Land Report

Number 132, Spring 2022 · The Land Institute

About The Land Institute

MISSION STATEMENT
When people, land and community are as one, all three members prosper; when they relate not as members but as competing interests, all three are exploited. By consulting nature as the source and measure of that membership, The Land Institute seeks to develop an agriculture that will save soil from being lost or poisoned, while promoting a community life at once prosperous and enduring.

OUR WORK
Thousands of new perennial grain plants live year-round at The Land Institute, prototypes we developed in pursuit of a new agriculture that mimics natural ecosystems. Grown in polycultures, perennial crops require less fertilizer, herbicide and pesticide. Their root systems are massive. They manage water better, exchange nutrients more efficiently and hold soil against the erosion of water and wind. This strengthens the plants' resilience to weather extremes, and restores the soil's capacity to hold carbon. Our aim is to make conservation a consequence, not a casualty, of agricultural production.

LAND REPORT
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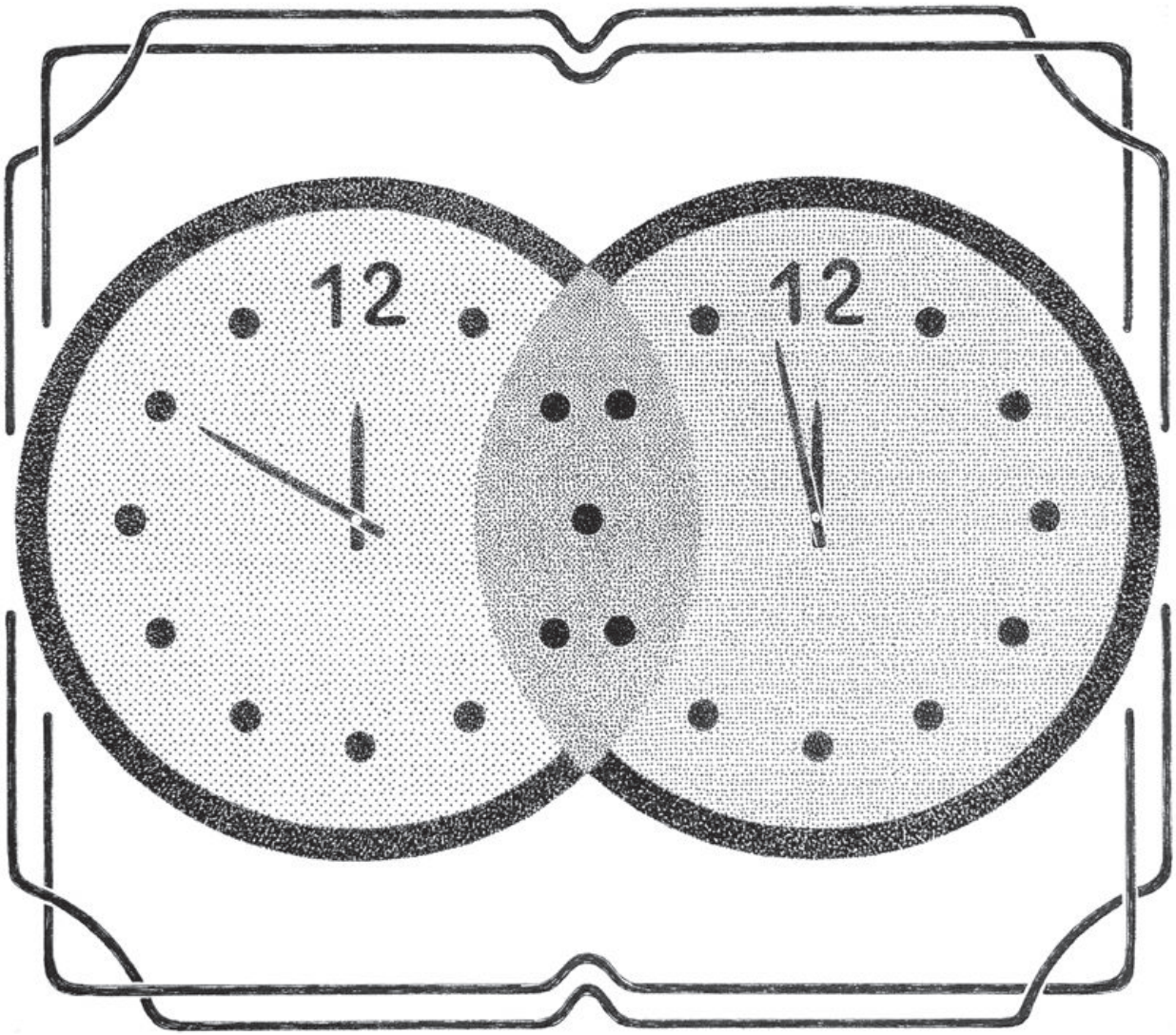
Cover

Which door: we face critical choices not only to stem climate change but to maintain our democracy – they go together. See Stan Cox's essay on page 4. Photo of barn southeast of Wichita, Kansas, by Scott Bontz.

Preparing young clover leaves for measurement that might enable prediction of how the adult plant will grow – and so speed selection for breeding. See the story on page 18. Scott Bontz photo.



CLIMATE CHANGE TIME DEMOCRACY TIME

We have ten years to quit fossil fuels and check ecological meltdown, and only two years to save our union from autocracy that will fiddle while the world burns. Pen-and-ink drawing by Priti Gulati Cox.

We the People and climate change

The fate of the ecosphere depends on keeping our democracy

STAN COX

In the United States of 2022, we find ourselves living in the shadows of two terrifying prospects: one, that continued abuse of the ecosphere could render much of the Earth unlivable and, two, that our current political drift toward autocratic rule could accelerate, dashing any hope of attaining a just, pluralistic democracy. These crises are intertwined. Either we find meaningful responses to both, or we fail dramatically on both.

We have known for decades that urgent action is required to prevent ecological catastrophe, but the United States has frittered those years away. Time after time, legislation aimed at suppressing greenhouse-gas emissions, curbing the die-off of biodiversity, or halting the disruption of other critical Earth systems has been pronounced dead on arrival in Washington out of fear that it would interfere with economic growth. And we are far from alone in this among the affluent nations.

We could do our fair share for a global effort to achieve steep greenhouse-gas reductions by placing statutory caps on oil, fossil gas, and coal use, with the caps ratcheting down quickly, year by year, to zero. Our government, however, has come nowhere close to adopting such policies. The recent record is especially dismal. We saw a 17 percent increase in coal-powered electric generation in 2021, and analysts expect US oil extractors to pump out a record-high 4.5 billion barrels next year.

There's no help in sight. Drilling continues on public lands, and new offshore oil and gas leases are still being handed out. Climate legislation now languishing in Congress, if passed, would only nibble around the edges of the emergency; most egregiously, it doesn't provide for phasing out the use of fossil fuels.

Our institutions have failed us in large ways and small, but we now face the possibility of a broader systemic breakdown. Many sober-minded elected officials, scholars, analysts, and others are raising ever-louder alarms over the precarious state of representative democracy itself. And if that crumbles, the opportunity to achieve effective government action, not only for climate but for a host of other issues on which we have long fallen short – general ecological degradation, Indigenous rights, economic and racial justice, health, food and agriculture, women's rights, workers' rights, and, crucially, universal voting rights – will quickly slip even further out of reach.

Terra incognita

Scholars who study the decline of democracies are warning that the Capitol attack of January 6, 2021, was not the culmination of a coup attempt but just one especially dramatic moment in a years-long effort by right-wing, pro-authoritarian elements in our government and throughout society at

large to exploit constitutional vulnerabilities and weak voting-rights laws to subvert elections. Their intent is to extend their control over state governments, gain full control of all three federal branches of government, and put laws in place to consolidate their power for many years to come.

In the news media, this subversion of the political process is often discussed as if it's no more than a feud recently erupting between the two major parties, with reports often taking on the tone of sports coverage. In reality, it's a grave struggle pitting our already damaged democracy against an attempted autocratic takeover, it has been building for decades, and it is now coming to a head within government and throughout society at large.

The historian Thomas Zimmer wrote recently that the US right wing's "allegiance has never been to democratic ideals – their acceptance of democracy was always conditional and depending entirely on whether or not it would be set up in way that allowed for the forces of multiracial pluralism to be kept in check." In recent years, Zimmer argues, "the lack of legitimacy for the restricted white elite version of democracy" – the system we have lived under all our lives – has become too stark to ignore. A solid majority of voters now find that hoary old version of democracy to be wholly unacceptable, so candidates who oppose pluralism find it harder and harder to prevail in properly conducted elections. Therefore, Zimmer concludes, "America will either slide into authoritarianism or make the leap to multiracial, pluralistic democracy."

The verbs Zimmer uses convey the challenge we face: if we don't take a bold "leap" toward the multiracial democracy that America has so far failed to achieve, we will "slide" inexorably into an autocratic future. The current version of democracy – of, by, and for only some of the people – cannot hold together much longer.

In 2022, the Stockholm-based International Institute for Democracy and Electoral Assistance moved the United States for the first time out of the "democracy" category, classifying us instead as a "backsliding democracy". In 2020, the Center for Systemic Peace downgraded the United States' status from "democracy" to "anocracy", the latter term signifying a nation in limbo between democracy and autocracy. CSP edged us back, just barely, into the "democracy" portion of their scale in early 2022. Nevertheless, warned the historian Barbara Walter, "We could easily slip back into anocracy" and from there, she wrote, in an echo of Zimmer's analysis, things could go either way: "Anocracy is usually transitional – a repressive government allows reforms, or a democracy begins to unravel – and it is volatile."

A crucial two years

There couldn't be a worse time for our nation to succumb to the forces of authoritarianism. Projections by international panels of scientists who track climate change are pointing to a stark conclusion: actions we take in the next ten or so years will largely determine whether a future catastrophic heating of the Earth can be prevented. One could now argue that in the United States, the climate movement faces an even shorter deadline. Given the anti-democracy camp's love of fossil fuels and hostility toward climate mitigation, the question of whether or not we will have an opportunity even to work for and achieve necessary federal legislation within the next decade or two could be decided within just the next two years or so.

Ambitious climate action remains an absolute necessity, and that action must

Erosion in a field of annual crops southeast of The Land Institute. Work to bring human activity into harmony with the rest of the ecosphere must carry on, whatever the sociopolitical context. Scott Bontz photo.

now include preventing, if we can, the ascendance to power of a federal/state regime under which laws and regulations ensuring climate mitigation and justice – or for that matter, any kind of mitigation or justice – are simply not achievable. Prospects not only for effective climate action but also for defense of other planetary boundaries, as well as Indigenous sovereignty, economic, racial, gender, and environmental justice, and other crucial necessities, could very well hinge on efforts to head off the consolidation of autocratic rule in the coming few years. Can we continue to strive for a just ecological civilization whether we are living under a pluralistic, multiracial democracy or an autocracy?

There is a lot of ferment out there right now, and no one can predict how events will unfold. With vigorous mobilization and hard work, we and our institutions may manage to make that leap toward a more pluralistic democracy. But with so many warning lights flashing, I believe we also need to be discussing how we can live and act if and when we find ourselves living under an authoritarian government. Such a discussion will be productive whether or not the pro-democracy camp wins out in the end, because we need to prepare for the social-ecological transformation that has been so long delayed – whichever path our polity takes in the months and years to come.

I'm among those who've argued that although reducing emissions and respecting ecological limits at the individual, household, and community scales is good and essential, we have so few years left for the US to eliminate fossil-fuel use that only firm, equitable federal limits can ensure that we are all playing by the same fair rules and that oil, gas, and coal use is driven down to zero quickly enough. In a society where it's still the people who decide, we will have a fighting chance to get such policies passed into law. But if the anti-democracy camp manages to take the driver's seat and shift federal climate policy into reverse, regions, states, municipalities, neighborhoods, and households all around the country will need to redouble our efforts to confront the climate emergency and preserve economic and civil rights.

The authoritarian threat we all now face will likely be regarded by our nation's marginalized communities as old news. These communities have long had to find their own way in the face of a federal government and national economy that are structured in favor of an affluent white minority. In that struggle, the communities have built mutual aid groups, food sovereignty movements, and other collective efforts. The people of the environmental justice movement, led by Black, Latino, and Indigenous communities, have been fighting toxic industries in their own backyards for decades.

Many in the climate movement are looking to Indigenous communities for leadership. For millennia, Indigenous peoples have lived in harmony with non-human nature on the vast landscapes that were stolen from them in recent centuries. They now are in the forefront on climate, standing up to the fossil fuel industry, undermining its ability to operate, and fighting off its assault on the Earth.

In coming years, if we find ourselves living not only with severe consequences of climate disruption but also without a federal government of, by, and for *all* the people, historically oppressed communities will be well positioned to lead a new ground-level transformation. Grassroots movements would naturally focus even more on local and regional approaches, but jointly they could have national effect. Greenhouse

emissions won't be eliminated as soon as is needed without a federal policy to phase out fossil fuels, but they can at least be reduced, and every one-tenth degree of atmospheric warming that's avoided will help keep the Earth a little more livable than it would be otherwise.

Existing and emerging efforts to bring human activity into harmony with the rest of the ecosphere must carry on, whatever the sociopolitical context. Efforts by The Land Institute and allies to transform food production and reverse soil degradation, biodiversity loss, and greenhouse-gas emissions can play a central role. This involves more extensive breeding of perennial grain crops, along with ecological intensification of crop production, including greater species diversity.

A tsunami for democracy

The world we see around us today, and the hyperactive economy underlying it, could not have been built and sustained without the fossil-fuel bonanza of the past century and a half. That ever-expanding material world is coming to an end, whether or not we take the leap toward full democracy and bold climate action. On the one hand, collectively doing what will be necessary in order to head off climatic calamity – including the rapid phase-out of fossil fuels – will require voluntarily ditching the quest for economic growth in favor of a quest for satisfying universal human needs and ending our assault on the non-human world. On the other hand, growth will end just as surely if the anti-democracy camp prevails, but in a very different way: sputtering out involuntarily and inhumanely, a consequence of societal breakdown and degradation of the Earth's atmosphere, lands, and waters.

If the wrong camp prevails, and those of us seeking the voluntary, humane path lose much of our ability to effect change through the ballot box or public service, grassroots climate action will become more important than ever. Through nonviolent direct action, movements like the Indigenous-led pipeline struggles, Extinction Rebellion, youth climate strikes, the Sunrise Movement, etc., have helped lift climate and its broader ecological-social context, polls show, to near the top of the list of public concerns – even in the face of corporate and political hostility that is explicit, unapologetic, and at times violent.

The possibilities looming ahead may look grim, but we are not powerless bystanders capable only of gawking at events as they unfold over the next couple of years and beyond. Pro-democracy voters could, through our sheer numbers, overwhelm the anti-democracy camp's attempts to subvert the Constitution. The movements for climate mitigation and justice, Indigenous sovereignty, Black lives, economic democracy, and the Earth could merge into one big wave. Other events, unforeseeable today, also might change the landscape of possibilities in our favor.

But we don't have time to stand back, wait, and see. The clock is ticking. Will we leap or slide?

From "A Walk After Dark"

Unconscious of final ends,
As I walk home to bed,
Asking what judgment waits
My person, all my friends,
And these United States.

– W. H. Auden

Care work is understood as necessary, but it is not monetarily well rewarded, and is often rendered invisible and taken for granted. Illustration in charcoal and Affinity Photo by Lydia Nicholson.

Take care

Building soil is like doing dishes: both actions deserve our recognition and love

AUBREY STREIT KRUG

Growing up in a small town in Kansas, where my parents still farm wheat and raise cattle, I understood that humans are social beings who need each other. Only through community effort was it possible to accomplish education in the school system, religious practice through the church, the economic realities of agricultural labor from planting to harvest.

And we depended upon each other for basic needs. My grandma watched my sisters and me after school. My mom cleaned and baked and counseled a range of friends and family. Though I preferred to spend my time reading, I babysat other kids and went to my great-grandma's house to scrub her bathroom and kitchen. (She taught me to crochet, an activity I still love. The first thing I learned to make were dishrags.)

The creation and maintenance of human community requires work. *Care is work* and requires skill and effort. Care work is both relational and material. It can include doing the dishes, calmly responding to a toddler's tantrum, and remembering who needs what medicine and when. Caring for others is the necessarily repetitive work that doesn't get "done" in any final sense – it must be done over and over again for daily life to continue.

As an adult (and a parent), I've not only continued to do care work but also become more interested in seeing and studying it critically. Care work is understood as necessary, but it is not very well monetarily rewarded and is often rendered invisible and taken for granted. Though some of it is visible in professions like childcare, nursing, and teaching, much goes unseen and under-recognized. As feminist economists have demonstrated for years, care work is unevenly distributed across genders and stereotyped as feminine. The vast amount of unpaid and underpaid care work is done primarily by poor and marginalized women and girls.

All humans depend on the care work of others, and that dependency is only likely to increase in a world with less discretionary energy in the form of fossil fuels. We will need each other more than ever in the face of climate change.

For those of us working to build networks in the face of social-ecological crisis, we should seek to make visible and recognize who is doing the care work in our collaborative relationships.

In our organizations and communities, is the care work that goes into building partnerships fairly distributed, or is it primarily people of color, immigrants, and women who carry that responsibility? How are care workers and their work recognized (or not) socially and economically? How could white people and men become more willing and able to do care work and do it well? And who will do the work of teaching people

how to care well? How do we learn the skills of care work?

I feel both grief and relief at the realization of the care work needed now, at this moment in human and planetary history. Relief because undervalued but vital care work is being paid attention to; grief because paying attention to care work doesn't mean it will become valued beyond its ability to serve currently dominant social and economic systems.

In other words, it's not enough to care about care work. Even if care work is made more visible, and the people who do it are paid more, we still need to critically consider what kinds of human communities care work is creating and maintaining. Where are we directing our care?

Through the work of Leah Lakshmi Piepzna-Samarasinha and others, I've learned how the concept of justice in care work grows from ideas of disability justice. Disability, illness, and mortality are realities shared across humanity – and our human communities should not marginalize these realities or perpetuate injustices based on discrimination.

In many cases, the people taking up care work are survivors of historical trauma and ongoing structural violence, and are now bravely working to heal and flourish. For example, in North America, Indigenous peoples who have survived catastrophic and genocidal system change, and who have already experienced climate change through forced relocation, are leading ecological advocacy efforts, which depend on practices of care work.

Connecting the concept of justice to care work has helped me realize that for members of the dominant society, letting go can be an act of care. For people like me – a white person from a farming community, who has benefited from access to land, knowledge, and resources due to systems of settler colonialism and white supremacy – the work of care involves letting go of the denial of crisis and harm, and letting go of the illusion of control. It includes unlearning systems and structures that perpetuate injustices, and learning how to return homelands and make reparations to the Indigenous peoples of the continent.

I don't say these things because I have accomplished them. Rather, this is the call and challenge I hear for myself: care work must be practiced over and over again in the pursuit of more just human communities in which everyone can find a sense of belonging in place.

Through the lens of care, I am reminded that I do not live as a singular, self-made, and self-willed individual. We humans are limited, mortal beings. We exist and persist through our relationships, both social and ecological. I cannot fully separate my sense of self from the people I've cared for and who have cared for me. I think of my husband's cooking, the family members who helped us carry boxes and furniture in a recent move, my sisters who always know exactly how to respond to an anxiety-fueled text message, the colleague who offered to watch my son while I was writing and taught him how to use the apple cider press at work.

And I think, not surprisingly, of the more-than-human world in which we humans are enmeshed: the ecosphere.

The ecosphere is the dynamic mantle of life on this sun-fed planet in the Milky Way – the nexus of airs, waters, rocks, and creatures whose interactions together with light make life. The ecosphere includes lithosphere, hydrosphere, atmosphere, and biosphere. To me, an ecospheric approach prioritizes integration and the particularities of process across what has often been di-

vided into static abstractions. The ecosphere is just one way to name the astonishing realization that there is indeed a dynamic mantle of life on *this* planet at *this* time in *this* galactic place – and here we are, interdependent and alive, for now.

Our understanding of care must place people in their ecological, relational context. Through being here with the rivers, prairies and fields, Mollisols, birds and bees and bindweed, I have come to realize the interconnected work of caring for the land.

We might turn and return to the ecosphere as a recipient of and participant in care work. Ecosystem processes are the supposedly "background" work of ecosystems that is necessary for Earth as ecosphere to sustain human life. Think of the cycles of nutrients, the flows of water. These ecosystem processes are vital, yet they are made invisible by our human-centered culture. We don't fully understand or properly value the intricacies of how soils form, for instance, yet soils are increasingly disturbed and degraded. Similarly, care work is the supposed "background" work of our lives and jobs

Isaiah Marcotte trains sorghum: perennial agriculture allows people to engage in care work. Scott Bontz photo.

that is necessary for communities to sustain human life, but is too often undervalued and degraded.

Perhaps care is about doing the background work of the world, and doing it with love. Except there is no background down here on the Earth. Since human communities are embedded in ecosystems and the ecosphere, we humans need both ecosystem processes and care work to continue.

Tending to gardens, laboring in fields and pastures, restoring landscapes, protecting biodiversity – these material practices could also be considered as forms of care work, practiced by humans and non-humans, supporting and enabling social practices of care and repair. For our part, we can choose where to direct our care, and how to prioritize ecosystem processes. We can learn how to do our care work both for the land and each other more skillfully and fairly and value it appropriately.

We can help build the community capacity needed to support a just transformation to diverse and perennial agricultural economies. Hands-on projects in perennial agriculture allow people to engage in such care work: to provide physical, emotional, and ethical labor to build ecological relationships with plants, animals, land, and water.

For instance, at The Land Institute I organize collaborative civic science communities, in which people grow, study, and care for future perennial grain crops. These perennial plants could someday care for people by feeding them while holding on to soil and supporting biodiversity.

Perennial agriculture is a long-term vision for positive human reconnection with the land, or ecosphere, that stretches across generations and geographies. My experience has helped me to realize that this long-term vision can be aligned with now-urgent human tasks. I have learned that serving potentially radical long-term solutions is exactly what I need to persist at this moment in time.

As I go about my daily tasks – putting on a pot of coffee, unloading and reloading the dishwasher, managing projects and emails, meeting with research collaborators, listening to a colleague and friend as we walk in the prairie, tending the plants in my home garden, reading books with my son – I can practice the skilled work of care.

I can exercise what choices I have to struggle to divest my care from exploitative systems, and to support and join with others in their work to do the same. I can come back over and over again to the humble, imperfect, ancient labor of collaboratively creating communities who care for each other and the land; and I can collaboratively help to make metaphors, experiences, relationships, opportunities, food systems, and cultures that are new.

I can slow down long enough to listen to what lasts, to remember what humans have come to know about care through much of the history of our species. And I can also move with the quick pace of courage, to face up to the consequences and choices now at hand.

Through this work of caring for other people as we together in community learn to care for perennial plants, I have started to grasp my personal answer to the question Kathleen Dean Moore and her colleagues pose: "What would you be willing to spend your whole life taking care of?"

Aubrey Streit Krug is director of Ecosphere Studies at The Land Institute. This essay is adapted from her longer article "Ecospheric Care Work", published in 2020 by The Ecological Citizen, which is available and includes more information and citations: https://www.ecologicalcitizen.net/pdfs/v03n2-09.pdf

Extracts

"Useless but indispensable." – Jean Cocteau on poetry

Grass is our flag. It whispers, "Asia,
Asia, Dakota, Dakota, Prairie, Steppe."
All over the world it leans above rivers –
Volga, Amazon, Ganges – a grass like wheat
and its friend the wind, carrying our message
everywhere, leaf by leaf.
– William Stafford, in "Globescope"

Pile the bodies high at Austerlitz and Waterloo.
Shovel them under and let me work –
I am the grass; I cover all.
– Carl Sandburg, in "Grass"

Poets
Are rich in points of view if they are rich
In anything. The farmer thinks one thing;
The poet can afford to think all things
Including what the farmer thinks, thinking
Around the farmer rather than above him,
Loving the evergreen the farmer hates,
And yet not hating him for hating it.
– Robert Francis, in "Juniper"

Who would have thought my shrivel'd heart
Could have recover'd greenness? It was gone
Quite under ground, as flowers depart
To see their mother-root when they have blown;
Where they together
All the hard weather,
Dead to the world, keep house unknown.
– George Herbert, in "The Flower"

The point in life is to know what's enough –
why envy those otherworld immortals?
– Gensei, "Poem Without a Category",
translated by Burton Watson

The law locks up both man and woman
Who steal the goose from off the common
But lets the greater felon loose,
Who steals the common from the goose.
– old English quatrain

Even those who do not know me,
if their actions are straightforward,
just, and loving, venerate me
with the truest kind of worship.
– from "The Bhagavad Gita",
translated by Stephen Mitchell

O joy! that in our embers
Is something that doth live,
That nature yet remembers
What was so fugitive!
– William Wordsworth, in "Ode"

Ask the questions that have no answers.
Invest in the millennium. Plant sequoias.
– Wendell Berry, in "Manifesto: The Mad
Farmer Liberation Front"

Odours rose from the trees,
Grapes fell from the vines,
The sand was made of gold
The pebbles were made of pearls.

'I've never seen the like', said Eve.
'Naturally', the Landlord smiled.

'It's unimaginable!' sighed Adam.
'You're not obliged to imagine it',
Snapped the Landlord. 'Yet'.
– D. J. Enright, in "Paradise Illustrated"

Most biomass of a forest – background here – or prairie – foreground – remains alive from year to year. Trees serve birds, and undisturbed soil harbors microbes that make plants more productive. The Land Institute's perennial crops – center – can be a sweet spot of biomass maintenance balanced with food production. Scott Bontz photos.

Land Report shorts

Critical mass

The word "mass", as in matter, traces to the Latin *massa*, for kneaded dough or something that adheres like dough. This might go back to a proto Indo-European verb meaning to knead or to fit. (Despite the bread it involves, Catholic mass took a different etymological path.) So, *biomass* can be more than a mashup word for science journals or a crop burned for industrial energy. Think of it meaning life that sticks together. Except that in grain agriculture it doesn't yet.

There, with annuals, every year everything dies – not just what we eat of it, but leaf, stem, and root. In biomass terms, why does this matter? Another verbal amalgam from the journals is "ecosystem services". This is when relationships develop and make for things such as conservation of soil and water, which makes for more life in the long run. Most of a forest or perennial grassland's biomass remains alive from year to year. Aboveground this means that things like trees serve as homes to birds. Belowground it means a vast array of life whose intricacy we're just learning but which clearly makes soil more secure and productive.

A recent issue of the online journal One Earth focuses on biomass, and from that perspective an essay by The Land Institute's Lee DeHaan and David Van Tassel makes another argument for perennial grain crops. They note that we humans have come to

take about a quarter of the mass that Earth's land plants grow each year, and that we might be taking a third of it by 2050. The results of this conversion from forests and grasslands have been catastrophic, frequently beginning with severe soil erosion followed by land denudation. That's why the US government instituted the Conservation Reserve Program to protect erodible cropland using perennial plants. DeHaan and Van Tassel compare growing annual wheat with perennial grassland hay. The same amount of protein-building nitrogen comes off each field, despite the hay field getting no fertilizer. The hay exports more than half again as much biomass but uses less than a tenth of the energy used to grow the wheat. Soil carbon and nitrogen are 30 percent higher in the hay field, root carbon more than six times higher. This efficiency is why the industry aiming to make fuel from biomass has moved from maize, an annual, to perennial grasses and trees.

But people can eat little of this kind of biomass. Van Tassel and DeHaan consider more than one solution. One is the "biorefinery", which would do for humans what the rumen does for cattle – enable us to digest leaves. Labs have recently made plant seeds and oils taste like meat, but converting the indigestible molecules that make up so much of a plant, eliminating parts that hinder digestion, and concentrating proteins – these are daunting challenges for biochemistry and engineering. What about fruits and nuts from trees? These provide less than 10 percent of human calories, nowhere near the 70 percent coming from grains, and the cost is high because of years before the first crop and then special harvest techniques. With enough money for research, these paths could fill the current role of grains in our food. But the cost would be high and the dietary change possibly extreme.

Our palettes would need little adaptation to perennial grains. The research to achieve them would cost less, and their soil carbon, soil health, and nutrient cycling would be on par with the alternatives, DeHaan and Van Tassel say. The biomass would not turn over as slowly as in forest, the endpoint of ecological development where there's enough rain. But the "mid-successional" ecology of herbaceous perennials like those in a grassland can be a sweet spot of biomass maintenance balanced with food production. And until perennial grains, now in early commercial production, become widespread, farms can improve matters by growing annual grains amid low perennial ground covers like nitrogen-fixing clover.

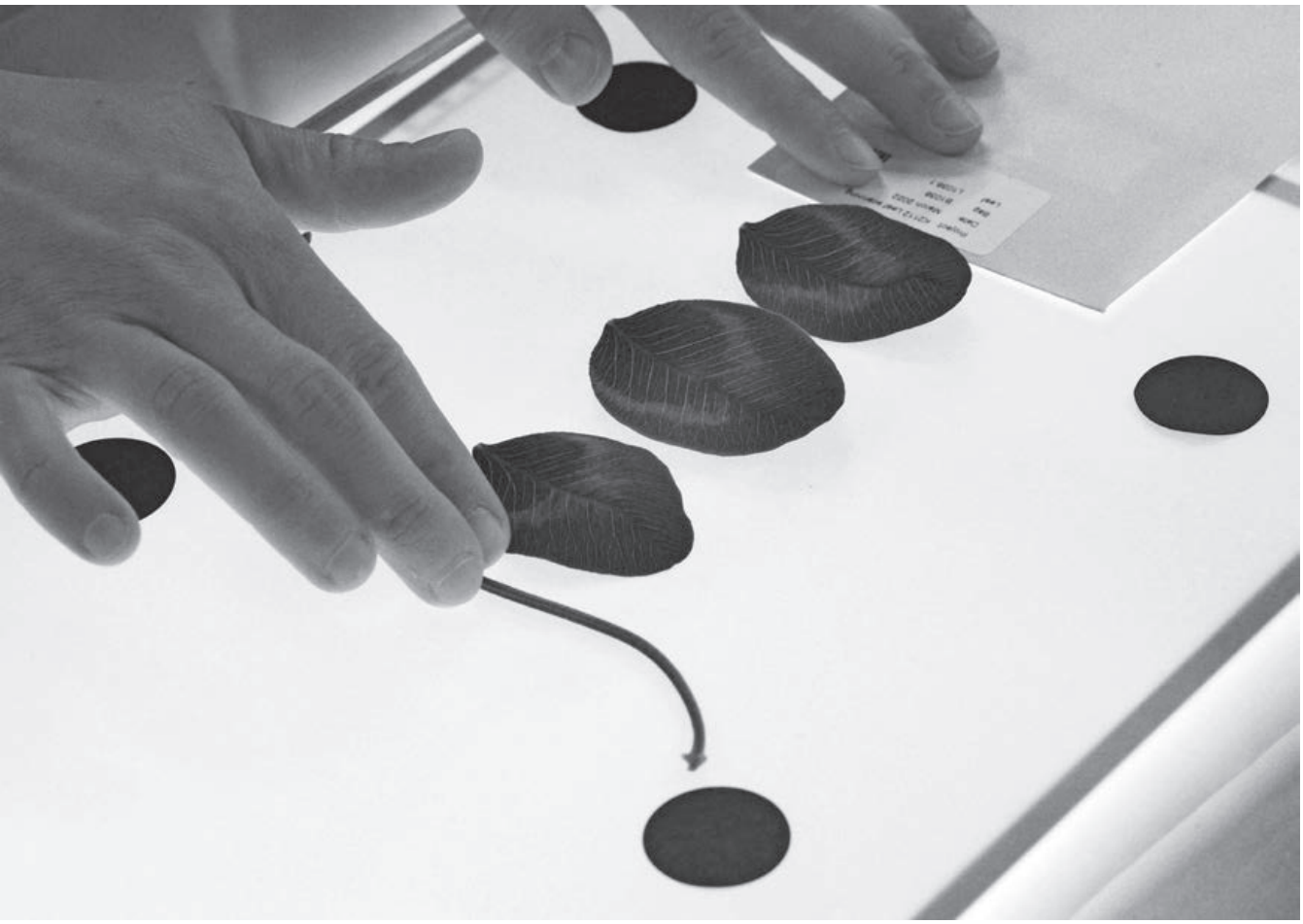
A faster read on the future

Close relatives share a lot of genes, and DNA fingerprinting is the most accurate technical means to establish a child's father. This requires taking tissue and then extracting DNA to compare what are called markers, distinct sequences in immense strands of macromolecules. What if you wanted to reckon paternity with less cost and trouble?

Computer analysis can identify someone in a picture based on information from old photos, even if they were made in different kinds of light and from different angles. Many tiny, seemingly insignificant data points are put together as a model. With photos of many children and their parents, perhaps when they were also children, you can train the model to predict which people are close relatives. Then you might have the computer scan thousands of images and construct a family tree, grouping people who are the most related to each other simply by their facial features. It won't be 99.9 percent

accurate like DNA testing, but since it is so cheap to take photos compared with extracting DNA, you can approximately sort a lot more people.

In the past few years, The Land Institute has sped the breeding cycle of intermediate wheatgrass by connecting genetic markers and field results, and then predicting from the DNA of mere seedlings what they could become and produce. Now we are exploring whether we can skip DNA analysis of the genotypes of thousands of plants each year with something analogous to facial recognition. You can see roughly how this works with the Seek app on a smartphone. Point the phone's camera at a plant or animal, and it identifies the species. Sometimes it's amusingly wrong, as when it identified the editor's dog as a seal. But often it's arrestingly accurate. Land Institute researcher David Van Tassel aimed at the needles of a tree atop a mountain in Utah and was told correctly that he'd found a rare Great Basin bristlecone pine.



Shannon Meehan, of the Donald Danforth Plant Science Center in St. Louis, arranges cuttings from Kura clover for photo analysis of details that might help predict how the plant will grow to production.

Land Institute breeders must look for distinctions *within* a species, for minutiae well beyond what Seek or your eye can pick up from a leaf, and put them through math far beyond pencil and paper. The Donald Danforth Plant Science Center in St. Louis has helped here with their LemnaTec Scanalyzer 3D. This instrument can robotically make daily images of 1,000 plants on a conveyor belt connected to the Conviron Growth House, where light, temperature, and humidity are all under fine, experimental control. Van Tassel's silphium plants are going through the process this spring. The Danforth's is a multi-million-dollar system far from our home fields. We want to compare models it helps make with models built using handheld scanners that cost from $200 to $8,000. With their reading of a leaf we might see both to whom the plant appears closely related and if we likely have something worth growing.

Danforth researchers helped us use and compare such scanners in early March. Leaves from 500 Kura clover plants in The Land Institute greenhouse were clipped and brought to the lab. Leaflets and stem were cut apart, photographed under glass, and weighed. Then it was on to a long table of black felt that cut reflectance from anything but the leaves. A leaf from each plant was covered and read in turn with four scanners. One scanner worked primarily with visible light, and the three others worked in the near-infrared, wavelengths longer than what we see and occupying a range five times that of visible light.

Eric Cassetta regularly applies these scanners to silphium, our oilseed crop, to intermediate wheatgrass, and to sainfoin, our grain legume. (The Kura clover is to intercrop with grains for ground cover and fixing nitrogen.) His work is funded by a five-year grant from the Foundation for Food & Agriculture Research. The job involves measuring many leaves quickly, because sunlight, temperature, and humidity changes can affect things like the opening of stomata for leaves to breathe, and expression of proteins, both of which might change what's reflected in the near-infrared. After almost a year, his measurements already number in the tens of thousands, building the model, the algorithm, to make predictions.

Predictions can also be made without having leaf in hand. While a graduate student at Texas A&M University, Shakirah Nakasagga repeatedly flew a drone over plots of perennial sorghum and made photographs for correlating plant form with later growth. Nakasagga, now a post-doc at the University of Wisconsin, said this is both quicker and more certain than predictions made by uncovering the perennial crop's signature underground rhizomes.

Such measurements won't stop after five years or even with a useful model in hand. Like development of influenza vaccines, plant breeding, the refinement of a crop's genetics, never ends. Performance of plants predicted to excel will be compared with plants predicted to be mediocre, and the model adjusted if needed.

Leaves of intermediate wheatgrass were scanned last summer, but Land Institute researcher Lee DeHaan hasn't found enough information to replace the genomic selection that roughly halved the crop's breeding cycle time. Sainfoin and silphium are still less far along. The leaf reading has helped with cassava and maize, but for Land Institute crops it's at proof-of-concept stage. We hope it gives us the power to make predictions by looking skin deep – after seeing that skin is far deeper than previously thought.

Jenna Hershberger, center, teaches Andrea Sweeting how to use one of the scanners that read light both visible and beyond our perception, for more data on predicting later Kura clover growth. Hershberger was with the Danforth center and moved on to plant breeding at Clemson University. Sweeting is a Land Institute research assistant.

More land, goods with Kernza

Land planted with intermediate wheatgrass for Kernza® production has expanded from about 500 acres in 2019 to just under 4,000 today, and the perennial grain is now used in national brands of pasta, cereal, and beer. Kernza is The Land Institute's registered trademark for the grain.

Cascadian Farm, an organic brand of General Mills, offers a cereal labeled "Climate Smart Kernza Grains". The company made a small batch of Kernza cereal in 2019, but not for retail. The new cereal appears at Whole Foods and is available on order to other grocers. Patagonia Provisions, the earliest national name to use Kernza, in a beer, now sells a pasta made with the perennial grain and durum wheat. It also has a new pilsner beer, called Kernza Pils, made in collaboration with distiller and brewer Dogfish Head, that is available on both coasts, with moves inland pending state alcohol regulations. The original Long Root Ale from Patagonia Provisions is sold only on the West Coast and in Asia.

Our Kernza® perennial grain is used in pasta, cereal from Cascadian Farm, a new beer, also from Patagonia Provisions, and various baked goods.

Perennial Pantry now sells a pancake and waffle mix in addition to its Kernza flour. It also offers a Kernza "cracker tasting pack". Doughp Creations makes Kernza sourdough bread. (The name is pronounced "dope", slang for "good".) Artisan Naan Bakery has naan, pita, and pizza crust made with Kernza. All three Minnesota businesses sell online. Sustain-A-Grain has Kernza egg noodles for sale online and in Kansas stores.

The large majority of intermediate wheatgrass is grown in Minnesota and Kansas, with third-place Montana coming up. Other fields are in South Dakota, Wisconsin, North Dakota, Iowa, Wyoming, and Canada. Fifty-two growers have signed contracts to grow and sell Kernza, and 36 have land in production.

Red shift

Predicting an adult plant's performance from seedling DNA has more than doubled our rate of progress in breeding intermediate wheatgrass. Now we are looking to double the rate again and perform two complete generations per year. If we can achieve this goal, extrapolations of our current progress would mean achieving wheat-like yields with just another 17 years of breeding intermediate wheatgrass, products from which use our trademarked name Kernza®.

Traditional breeding of perennial crops requires two to five years per generation. This is because plants must be grown in the

field for several years to identify the outstanding individuals who will serve as parents for the next generation. Genomic selection gets around this requirement for field evaluation by building a statistical model that accurately predicts mature-plant performance from seedling DNA. We can now do one generation of breeding per year, which is a huge improvement.

Growing two generations per year has not been feasible with intermediate wheatgrass because even in a greenhouse the plants take a long time from planting to seed harvest. Much of that time goes to "vernal-

The latest generation of intermediate wheatgrass, the crop that gives us Kernza. An accidental discovery with far red light may enable the plant's breeding cycle time to be cut in half.

ization". The plants will not make heads until signaled by winter temperatures and day lengths. We trick them with seven weeks in a walk-in cooler. After they move back to the greenhouse, stems elongate and heads appear. The difficulty is that two generations per year demands 14 weeks spent on vernalization. This doesn't allow enough time for DNA sequencing and for selected plants to head, intermate, and produce ripe seed.

But last year we made a serendipitous discovery. We were studying the effect of far red – nearly invisible – light on plant competition and crowding. Although we learned nothing useful there, we were astonished to see that plants exposed to far red light started to produce abundant heads even though they were never vernalized. This winter we ran additional experiments to verify the finding that far red light exposure can replace vernalization. So far, the idea is holding up. We have plants that grew from seed to seedling to heading to ripe seed in less than six months. This means we now have a way to perform two generations of genomic selection per year for intermediate wheatgrass. The method will be more expensive – we have to grow and sequence twice as many plants as before. But it's an excellent way to substitute money for time with a fantastic return on investment. For a plant breeder, this is a dream come true.

Benefit of borders

Crop Protection Ecology at The Land Institute includes finding not only what arrangements help protect perennial grain crops, particularly against pest insects, but also how the crops can serve their ecosystems. The research is important for both conservation and socioeconomics. Conservation examples include, one, if a perennial grain suppresses weeds well, herbicide use could fall, and, two, if the crop supports native pollinators, they could be brought back from their recent declines. Both gains could encourage adoption of the crop. Socioeconomic examples include, one, if a perennial grain also has good forage quality and quantity, it might give farmers a second use in a bad grain year, and, two, a perennial grain that attracts pollinators can also benefit the farmers' other crops. The more demonstrable strengths we have for our perennial grains, the more likely that farmers and the general public will take to them. Increased adoption is sorely needed for studying benefits and challenges over a wide geographic range. But here are recent results.

Many crop fields have borders, which might be demanded by a right of way or a steep slope or marginal soil. Specific plants in these borders can benefit crops and ecology. They can attract insects to help pollinate crops such as soybean, make forage for livestock, curb erosion, and manage weeds. Which plants might make such good neighbors was examined by The Land Institute and Kansas State University, for the Conservation Innovations Grants Program of the Natural Resources Conservation Service. All borders in the three-year study were perennial plants. One was a nine-species prairie mixture. Prairie mixtures provide excellent pollinator habitat but can be hard to establish and might not make the best forage. The other borders were single-species plantings of alfalfa, which is the dominant hay crop in Kansas, and four species that we're developing to feed people: intermediate wheatgrass, the legume sainfoin, and two silphiums, here called silflower and cup plant, bred for oilseed.

The prairie mix drew the greatest variety of pollinator species, with 49, but

the single-species silflower border still attracted 35. For sheer number of pollinator bees, moths, and butterflies, both silphiums attracted a similar number of pollinators compared to the prairie mix, with alfalfa and sainfoin down by about half.

Despite alfalfa giving three hay harvests per year, single cuttings of the silphiums had more than double the yield in biomass. Sainfoin yielded least but had seen poor establishment. The prairie mix was second lowest. Alfalfa had the highest protein proportion, but the cup plant and silflower excelled with low neutral detergent fiber, meaning they should be highly digestible by livestock. All of the border crops had to be managed for perennial bindweed, especially the first year, and sainfoin stayed behind with weeds. The prairie mix edged cup plant as the best weed suppressor, with silflower, alfalfa and intermediate wheatgrass in the middle.

Best all-around performance under the five measures was clearly by the silphiums. Their seed is in short commercial supply, but we're working to bulk up for interested growers. We'll also develop management guides for all four of our perennial crops in the study.

Eric Cassetta pollinates silphium in the greenhouse. Silphium species were the best all-around performers in a test of border plantings around crops, attracting pollinators and growing lots of forage mass.

Humanure

SCOTT BONTZ

The thermometer on the north porch of my straw-bale house reads 15 degrees Fahrenheit. I walk to under trees nearby, brush snow from the face of another gauge, and read 150 degrees. This thermometer sticks into a pile of kitchen scraps, straw, coffee grounds, and what in most any other house amid industrial civilization would have gone down the toilet – out of sight, out of mind, and largely out of the cycle of life and food.

My poo and pee stay at home for recycling. First step is to heat them in decomposition by thermophilic bacteria. I want the temperature high enough to kill pathogenic microbes. Food can be pasteurized in 30 minutes at 145 degrees. The aim at sewage treatment plants is to compost sludge at 131 degrees for several to 15 days, depending on the method. The reaction in my home pile comes from building a critical mass at least 3 feet across, and with the right ratio of carbon to nitrogen, about 30 to 1.

"Human and Animal Pathogens in Manure", by M. E. Olsen, presents a table showing the life expectancy of cryptosporidium, salmonella, campylobacter, and E. coli in different conditions. Crypto can live more than a year frozen or in liquid manure, and four weeks in composted manure. The other, shorter-lived pathogens last a week or two in compost. On a dry surface, only salmonella lives more than a day – up to a week.

After my pile tops out at three to four feet, depending on whether I've used hardware cloth or old pallets for containment, I let it settle and dry for a year. Then I roll several large wheelbarrow loads of compost to the garden.

By the kitchen sink are two buckets. One is for things that chickens will eat. The other is for things they won't, such as onions and wet paper towels. This goes to the compost. Most of the pile's fuel comes from the bathroom. There, covered by a wooden box with a toilet seat, is a plastic, five-gallon bucket. It's red, to avoid confusion with any of the other (white) buckets around the place. Nearby is another bucket, with chaff to cover the excreta. The lightest blanketing is enough to avoid odor and flies. When the toilet is full, I dump it in the middle of the compost pile. Around and atop this go buckets of grounds from a local cafe, and dry foliage – straw, leaves, whatever – to balance carbon against the humanure's nitrogen content of 5 to 10 percent, and to assure oxygen for the microbes. Trees shade the pile, and I usually don't add water beyond what's used for bucket rinsing.

The chaff in the bathroom comes from threshing at The Land Institute. My partner, Emily Rude, and I shovel from bins-full that would otherwise go to the institute's huge compost pile. Not everyone is so lucky. But there are other absorbent covers, including peat, shredded leaves, and sawdust. The last is used by J. C. Jenkins, author of "The Humanure Handbook", our guide.

Composting humanure might seem repulsive, but Jenkins turns the table: the developed world's citizens defecate in drink-

ing water. By my reckoning, Americans flush at least a billion potable gallons per day. This now-polluted water then mixes with industrial effluent at treatment plants that cost cities millions of dollars and billions of BTUs. Then it's to streams that don't need the extra nutrients, and to landfills, where the nutrients are lost forever, or to farmland, as sludge that may also carry heavy metals from industry, plumbing pipes, and sewer mains. The metal quantity in one load of sludge spread on the land might be slight, but repetition over years could build to dangerous levels. Debate about this continues.

Years on in my own process, I admit to still not quite relish dumping the dump bucket. It's a chore, and it takes some care. But I don't think of going back to a flush toilet. Seeing the pile heat rise remains a wonder, and a year later comes a payoff.

East Asians long knew the value of taking to farm fields their "night soil", though it might not have been composted, and posed risk of disease. In 1911, American F. H. King wrote of how this helped keep farms productive, with no further imports of fertilizer, for millennia. By King's time, American farmers had already run down their soils and imported guano from South America. And now both we and Asia have unbalanced the world nitrogen cycle with megatonnage of synthetic fertilizer made by burning proportional amounts of fossil fuel.

King told of dealers in China that took night soil from the cities to the fields – it wasn't just rural people who practiced recycling. The haulers weren't paid for this, *they* paid, for a valuable good. What if Western cities enabled as profitable and honorable the service of recycling excreta without so much water and waste? Or, with a backyard, let you take care of your business?

The writer mixes straw, coffee grounds, and excreta for pathogen-killing compost. Emily Rude photo.

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Lab bubblers

Soxhlet extractors, named for the German agricultural chemist who invented them, allow a small amount of solvent to bubble for hours at making tough extractions. Damian Ravetta, a Land Institute collaborator from Argentina, removes resin from our silphium plants. He wants to see if domestication brings silphium to make more resin or less, and whether drought or infection can be a trigger. We don't yet know if resins are important for stress tolerance or for defense. But the common name of silphium is rosinweed, reflecting the generous production of resin by plants in this genus. Scott Bontz photo.

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Mario Morales · Evan & Lila Cobey, from Georgia L. Deal & Tom Ashcraft · Earth Island, from Philip Hodges · Kira Gould, from Michael Ebeid · Rachel Greenberger, from Julie McCoy · Sara M. Gregg, from Bentley Gregg · Sally Hampton, from John McMillan · Barbara Horter, from Nathan & Sarah Horter · Wes Jackson, from Charles N. Giller & Jenny R. Sorensen, Roger McDaniel, Ann Simpson, E. Crichton Singleton · Lorri Jakubuv, from Gregory Steinmetz · Martin Kimm from Michael Lubbers · Laura Klein & Henry Markham, from Candice Meyers Kathleen Koplik, from Joshua Koplik · The Langbehn Family, from Andrew Langbehn Marilyn Long, from Andrew Long · John Luebbe, from Doug Luebbe · Kevin Markey, from Karen Markey · Ross & Mary Morgan, from Tim Morgan · Sara Niemann, from Jennifer Noll · Heather Niese, from Susan Niese · Andy Olson & Jason Crain, from anonymous · Kate Olson, from Charles Buckman-Ellis · Emily Rude, from Matthew D'Asaro · John Howard Schwartz, from Albert Schwartz · Lex Seguin, from Marisa Vertrees · Frieda C. Smith, from Douglas Smith · James & Courtney Spearman, from James & Patricia Spearman · Allan Stephan's sons, from Allan Stephan · James Struby, from Shauna Struby · Matthew Van Dyke, from Nancy Freeze · Isaac Vayo, from Harris Vayo · Mother who nurtures future generations, from Mari Ito

MEMORIALS

Virginia Elizabeth Beazley Chambers, from Gretchen Chambers · Martha Damon, from John Kane · Strachan & Vivian Donnelley, from John Hoskyns-Abrahall & Winnifred Scherrer · Lee & Kay Fiske, form Catherine Rebholtz · John Holland, from Catrinka Holland · C. Dale Johnson, from Michael & Cheryl Johnson · Wayne Johnson, from Anna McKenzie · Kristin Olgren, from Judy Fabry Emelyn Poitter, from Candace Galen · Harris Rayl, from Wendy L. Thompson John Schmidt, from Clair Schultis · Miner Seymour, from Tom Friesen, Tony Wahl Gary Tegtmeier, from Mary Kowalski, Francis & Christine Martin · David Zahrt, from Linda M. Zahrt

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