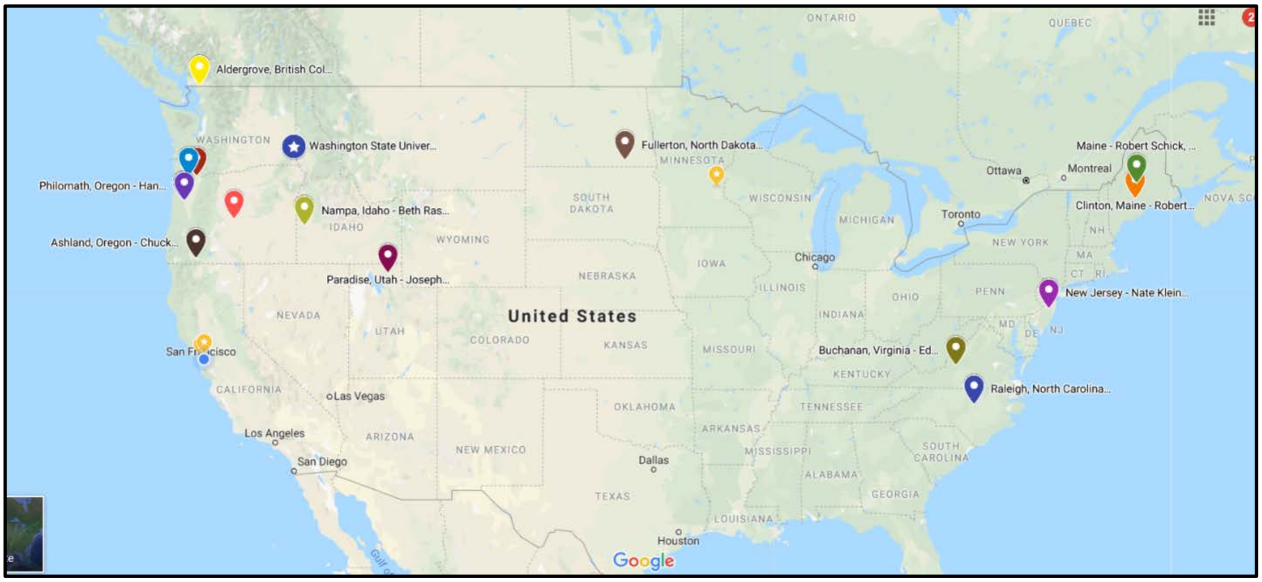

Figure 23. **Mapping 'Where the Breeders Are'**

Survey Instrument & Post-paper work

To begin analyzing OSSI's relations with seed sovereignty movements in the Global South, I initially distributed a survey and explanatory brief about open-source seed to 15 key seed sovereignty informants in Venezuela, India, Mexico, the US, and Canada in late 2016. However, while this yielded valuable data from 2 respondents, it proved difficult to obtain responses within a reasonable thesis timeframe. Learning from this experience, I added four follow-up interviews with civil society groups that deepened my understanding of peasant and indigenous concerns. The **survey instrument** and **'OSSI Brief'** are found below in Appendix 3. I developed this survey with feedback from Marcia Ishii-Eiteman, a senior scientist with the Oakland-based North American Pesticide Action Network (PANNA), Christina Schiavoni, a graduate student at the Institute for Social Sciences in The Hague, and Alejandro Argumedo of ANDES, an NGO in Peru. Ishii-Eiteman was selected for her experience in global seed systems as lead author of the 2008 IAASTD report; Schiavoni for her expertise in Venezuelan seed law and sovereignty struggles; and Argumedo for specific concerns regarding indigenous knowledge and territory. These key informants helped me develop questions to interrogate biopiracy concerns as well as 'territory' and 'rootedness' in contrast (or in parallel) to concepts of 'open source.' I asked open ended questions about understandings of ‘seed sovereignty’ in relation to open source. In the end, this survey instrument became the open-ended protocol for my interviews.

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APPENDIX 2. OSSI Interview Guide

These are questions for the public plant breeders, social scientists, agroecologists, NGO leaders, and small seed company entrepreneurs who comprise the Open Source Seed Initiative network. They include the members of the steering committee ("core OSSI") as well as OSSI-affiliated breeders ("OSSI breeders") and partnered seed companies ("OSSI companies"). Questions were adapted according to the individual's role in the network (eg. farmers who plant open-source seed; breeders who create it).

Opening questions

Begin with "Thank you for taking the time to talk with me…"

(1) Could you please tell me a little about your background?

(1.1) Could you please describe your labor or professional expertise?

(1.2) How did you get involved in the Open Source Seed Initiative?

History and characteristics of OSSI

[AIMED AT CORE = board of directors; i.e. *'Founders' perspective'*]

(2) How did the idea for OSSI originate?

(3) Goals and objectives

(3.1) What are the objectives of OSSI and what activities does it do to achieve these objectives?

(3.2) Have the goals changed over time? What factors (or whom) have influenced these changes?

(4) Has OSSI encountered any difficulties? How were these addressed?

(5) How was/is OSSI supported or funded?

(6) Do you view OSSI as a movement? Do you see yourself as part of a 'seed freedom' movement?

[AIMED AT AFFILIATES = OSSI breeders, OSSI companies, OSSI farmers; i.e. '*Breeder-farmers' perspective*']

(2) How did you hear about OSSI? What attracted you about it?

(3) How long have you been involved in breeding, selling, producing, planting open-source seeds?

(3.1) Have you encountered any particular benefits or drawbacks from the open-source model for seed sharing?

(3.2) How is it different from working with conventional (i.e. organic) seed that is not open-sourced?

(4) Has working with OSSI changed your views about seed? About agriculture and food systems more generally?

(5) Have you experienced any frictions or difficulties working with OSSI? What was the source of these difficulties, and how were they resolved?

(6) Do you view OSSI as a movement? Do you see yourself as part of a 'seed freedom' movement?

Motivations and Incentives

(7) What are the motivations and incentives (economical, ethical, intellectual, etc) for **breeders** to join a seed commons?

(7.1) What motivates **farmers** to use and grow open-source seed? What might motivate **consumers** to buy food produced with open-source seed?

Participation and community characteristics

(8) Could you tell me about *who* participates in OSSI?

(8.1) How does a [breeder, seed company owner, farmer] get involved?

(9) Is *anybody* allowed to participate?

(9.1) Are there any rules excluding certain participants (for eg., large seed corporations, private breeders)?

(9.2) What is the scope and scale of OSSI participation at present? (number of participants, characteristics of participants, geographic reach).

(10) How is OSSI managed and governed?

(10.1) Are there leaders in OSSI? Who makes decisions?

(10.2) What kind of authority or responsibility do they have?

(11) Claire Luby told me that OSSI began mostly with a small corps of land-grant public plant breeders but is increasingly populated now by 'freelance breeders' in the informal sector. Can you tell me more about this?

(11.1) What is a freelance breeder? What characteristics of open-source make it attractive to the freelance breeding community?

IPR and political economy

(12) Intellectual property, commons, and the moral economy pledge

Early on, OSSI moved from a contract law approach to a moral economy pledge.

(12.1) Can you describe for me how the OSSI pledge works? What is the significance of OSSI moving in this direction?

(12.2) What does it mean to create a "protected commons"? Do people easily understand the difference between *open access* commons and *protected* commons?

(12.3) What is going to drive the viral spread of OSSI seeds?

(13) In the 1970s, the open source software movement wanted to draw the distinction between free from intellectual property protection and free for sale. They developed the saying: "Free as in Speech, Not as in Beer." Can you help me understand how the analogy works with seed? A freed seed is still a material thing, so how can seed be free as in speech? What do you mean when you say OSSI seed is "freeD," but not "free"?

(13.1) Property: If OSSI seed is not protected by IPR but instead is part of a protected commons, what enables the benefit-sharing arrangements to work, where breeders can charge royalties for their work? Is there still an element of property affixed to OSSI-seed that enables, say, a breeder to get a cut of seed sales, or small companies to charge gardeners for OSSI-varieties?

(13.2) I understand that derivatives are important when it comes to virality: derivatives of initially pledged seed will also be pledged, making the OSSI protection perpetuate virally. But doesn't this raise a bit of a contradiction from the vantage point of seed companies? How do you build a *market* for ethically produced seeds while also encouraging non-market saving, exchanging, and replanting? (historically, wasn't the free US public seed distribution program an obstacle for development of the seed industry?) [*if necessary:* How do seed growers and seed companies earn income if 'freed' seeds can be saved and replanted by farmers?]

(13.3) How are the OSSI-affiliated seed companies different than dominant seed industry actors? Scale? Values?

Knowledge economy and the place of breeding

(14) Formal and Informal Seed Systems

"Scientists often make a distinction between **'formal seed systems' –** heavily regulated systems made up of public institutions and private industries engaged in scientific plant breeding – and **'informal' or farmers' seed systems –** which are almost completely unregulated and dependent on farmers' knowledge" (Wattnem 2016). **How does OSSI fit into either or both of these systems?**

(14.1) In Carol Deppe's book, she writes that professional breeders in the formal sector have done many amazing things, but they also tend to focus on commodity crops, on temperate climate cultivars, on broad adaptation for larger seed markets, and on traits such as processing quality for industrial supply chains – instead of on locally adapted crops, on subsistence staples, or on varieties that are selected primarily for flavor even if they wouldn't withstand a 5 mile truck drive. **How do you see OSSI as changing the dynamic between professional and amateur or farmer breeders**?

(14.2) Is there any inherent tension between farmers' ability to save, select, and replant their own seed under OSSI and the continued role and relevance of professional breeders? How might open source change the role of institutional, 'formal' plant breeding?

(14.3) Can you talk to me about ecological diversity/place in breeding and why it's important? [if further prompting necessary: By empowering all/any farmers to regenerate their own germplasm, OSSI may help restore the practice of in situ breeding to local places and practitioners. But many US growers need more intimate knowledge of their own agroecosystems in order to become effective seed breeders.)

Commons and sovereignty

(15) What kinds of efforts has OSSI made to engage with other actors in the broader 'seed freedom' movement (eg. US Food Sovereignty Alliance, Navdanya, GRAIN, ETC Group)?

(15.1) Was the OSSI model developed with any feedback or participation from indigenous peoples, global south partners, marginalized agrarian communities?

(15.2) Has OSSI encountered any critiques of the open-source model from these actors? What types of concerns have been expressed?

(15.3) Has OSSI responded or evolved in some way in response?

(16) Food sovereignty movements articulate a particular concept of rights to decision-making in agri-food systems. Seed sovereignty is often seen as central to food sovereignty. What does food/seed sovereignty mean to you? How do these concepts relate to the OSSI seed commons?

(16.1) Are there any tensions or contradictions between sovereignty thinking/practice and 'open source' thinking/practice?

(17) Many seed sovereignty groups work to prevent bioprospecting. Does a non-legally binding pledge prevent such appropriation? (What are the penalties for breaking the rules of the protected commons)? Has building trust in OSSI in the global south – or in the North for that matter – been impeded by bioprospecting concerns?

Building legitimacy

(18) How do open-source seeds become more widely accepted and legitimated?

(18.1) Given the power of the industry-dominated market model for seed production and private property rights for seed, what chance does OSSI stand to create an alternative regime?

(18.2) Legally-defensible licenses would have held greater legitimacy in the eyes of courts, governments, and industry. How does a moral economy pledge achieve similar levels (if not types) of legitimacy?

(18.3) How can a seed commons become more credible within and across different constituencies: farmers, breeders, scientists, policymakers, the public?

(18.4) What are the greatest challenges to the credibility of a seed commons?

(18.5) Does open-sourcing seed call for open-sourcing of other elements in the agri-food system? Land, technology, energy, knowledge?

Future Development of OSSI

(19) How would you define "success" for the seed commons? For OSSI? Do you envisage that OSSI would expand to include many more crops and varieties, and would grow across the US and around the world?

(19.1) Could farmer-varieties (landraces) and heirloom varieties ever become part of OSSI? What complications does this raise in terms of who would have the rights to pledge an heirloom or landrace?

(19.2) At present, while replanting is promoted, the open source model seems to retain the characteristics of a commodity pipeline: Where germplasm from professional breeders gets outsourced by companies to seed growers, who produce it as a crop for sale to farmers and gardeners. Is OSSI's vision to replace what is now a surplus-extractive seed industry pipeline with a fairer value chain? Or does it ultimately see open-source as eroding the foundations of commercial seed production – and even the need for professional breeding – by facilitating in situ, farmer-led regeneration?

Concluding question

(20) Whom (else) should I talk to about OSSI and the relationship of commons to sovereignty?

[Thank participant and ask permission to follow-up for any necessary clarifications.]

APPENDIX 3. Survey Instrument and OSSI Brief

These are questions for civil society organizations in, or focused on, the Global South that advocate for seed freedom and/or food sovereignty. Informants from India, Mexico, Venezuela, Canada, Iran, and Zimbabwe were identified by snowball sampling from a few key contacts and texts including Seed Freedom (2012) and the Future of Food: Seeds of Resilience (GAFF 2016).

(1) Background

- What is your labor or professional expertise?

- How long have you been working in this field, position, or capacity?

(2) Seed Sovereignty

- How did you get involved in seed/food sovereignty work?

- What does the concept of seed sovereignty mean for you?

- What are your primary concerns about the seed systems we have now? Can you please describe? (These might be cultural, economic, IP, biodiversity, practical, knowledge, agronomic concerns, or a combination).

(3) Introducing OSSI

Prior to my reaching out to you, had you heard about the "The Open Source Seed Initiative" (OSSI)?

- If "YES":
What is your understanding of the open-source seed model? How does it work?

- If "NO": *Please refer to the brief description of OSSI provided in the email sent to you.*

(4) Opinions & Concerns

What is your overall opinion of the Open Source Seed Initiative, and the model it is attempting to propagate? Specifically:

- What objectives does it advance, or not advance?

- What sort of access do you think OSSI offers, and to whom?

- Who do you feel may benefit from this model? Who may not benefit?

- What kinds of concerns do you have (if any) about the creation of an open-source seed commons?

- Does it make a difference to you if the "open-source" model is a *protected commons* populated by those who agree to share <u>but effectively inaccessible to those who will not</u>? (That is, not an "open access" model that is accessible to all, including those who may privatize the resource).

(5) Bioprospecting

OSSI attempts to prevent bioprospecting with a voluntary Pledge which disallows users of pledged seed from restricting others from using and sharing the seed, or their derivatives – by patent or other means. Are you concerned that:

- Some groups may still try to restrict others from others from equivalent access?

- A Pledge may be insufficient to deter industry from bioprospecting of seeds in the open-source commons?

- Do you have other concerns regarding bioprospecting?

(6) Territories, 'Rootedness,' and Open-Source

Many indigenous peoples view seeds as inextricable from land, culture, and community – that is, seeds are 'rooted' in particular territories and with particular peoples. Open source seed is inspired by open source software, a movement often associated with high-technology, globalized information, and data as fluid and fungible.

- Is the concept of 'open source', for you, compatible with: Seed sovereignty? Seeds as 'rooted' in territories? Why or why not?

- What does "rooted" mean for you in terms of seed and crop genetic resources?

(7) Sovereignty and commons

Is the concept of "sovereignty" (rights of people to define their own food systems) compatible with the idea of a "commons" (cultural and natural resources freely available to all members of society as long as they adhere to certain rules of use.) Why or why not?

- Is there any mismatch – cultural, ideological, values – between the OSSI commons model and your own seed sovereignty work?

- Is the moral pledge likely to resonate with many farmers in your country/region? If not, why not?

(8) Landraces and Farmer Varieties

The inclusion/exclusion of farmer varieties and landraces under current OSSI guidelines is a subject of ongoing conversation as OSSI reaches out to more farmer and breeder communities (see Brief p. 2 for pledge guidelines).

- Should landraces and farmer varieties be included in the OSSI commons? Why or why not?

- If you think landraces and farmer varieties should be included in the commons, under what conditions?

- Who should have the authority to pledge a landrace or farmer variety, and why?

(9) Freed seed vs. "Free seed"

Open source is not equivalent to de-commodification – as OSSI advocates like to say, freed seed, not *free* seed. Through its educational and outreach activities, OSSI attempts to raise awareness of the value of purchasing "freed seed," and to guide customers to its Seed Company Partners. OSSI is hoping to create a market for ethically produced, "freed seed" analogous to the markets for "fair trade" and "organic" products.

- In generating possibilities for both commercial and subsistence reproduction, do you feel the OSSI model may meet resistance from some seed sovereignty groups? Why or why not?

(10) Future directions for OSSI

- On a scale of 1-10, how optimistic are you that the Open Source Seed Initiative will contribute to seed sovereignty? Why or why not?

- What would make an open source seed commons more credible or legitimate in terms of supporting seed sovereignty in the conditions prevailing in your country or region?

— END —

OSSI brief: *This is a description of the Open Source Seed Initiative that I distributed alongside the survey instrument. The initial part was intentionally left in OSSI's own words to retain the character and tenor of their own voice. Guidelines for Pledging seeds were not publicly available from OSSI, so I consulted with them in drafting these guidelines before circulating to CSOs and social movements.*

The Open Source Seed Initiative

OSSI was created by a group of plant breeders, farmers, seed companies, and sustainability advocates who want to free the seed!

Today, only a handful of companies account for most of the world's commercial breeding and seed sales. Increasingly, patenting is used to enhance the power and control of these companies over the seeds and the farmers that feed the world.

Patented seeds cannot be saved, replanted, or shared by farmers and gardeners. And because there is no research exemption for patented material, plant breeders at universities and small seed companies cannot use patented seed to create the new crop varieties that should be the foundation of a just and sustainable agriculture.

Inspired by the free and open source software movement that has provided alternatives to proprietary software, OSSI was created to free the seed - to make sure that the genes in at least some seed can never be locked away from use by intellectual property rights.

How OSSI Works:
OSSI works with plant breeders who commit to making one or more of their varieties available exclusively under the OSSI Pledge: ***You have the freedom to use these OSSI-Pledged seeds in any way you choose. In return, you pledge not to restrict others' use of these seeds or their derivatives by patents or other means, and to include this Pledge with any transfer of these seeds or their derivatives.*** This "copyleft" commitment ensures that the Pledge is transmitted with any further distribution of the seed or the seed of any new varieties bred from it. In this way, OSSI preserves the unencumbered exchange of plant germplasm for breeding purposes and guarantees the rights of farmers and gardeners to save and replant seed.

- OSSI Partner Seed Companies sell OSSI-Pledged varieties, acknowledge the OSSI breeders in their variety descriptions, label OSSI-Pledged varieties with the OSSI logo, and include the Pledge and information about OSSI in their catalogs and on their websites.

-The Seed List of OSSI-Pledged varieties gives complete descriptions and photos for each OSSI-Pledged variety and links to every OSSI Partner Seed Company that carries each variety.

Through its educational and outreach activities, OSSI creates awareness of the value of purchasing "freed seed" and guides customers to its Seed Company Partners. OSSI is thereby creating a market for ethically produced, "freed seed" analogous to the markets for "fair trade" and "organic" products.

More information can be found online at the Open Source Seed Initiative website. For quick links, see:

- About - Vision statement and brief biographies of OSSI core members)
- 'Growing Access' - Specifics of OSSI Pledge, operations, and international cooperation

- Seeds - Database of OSSI-Pledged varieties
- Plant Breeders - List of plant breeders currently in the OSSI community
- FAQ - Frequently asked questions about breeders' rights and farmers' rights; hybrids; benefit-sharing, etc.

Brief history of OSSI

Readers, early in its history, OSSI underwent an important shift: from an approach based on open-source licenses (a form of contract law) to one based on a moral economy – a social contract between farmers, breeders, and seed companies. Below, I include a description of this important pivot, since there is often confusion about OSSI's intellectual property orientation. The following text is excerpted from a research article published by OSSI founding members in 2016,[88] with the full open access version available online here.

"The success of the free and open source software (FOSS) movement has been a key inspiration for OSSI and appeared to present a plausible alternative to the conventional IPR regime. Notably, the legal tool that engenders this plausibility is a license, which is an expression of *contract* law (*not* IPR law). FOSS is copyrighted and then made available under a license that permits further modification and distribution as long as the modified software is distributed under the same license. This arrangement produces a "viral" effect that, critically, enforces continued sharing as the program and any derivatives and modifications are disseminated. Also critically, the virality of the license prevents appropriation by companies that would make modifications for proprietary purposes since any software building on the licensed code is required by the license to be openly accessible. This feature – called "copyleft" – is what distinguishes "open source" from mere "open innovation." Thus, software developed under an open source license is released not into an open innovation/open access commons, but into a "protected commons" populated by those who agree to share but effectively inaccessible to those who will not.

In April 2010, a small meeting was held in Madison, WI, to explore the prospects for implementing some sort of open source initiative for seeds. Enthusiasm for the idea led to targeted recruitment for attendance at a second meeting held in May 2011 in Minneapolis, MN. Participation was expanded to include additional public breeders, farmers, indigenous groups from both global North and South, an organic seed company, and several nonprofit advocacy organizations. Those attending the Minneapolis meeting constituted themselves as the "Open Source Seed Initiative," discussed principles and objectives, and outlined a course of action. The

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[88] Luby, C. H., J. Kloppenburg, T. E. Michaels, and I. L. Goldman. 2015. Enhancing Freedom to Operate for Plant Breeders and Farmers through Open Source Plant Breeding. *Crop Sci.* 55:2481-2488. doi:10.2135/cropsci2014.10.0708

priority task was determined to be creation of a legally defensible, open source license for plant germplasm (Kloppenburg, 2013).

However, a sustainable and enforceable mechanism for an open source system for plant germplasm proved difficult to develop. OSSI's attorneys could – and, indeed, *did* – draft a legally defensible, "copyleft" license that would ensure that OSSI-licensed seeds and their derivatives would, by legal mandate, remain freely available for use. However, the eight-page license that resulted was densely packed with legal terminology. Further, since a license is a private contract which prospective licensees must have an opportunity to read its entirety, the complete language of the license would have to appear on every package or container of seed sold or exchanged. The probability that such a license would be transmitted with the seed for more than a few exchanges is very low, and the consequent failure to virally propagate would negate the key and most powerful feature of the open source license approach. Additionally, while software code is protected by copyright, plant cultivars do not have copyright to back up a "copyleft" or open source license.

After nearly 2 years of trying to overcome these obstacles, OSSI decided to shift its efforts to a different plane. Abandoning the cumbersome legal approach, OSSI chose instead to base its efforts on the ethical plane and to build on the obligation that many breeders have historically felt to freely share their work in the public interest. In place of a license, OSSI has crafted a Pledge that reads: "*You have the freedom to use these OSSI seeds in any way you choose. In return, you pledge not to restrict others' use of these seeds or their derivatives by patents, licenses or other means, and to include this Pledge with any transfer of these seeds or their derivatives.*"

With this Pledge, OSSI appeals to the ethical and social norms that link plant breeders, seed companies, farmers, gardeners, and eaters. The Pledge represents a call to revitalize a system of practices characterized by germplasm exchange unencumbered by complex legal agreements. The Pledge is meant to recognize and honor the historic and collective contributions of farmers and plant breeders to the generation and maintenance of the existing pool of crop genetic material. Cultivars released under the Pledge function both as entities that can be planted and consumed as well as vectors for the genes they contain. Over time, these freely available materials will help to maintain access to the diversity of alleles contained in an open source repository within which plant breeders continue to have maximum "freedom to operate." ….

…On the basis of the Pledge, OSSI-designated seed is considered to be "free seed" or, alternatively and more accurately, "*freed* seed." That is, it is free for any use, though not necessarily free of cost. The FOSS advocate Richard Stallman has famously proposed that FOSS code is "'free' as in 'free speech,' not as in 'free beer'" (Stallman, 2002). Under the auspices of open source, it is imperative that the word "free" is understood to connote *freedom* and not price.

Free and open source software code is not necessarily given away free, it can be sold. Nor does free software *have* to be given to anyone who asks. Similarly, OSSI seed can be sold, and it can be sold exclusively to a single recipient. The OSSI-designated seed need not be provided to anyone who asks for it. The purpose of the Pledge, and the basis of the concept of "freed seed" as OSSI defines it, is that "freed seed" has been freed from restrictions on the uses to which the seed can be put by those to whom it is transferred, by sale or without charge, under the OSSI Pledge."

Summary Guidelines for Pledging Seed

The following Pledge guidelines offer a picture of OSSI's current thinking with regard to seed both formal ***and, to a lesser extent, informal seed systems.*** *OSSI's origins and primary focus is in the US, a country whose seed system is characterized by highly formal institutions of seed research/breeding, production, marketing, and regulation. OSSI's starting point, then, has been to work primarily with plant breeders who commit to making one or more of their 'new' varieties available under the OSSI pledge. However, OSSI recognizes that such criteria will not be appropriate for all social or ecological contexts.*

The following text is based upon the formal Variety Designation Agreement,[89] as well as my own interviews with OSSI members, during which I inquired about farmer selection methods, landrace varieties, and indigenous communities' seed.

To be eligible for inclusion in the OSSI protected commons, the variety, population, or propagating material must meet the following criteria:

Biological

(1) Must be a "new variety" **–** i.e. identifiable as "selected from a heterogeneous population."

- this can be achieved through cross-breeding and subsequent selection
- this can be achieved through farmer seed-saving and selection

Social

(2) Must have breeder, co-breeder, or agent, with the authority to pledge them.

Further considerations: indigenous landraces, heirlooms, genetically engineered seed

(3) Heterogeneous populations, such as landraces, may also be pledged, where it can be determined that the population was created by an identifiable breeder, agent, or community. The developer(s) must have authority to pledge the population.

[89] See: http://osseeds.org/wp-content/uploads/2016/03/Open-Source-Seed-Initiative-Variety-Designation-agreement-v10-2-25-16.pdf

(4) Heirlooms are not considered pledge-able at this time, due to availability from multiple sources and difficulties in determining a breeder.

(5) Genetically modified crops are not considered pledge-able at this time.

(6) Future prospects may include numerous, locally adapted ‘OSSIs.’ These would utilize the ‘universal model’ of open-source but adapt the governance and inclusion criteria to specific local/indigenous priorities and needs.

OSSI recognizes that what is ‘new’ has been a long-time debate for farmers, breeders, and the seed industry. Current OSSI guidelines are mostly oriented to the US context where the definition of ‘new’ is selected from a heterogeneous population, often via mating of at least two parent varieties. However, OSSI recognizes that such criteria will not be relevant or appropriate globally.

In my interviews with OSSI members, they express willingness and excitement to ‘work with indigenous groups to develop their own form of open source that would work for them, understanding that no individual can lay claim and that it has been a community effort, sometimes over centuries.’ While the circumstances within which they are currently working is less along these lines, they believe there are many ways ‘we can support these efforts or discuss what the core of ‘freed seed’ means in the many different indigenous contexts.’

APPENDIX 4. Popular Articles Based on Dissertation Research

Montenegro de Wit, Maywa. 2016c. 'Banking on Wild Relatives.' *Gastronomica*: The Journal of Food and Culture 16(1): 6-14. (PDF online here)

Montenegro de Wit, Maywa. 2016d. 'CRISPR is Coming to Agriculture.' *Ensia Magazine*, January 28.

Montenegro de Wit, Maywa. 2016e. 'How CRISPR Works.' *Ensia Magazine*, January 28.

*Note: *Gastronomica* is peer-reviewed but also caters to and reaches a wider popular audience.