

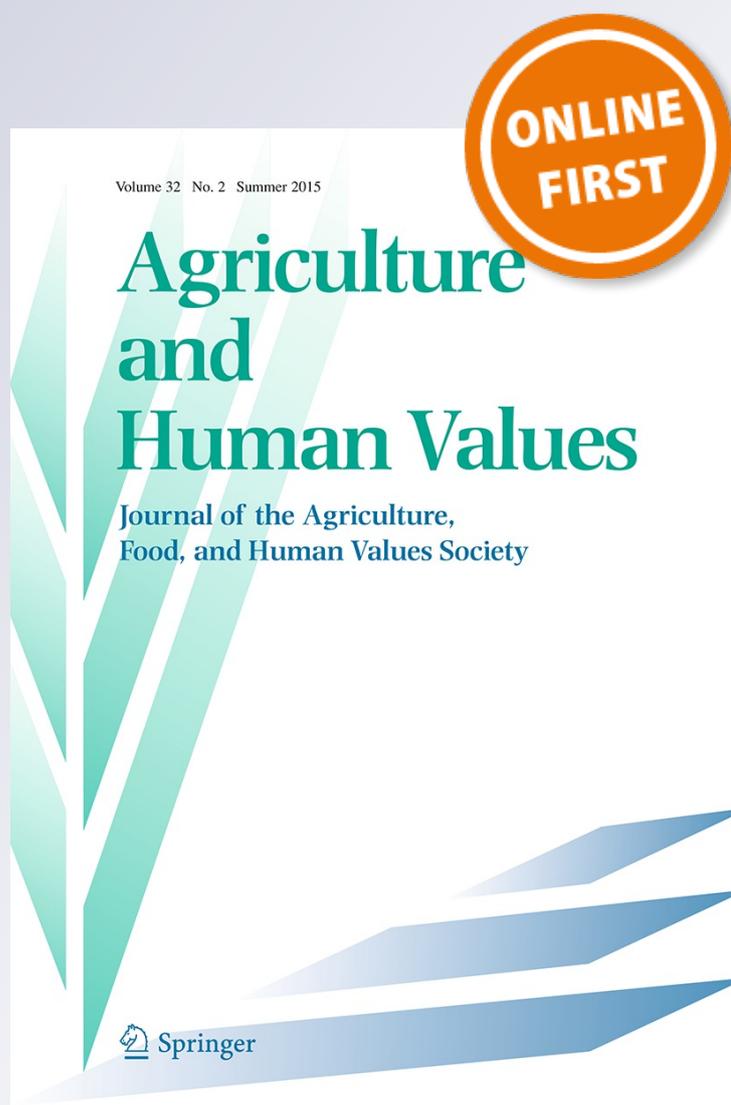
Are we losing diversity? Navigating ecological, political, and epistemic dimensions of agrobiodiversity conservation

Maywa Montenegro de Wit

Agriculture and Human Values
Journal of the Agriculture, Food, and
Human Values Society

ISSN 0889-048X

Agric Hum Values
DOI 10.1007/s10460-015-9642-7



Your article is protected by copyright and all rights are held exclusively by Springer Science +Business Media Dordrecht. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your article, please use the accepted manuscript version for posting on your own website. You may further deposit the accepted manuscript version in any repository, provided it is only made publicly available 12 months after official publication or later and provided acknowledgement is given to the original source of publication and a link is inserted to the published article on Springer's website. The link must be accompanied by the following text: "The final publication is available at link.springer.com".

Are we losing diversity? Navigating ecological, political, and epistemic dimensions of agrobiodiversity conservation

Maywa Montenegro de Wit¹

Accepted: 7 July 2015

© Springer Science+Business Media Dordrecht 2015

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

Abbreviations

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

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 2013 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

✉ Maywa Montenegro de Wit
maywa@berkeley.edu

¹ Department of Environmental Science, Policy, and Management, University of California Berkeley, 130 Mulford Hall, Berkeley, CA 94720, USA

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, p. 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 asparagus (*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])¹ 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, p. 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,

¹ The *International Affairs* paper (Thrupp 2000) is based on a larger World Research Institute report (1998) by the same author. The paper compiles biodiversity data from several sources, including Shiva (1991) and Hussein (1994), the origins of the statistics described here. See references for full bibliography.

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 it—which is a tricky matter. We must first define ‘agrobiodiversity,’ and 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.’² 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 (Graeb 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’³ within the always changing ecosystem, and ‘artificial selection’⁴ 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, p. 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 differentiate on a world scale. “The result,” Brush notes, “is a legacy of genetic resources that today feeds billions of humans” (Brush 2000, p. 3).

² 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).

³ 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.

⁴ 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, pp. 177–178; original emphasis)”.

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 Naltet—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 SNPs⁵—now enable researchers to assemble a picture of the extent and distribution of

⁵ 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

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.

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.'⁶ 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),

Footnote 5 continued
sequence variations occurring commonly (e.g. 1%) within a population.

⁶ 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). For crops, 'on-farm' is a frequent synonym for in situ, while for semi-domesticated and wild relatives, in situ consists of non-farm habitat. Yet *where* species developed their distinctive properties may be extraordinarily difficult to ascertain, given migrations and interbreeding across time and space (Fowler 2013).

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 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.⁷ The Trust, in turn, is funded by a consortium of public and private entities, with primary moneys coming

⁷ 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).

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.⁸ Indeed, the Crop Trust operates with an 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.⁹

In 2006, the Crop Trust was recognized as an “essential element” of the International Plant Treaty's¹⁰ funding

⁸ 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, p. 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, p. 25).

⁹ Four corporate donors—Dupont Pioneer Hi-bred, Syngenta AG, Australia Grains Research and Development Corporation, and Kleinwanzlebener Saatzzucht (KWS) AG—have donated a sum of \$7,030,000 to the Trust as of January 21, 2015 (see funding report: GCDT 2014).

¹⁰ 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).

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, p. 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 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)¹¹

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 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 Columbia, Agri-Food Canada, Dow, and Monsanto, among others¹²—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

¹¹ 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).

¹² 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/nrpo3 for full author list.

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’—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.¹³

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” (p. 107).

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 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.

¹³ 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).

Ethiopia's eclectic portrait of loss and persistence frustrates easy attempts to categorize. It insists on appreciation of unique geographies, linguistic cultures, and their co-evolution. 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 an event 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, p. 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 Agricultural 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, p. 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 gene-banked 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,¹⁴ 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 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.

¹⁴ 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.

Acknowledgments I am deeply grateful to Alastair Iles, Annie Shattuck, and Liz Carlisle for comments on earlier drafts of this article, and to Nathan Sayre’s UC Berkeley Geography lab for an excellent round of critical feedback. An anonymous reviewer provided insightful suggestions to hone the argument. This research was funded by a Graduate Research Fellowship from the National Science Foundation. Like all of my work, it carries forward the spirit and knowledge of Inti Montenegro de Wit, my seed.

References

- Alcorn, J.B. 1984. Development policy, forests, and peasant farms: Reflections on Huastec-managed forests’ contributions to commercial production and resource conservation. *Economic Botany* 38(4): 389–406.
- Altieri, M.A., and L. Merrick. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany* 41(1): 86–96.
- Alvarez, N., E. Garineb, C. Khasahc, E. Douniasd, M. Hossaert-McKeya, and D. McKeya. 2005. Farmers’ practices, meta-population dynamics, and conservation of agricultural biodiversity on-farm: A case study of sorghum among the Duupa in Sub-Saharan Cameroon. *Biological Conservation* 121: 533–543.
- Assefa, K., T. Hailu, M. Arnulf, K. Tiruneh, and H. Fufa. 2001. Quantitative trait diversity in tef [*Eragrostis tef* (Zucc.) Trotter] germplasm from central and northern Ethiopia. *Genetic Resources and Crop Evolution* 48: 53–61.
- Baragona, S. 2014. Global diets growing similar. Voice of America, March 3. <http://www.voanews.com/content/global-diets-growing-similar/1863397.html>. Accessed 23 Mar 2015.
- Baymetov, K.I., S.N. Rajametov, and P.T. Nazarov. 2009. Raznoobrazie i sokhranenie mestnikh sortovabrikosa v fermerskikh khozyaistvakh. (Diversity and conservation of local varieties of apricot on farms). *Materials of the republican scientific-practical, conference on “Conservation and sustainable use of biodiversity of agricultural crops and their wild relatives”*, 15–18. Tashkent: Uzbekistan (in Russian).
- Bellon, M.R., and J.E. Taylor. 1993. Folk soil taxonomy and the partial adoption of new seed varieties. *Economic Development and Cultural Change* 41(4): 763–786.
- Bellon, M.R., J.L. Pham, and M.T. Jackson. 1997. Genetic conservation: A role for rice farmers. In *Plant conservation: The in situ approach*, ed. J.G. Hawkes, 263–289. The Netherlands: Springer.
- Bezançon, G., J.L. Pham, M. Deu, Y. Vigouroux, F. Sagnard, C. Mariac, I. Kapran, A. Mamadou, B. Gérard, J. Ndjeunga, and J. Chantreau. 2009. Changes in the diversity and geographic distribution of cultivated millet (*Pennisetum glaucum* (L.) R. Br.) and sorghum (*Sorghum bicolor* (L.) Moench) varieties in Niger between 1976 and 2003. *Genetic Resources and Crop Evolution* 56(2): 223–236.
- Bioversity International. 2014. Bioversity International’s 10-year strategy 2014–2024. <http://www.bioversityinternational.org/e-library/publications/detail/bioversity-internationals-10-year-strategy-2014-2024/>. Accessed 6 June 2014.
- Bisht, I.S., P.S. Mehta, and D.C. Bhandari. 2007. Traditional crop diversity and its conservation on-farm for sustainable agricultural production in Kumaon Himalaya of Uttaranchal state: A case study. *Genetic Resources and Crop Evolution* 54(2): 345–357.
- Brown, A.H.D., and C.L. Brubaker. 2002. 24 Indicators for sustainable management of plant genetic resources: How well are we doing? In *Managing plant genetic diversity*. New York, NY: CABI.

- Brown, A.H.D., and T. Hodgkin. 2007. Measuring, managing, and maintaining crop genetic diversity on farm. In *Managing biodiversity in agricultural ecosystems*, ed. D.I. Jarvis, C. Padoch, and H.D. Cooper, 13–33. Rome, Italy: International Plant Genetic Resources Institute.
- Brush, S.B. 1991. A farmer-based approach to conserving crop germplasm. *Economic Botany* 45(2): 153–165.
- Brush, S.B. 2000. *Genes in the field: On-farm conservation of crop diversity*. Boca Raton, London, New York, Washington, DC: Lewis Publishers, International Development Research Centre.
- Brush, S.B., R. Kesselli, R. Ortega, P. Cisneros, K. Zimmerer, and C. Quiros. 1995. Potato diversity in the Andean center of crop domestication. *Conservation Biology* 9(5): 1189–1198.
- Brush, S.B. 2004. *Farmers' bounty: Locating crop diversity in the contemporary world*. New Haven, CT: Yale University Press.
- CBD. 1992. Text of the convention on biological diversity. <https://www.cbd.int/convention/text/default.shtml>. Accessed 6 July 2015.
- Collins, W.W., and C.O. Qualset (eds.). 1998. *Biodiversity in agroecosystems*. Boca Raton, FL: CRC Press.
- Darwin, C. 1875. The variation of animals and plants under domestication. 2nd ed. London: John Murray. http://darwin-online.org.uk/EditorialIntroductions/Freeman_VariationunderDomestication.html Accessed 18 July 2015.
- Dempewolf, H., R.J. Eastwood, L. Guarino, C.K. Houry, J.V. Müller, and J. Toll. 2014. Adapting agriculture to climate change: A global initiative to collect, conserve, and use crop wild relatives. *Agroecology and Sustainable Food Systems* 38(4): 369–377.
- FAO. 1997. The state of the world's plant genetic resources for food and agriculture. Rome, Italy: FAO. <http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/sow/en/>. Accessed 6 July 2015.
- FAO. 2010. The second report on the state of the world's plant genetic resources for food and agriculture. Commission on Genetic Resources for Food and Agriculture of the Food and Agriculture Organization of the United Nations, Rome, Rome, Italy: FAO. <http://www.fao.org/docrep/013/i1500e/i1500e00.htm>. Accessed 29 July 2015.
- FAO. 2014. *The state of food and agriculture: Innovation in family farming*. Rome, Italy: FAO.
- FAO. 2015. Dimensions of need—staple foods: What do people eat? Rome, Italy: FAO. <http://www.fao.org/docrep/u8480e/u8480e07.htm>. Accessed 12 Feb 2015.
- Fowler, C. 2013. Complementarity and conflict: In situ and ex situ approaches to conserving plant genetic resources. In *Seeds of resistance, seeds of hope: Place and agency in the conservation of biodiversity*, ed. V.D. Nazarea, R.E. Rhoades, and J. Andrews-Swann, 196–213. Tucson, AZ: University of Arizona Press.
- Fowler, C., and P.R. Mooney. 1990. *The threatened gene: Food, politics and the loss of genetic diversity*. Cambridge, MA: Lutterworth.
- Frankel, O.H., A.H.D. Brown, and J.J. Burdon. 1995. *The conservation of plant biodiversity*. Cambridge, UK: Cambridge University Press.
- GCDT (Global Crop Diversity Trust). 2012a. Who we are | Global Crop Diversity Trust. (Live site last accessed 9 Jan 2015). <https://web.archive.org/web/20141116152152/http://www.croptrust.org/content/who-we-are>. Accessed 18 July 2015.
- GCDT. 2012b. What we do | Global Crop Diversity Trust. (Live site last accessed 9 Jan 2015). <https://web.archive.org/web/20140717051050/http://www.croptrust.org/content/what-we-do-0>. Accessed 18 July 2015.
- GCDT. 2012c. Our Mission | Global Crop Diversity Trust. (Live site last accessed 9 Jan 2015). <https://web.archive.org/web/20150113222533/http://www.croptrust.org/content/our-mission>. Accessed 18 July 2015.
- GCDT. 2013a. Global Crop Diversity Trust fundraising strategy: 2014–2018. Global Crop Diversity Trust.
- GCDT. 2013b. Global Crop Diversity Trust strategic work plan: 2014–2024. Global Crop Diversity Trust.
- GCDT. 2014. Global Crop Diversity Trust funding status 2014–2012. Global Crop Diversity Trust. <https://www.croptrust.org/about-crop-trust/donors/funds-raised/>. Accessed 18 July 2015.
- GCDT. 2015a. What we do—Crop Trust. <https://www.croptrust.org/what-we-do/>. Accessed 23 March 2015.
- GCDT. 2015b. Putting crop diversity to work—developing the global system, January 16. <https://www.croptrust.org/event/first-global-stakeholder-discussion/>. Accessed 23 Mar 2015.
- GCDT. 2015c. Towards greater efficiency and sustainability—international crop diversity collections. January 16. <https://www.croptrust.org/event/first-global-stakeholder-discussion/>. Accessed 23 Mar 2015.
- Goldman, M. 2005. *Imperial nature: The World Bank and struggles for social justice in the age of globalization*. Yale Agrarian Studies Series. New Haven, CT; London: Yale University Press.
- Graddy, T.G. 2013. Regarding biocultural heritage: In situ political ecology of agricultural biodiversity in the Peruvian Andes. *Agriculture and Human Values* 30(4): 587–604.
- Graeb, B.E., M.J. Chappell, H. Wittman, S. Ledermann, R.B. Kerr, and B. Gemmill-Herren. 2015. The state of family farms in the world. *World Development*. <http://www.sciencedirect.com/science/article/pii/S0305750X15001217>.
- Guzmán, F.A., H. Ayala, C. Azurdia, M.C. Duque, and M.C. de Vicente. 2005. AFLP assessment of genetic diversity of genetic resources in Guatemala. *Crop Science* 45(1): 363–370.
- Hanski, I., and D. Simberloff. 1997. *Metapopulation approach, its history, conceptual domain, and application to conservation in metapopulation biology*, eds. I. Hanski and M.E. Gilpin, 1–26. San Diego, CA: Academic Press.
- Hanski, I. 2010. The theories of island biogeography and metapopulation dynamics: Science marches forward, but the legacy of good ideas lasts for a long time. In *The theory of island biogeography revisited*, ed. J.B. Losos, and R.E. Ricklefs, 186–213. New Jersey: Princeton University Press.
- Harris, D.R., and G.C. Hillman, eds. 2015 [1989]. *Foraging and farming: The evolution of plant exploitation*. 2nd ed. New York, NY: Routledge.
- Heywood, V.H., and M.E. Dulloo. 2005. *In situ conservation of wild plant species: A critical global review of good practices*. Rome: Bioversity International.
- Hodgkin, T., R. Rana, J. Tuxill, D. Balma, A. Subedi, I. Mar, D. Karamura, et al. 2007. Seed systems and crop genetic diversity in agroecosystems. In *Managing biodiversity in agricultural ecosystems*, ed. D.I. Jarvis, C. Padoch, and H.D. Cooper. New York, NY: Bioversity International and Columbia University Press.
- Hussein, M. 1994. Regional focus news: Bangladesh. Ecology and Farming: Global Monitor, International Federation of Organic Movements (IFOAM) January, p. 20.
- Huamán, Z. 1986. Conservation of potato genetic resources at CIP. *Centro Internacional de la Papa Circular* 14: 1–7.
- Jarvis, D.I., V. Zoes, D. Nares, and T. Hodgkin. 2004. On-farm management of crop genetic diversity and the convention on biological diversity's programme of work on agricultural biodiversity. *Plant Genetic Resources Newsletter* 138: 5–17.
- Jarvis, D.I., A.H.D. Brown, P.H. Cuong, L. Collado-Panduro, L. Latournerie-Moreno, S. Gyawali, T. Tanto, et al. 2008. A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. *Proceedings of the National Academy of Sciences* 105(14): 5326–5331.

- Jarvis, D.I., T. Hodgkin, B.R. Sthapit, C. Fadda, and I. Lopez-Noriega. 2011. An heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. *Critical Reviews in Plant Sciences* 30(1–2): 125–176.
- Kebebew, F., Y. Tsehay, and T. McNeilly. 2001. Morphological and farmers cognitive diversity of barley (*Hordeum vulgare* L. [Poaceae]) at Bale and North Shewa of Ethiopia. *Genetic Resources and Crop Evolution* 48(5): 467–481.
- Khoury, C.K., A.D. Bjorkman, H. Dempewolf, J. Ramirez-Villegas, L. Guarino, A. Jarvis, L.H. Rieseberg, and P.C. Struik. 2014. Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences* 111(11): 4001–4006.
- Kingsbury, N. 2011. *Hybrid: The history and science of plant breeding*. Chicago, IL: University of Chicago Press.
- Kloppenborg, J.R. 2004 [1988]. *First the seed: The political economy of plant biotechnology, 1492–2000*. 2nd ed. Madison, WI: University of Wisconsin Press.
- Lappé, A. 2014. Yes, Organic Farming Can Feed the World. TakePart, November 4. <http://www.takepart.com/article/2014/11/04/organic-food-world>. Accessed 21 Mar 2015.
- McCouch, S., G.J. Baute, J. Bradeen, P. Bramel, P.K. Bretting, E. Buckler, J.M. Burke, et al. 2014. Agriculture: Feeding the future. *Nature* 499(7456): 23–24.
- Magurran, A.E. 2003. *Measuring biological diversity*. Oxford, UK: Blackwell.
- Marx, K. 1977. *Capital*, vol. 1. New York, NY: Vintage Books.
- Monsanto. 2014. Monsanto delivers year of strong growth on performance of global seeds and traits portfolio: Foundation set for continued growth in FY15 and over multi-year horizon, October 8. <http://news.monsanto.com/press-release/financial/monsanto-delivers-year-strong-growth-performance-global-seeds-and-traits-por>. Accessed 3 Mar 2015.
- MSB. 2015. Royal Botanical Gardens Kew: Millennium Seed Bank statistics. <http://www.kew.org/science-conservation/save-seed-prosper/millennium-seed-bank/about-the-msb/msb-seed-count/seed-count-in-detail/index.htm>. Accessed 20 Feb 2015.
- Murphy, D.J. 2007. *Plant breeding and biotechnology: Societal context and the future of agriculture*. Cambridge; New York: Cambridge University Press.
- Nabhan, G.P. 1979. Cultivation and culture. *Ecologist* 9(8/9): 4.
- Nabhan, G.P. 1989. *Enduring seeds: Native American agriculture and wild plant conservation*. Tucson, AZ: University of Arizona Press.
- Nabhan, G.P. 2009. *Where our food comes from: Retracing Nikolay Vavilov's quest to end famine*. Washington, DC: Island Press.
- Nazarea, V.D. 2013. Temptation to hope: from the “idea” to the milieu of biodiversity. In *Seeds of resistance, seeds of hope: Place and agency in the conservation of biodiversity*, ed. V.D. Nazarea, R.E. Rhoades, and J. Andrews-Swann, 19–41. Tucson, AZ: University of Arizona Press.
- Norgaard, R.B. 1988. The rise of the global exchange economy and the loss of biological diversity. In *Biodiversity*, ed. E.O. Wilson, 206–211. Washington, DC: National Academies Press.
- Nuijten, E., and C.J.M. Almekinders. 2008. Mechanisms explaining variety naming by farmers and name consistency of rice varieties in the Gambia. *Economic Botany* 62(2): 148–160.
- Orlove, B.S., and S.B. Brush. 1996. Anthropology and the conservation of biodiversity. *Annual Reviews of Anthropology* 25: 329–352.
- Perfecto, I., J. Vandermeer, and A. Wright. 2009. *Nature's matrix: Linking agriculture, conservation and food sovereignty*. London: Earthscan.
- Perfecto, I., and J. Vandermeer. 2010. The agroecological matrix as alternative to the land-sparing/agriculture intensification model. *Proceedings of the National Academy of Sciences* 107(13): 5786–5791.
- Poudel, D., B. Sthapit, and P. Shrestha. 2015. An analysis of social seed network and its contribution to on-farm conservation of crop genetic diversity in Nepal. *International Journal of Biodiversity* 2015: 1–13.
- Prescott-Allen, R., and C. Prescott-Allen. 1981. *In situ conservation of crop genetic resources: A report to the International Board for Plant Genetic Resources*. Rome: IBPGR.
- Prescott-Allen, R., and C. Prescott-Allen. 1982. The case for in situ conservation of crop genetic resources. *Nature and Resources (UNESCO)* 23: 15–20.
- Qualset, C.O., and H. Shands. 2005. *Safeguarding the future of US agriculture: The need to conserve threatened collections of crop diversity worldwide*. Davis, CA: University of California Genetic Resources Conservation Program.
- Sadiki, M., D.I. Jarvis, D. Rijal, J. Bajracharya, N.N. Hue, T.C. Camacho-Villa, L.A. Burgos-May, et al. 2007. Variety names: An entry point to crop genetic diversity and distribution in agroecosystems? In *Managing biodiversity in agricultural ecosystems*, ed. D.I. Jarvis, C. Padoch, and H.D. Cooper, 34–76. New York, NY: Columbia University Press.
- Sagnard, F., A. Barnaud, M. Deu, C. Barro, C. Luce, C. Billot, J.F. Rami, S. Bouchet, D. Dembele, V. Pomies, C. Calatayud, R. Rivallan, H. Joly, K. vom Brocke, A. Toure, J. Chantereau, G. Bezançon, and M. Vaksman. 2008. Multi-scale analysis of sorghum genetic diversity: Understanding the evolutionary processes for in situ conservation (Special issue: Agrobiodiversities). *Cahiers Agricultures* 17(2): 114–121.
- Scott, J.C. 1998. *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.
- Shiva, V. 1991. The green revolution in the Punjab. *The Ecologist* 21(2): 57–60.
- Subedi, A., P. Chaudhary, B.K. Baniya, R.B. Rana, R.K. Tiwari, D.K. Rijal, B.R. Sthapit, and D.I. Jarvis. 2003. Who maintains crop genetic diversity and how? Implications for on-farm conservation and utilization. *Culture and Agriculture* 25(2): 41–50.
- Thrupp, L.A. 1998. *Cultivating diversity: Agrobiodiversity and food security*. Washington, USA: World Resources Institute.
- Thrupp, L.A. 2000. Linking agricultural biodiversity and food security: The valuable role of sustainable agriculture. *International Affairs (Royal Institute of International Affairs 1944)* 76(2):265–281.
- van der Ploeg, J.D. 2008. *The new peasantries: Struggles for autonomy and sustainability in an era of empire and globalization*. London: Earthscan.
- van der Ploeg, J.D. 2014. Peasant-driven agricultural growth and food sovereignty. *The Journal of Peasant Studies* 41(6): 999–1030.
- Veteto, J.R., G.P. Nabhan, R. Fitzsimmons, K. Routson, and D. Walker, eds. 2011. *Place-based foods of Appalachia: From rarity to community restoration and market recovery*. Tucson: University of Arizona Southwest Center.
- Walsh, B. 2014. Our global diet is becoming increasingly homogenized—and that's risky. Time, March 4. <http://time.com/12366/global-diet-becomes-homogenized/>. Accessed 23 Mar 2015.
- Wilkes, G. 1991. In situ conservation of agricultural systems. In *Biodiversity: Culture, conservation and ecodesign*, ed. M.L. Oldfield, and J.B. Alcorn, 86–101. Boulder, CO: Westview.

Maywa Montenegro de Wit is a Ph.D. candidate at the University of California, Berkeley. Trained in molecular and microbiology at Williams College, she investigated mechanisms of gene transfer between bacteria and plants before shifting gears to study science journalism at MIT. At Berkeley, she combines political ecology, geography, and STS perspectives in research on agrobiodiversity and the politics of access to seed. This work informs and reflects her broader research interests in agroecology, food sovereignty, and theories of transition to sustainable food systems.