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# Paying for Perennialism

## A Quest for Food and Funding

*Perennial crops hold great potential for long-term agricultural sustainability, but researchers are walking away from work on perennials because federal funding is too focused on short-term improvements and increases in yield.*

When Wes Jackson looks out across the wild prairie of Kansas, he sees far beyond the limits of his vision. "I'm surrounded by prairie here," he tells us, and the fields of waving grasses and deep roots have shaped how he thinks—about farming, about the relationship between our species and the planet, and about how to live.

Jackson speaks with a folksy authority, an assurance born out of decades of commitment to his cause. His words are calm and considered, but an underlying excitement buoys them along. Current agricultural practices are destroying soil, a precious resource that "we treat like dirt," and, unless we change them, this situation will only worsen with time. Jackson believes that perennial varieties of wheat, corn, and other crops that would not need to be planted every year could go a long way toward solving the problem. Perennials could be part of an agricultural system that tries to mimic the natural economy of an ecosystem such as the prairie, with its remarkably healthy soil. But first we'll need economically viable perennial varieties of major food crops, an ambitious goal. Jackson, who is 75, has been working to promote perennial agriculture for 35 years through an organization he founded, the Land Institute. He knows he may not live to see the fruits of his labor, but this doesn't trouble him. He insists we have an obligation to take on projects larger than ourselves. "A lifetime is a narrow interest," he says. His own interest is as wide as his beloved prairies.

Doomsday warnings about humanity's future follow a familiar narrative: The global population is growing. Greater demand is leading to the cultivation of marginal lands, which are less productive and more quickly exhausted. Overfarming causes erosion and the degradation of even high-quality soil, while nitrogen runoff from fertilizers expands dead zones in the rivers and oceans. And all this occurs against a backdrop of climate change. The status quo, it would seem, leads to catastrophe.

Jackson, like a prophet crying out in Kansas, provides an alternative vision: It will require real change, but these disasters can be averted, if we will take nature as our model of how to treat nature. The increased use of perennial crops, both those in existence and new ones yet to be developed, is a key component of this. The advantages of perennials over annuals (see sidebar) lead to the tantalizing promise of a more sustainable agriculture system, increased long-term soil health, and greater food security. Creating these new varieties, particularly major cereals, is not a trivial task. But developments in the past decade—increasing numbers of interested scientists, faster and cheaper genetic sequencing technologies, helpful knowledge gleaned from research on perennial biofuel grasses, and increasing concern about environmental deterioration—have made perennial crops both more important and more realistic.

But research on perennial crops suffers from a critical problem: lack of funding. Washington State University professor Steve Jones, who a decade ago helped identify a single chromosome region that tells annual wheat to die, has shut down his laboratory genetics work almost completely. Other researchers confirm the challenges of finding support for science that strays from the well-worn path of agricultural research and production supported by the U.S. Department of Agriculture (USDA).

Perennialism research is risky, and its payoffs are weighted toward the long term. For the agriculture industry, it is not an obvious place to invest. Perennial crops would be disruptive to the current business model, since one of their key benefits is requiring fewer inputs—seed every three to five years, less fertilizer use, less pesticide use. Industry might respond to demand from farmers or consumers, which is how organic foods gained a foothold. But this can't happen until perennial varieties with decent commercial potential actually exist. Even the most optimistic projections predict that we are still 10 to 15 years out from this goal. Lack of incentives and a daunting time horizon mean industry is unlikely to be the catalyst for perennials.

Perennialization presents different problems when re-

## Terry Evans

In 1978, photographer Terry Evans embarked on a project that would shape her artistic career. She agreed to document survey work the Land Institute of Salina, Kansas, was conducting on a nearby virgin prairie. She recalls, "My visits started in early March and as the spring progressed and grasses and legumes and other plants emerged from the ground, I began to see the rich ecological diversity of a prairie. This was my first experience of seeing an undisturbed ecosystem and I was almost overcome with passion to know it better. Its subtle beauty completely captured me. I came every day to photograph the ground."

Evans' work shown here is taken from two projects, *Canada to Texas* and *Prairie Specimens*. She writes: "Late in 1996, I began a photographic aerial survey of mixed grass prairie, covering the area of its ecological boundaries from Canada to Texas. At that time I began reading about the 19th century botanical expeditions to the Great Plains, and felt an immediate affinity and admiration for these naturalists. Probably the main reason I photograph at all is because I fancy myself to be an explorer. Lately, instead of exploring outdoors, I've been exploring the vast collections in the storage areas of Chicago's Field Museum, one of the world's largest natural history museums. I am equally moved by the beauty of both the virgin prairie and the carefully collected and preserved specimens."

Evans has exhibited widely, including solo shows at the Chicago Art Institute, the Smithsonian National Museum of Natural History, and The Field Museum of Natural History. She is a Guggenheim Fellow and recipient of an Anonymous Was a Woman award. Her work is in major museum collections including the Chicago Art Institute, New York's Museum of Modern Art, the San Francisco Museum of Modern Art, the Smithsonian American Art Museum, and many other collections. More examples of her work can be found at www.terryevansphotography.com.

## Why perennials?

Many plants are naturally perennials, but grain crops by and large are "big-bang annuals," as Steve Jones puts it, that put a huge portion of their resources into producing seeds before "dying very efficiently." The potential advantages of perennial grain crops have been explored in depth elsewhere (see articles in *Issues in Science and Technology* from Summer 2011 and Winter 2010), but we recount them here briefly:

**Reduced inputs** Seeds don't have to be planted every year. Perennials are more efficient than their annual cousins at absorbing nutrients, meaning that fertilizer inputs (and runoff) are reduced. Increased efficiency in using precipitation, combined with natural drought resistance, mean that less irrigation is needed. And natural pest resistance allows for the use of fewer pesticides.

**Erosion control** Not planting every year means less tillage. Also, perennials put down deeper, bulkier root systems than annuals, helping to hold the soil in place.

**Soil health** Existing perennial grass systems have much healthier soil than land under conventional or organic cultivation.

**Carbon sequestration** Thanks to their much larger root systems, perennials naturally sequester more carbon.

**The potential for better yields** Perennials have a longer growing season than annuals and don't have to devote resources to building a new root system each year. So although some worry that perennials will never yield as much as annual crops, other scientists believe they could one day actually produce superior yields.

searchers seek federal support. The USDA has long been focused primarily on increasing yield, a metric where perennials face significant disadvantages. Annual crops have a head start of thousands of years of selective breeding. Also, many researchers assume there's a tradeoff between yield and perennialism: If plants put their resources into deep roots, those resources can't go into producing big seeds. Other scientists now challenge this assumption, but there's no question that starting from behind makes perennials less appealing to federal funders.

Beyond the yield question, alarmingly few resources at any federal agency go to supporting long-term, high-risk, high-reward research. The three-year grant cycle, with its emphasis on incremental improvements, just doesn't lend itself to this kind of science. Vision as far-reaching as Wes Jackson's may always be rare. But even a modest shift toward longer-term thinking could make a huge difference in our progress with perennialization, as well as with other projects that languish because of their timeframes.

We spoke with a number of scientists, policymakers, farmers, and activists about the growing interest in perennial crops, and the challenges of finding resources to support research. Three in particular serve as exemplars of what's happening in the field, in terms of both progress and problems:

- Wes Jackson, native Kansan and founder of the Land Institute, has been working to encourage the development of perennials longer than anyone else in the field.
- Steve Jones, a locally minded wheat breeder, has devoted himself to Washington State agriculture as he tries to


NEW MEXICO STATE UNIVERSITY, RANGE SCIENCE HERBARIUM (NMCR)
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FIELD COLUMBIAN
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Aristida longisita Steud.
COLORADO FLORA.
Near Boulder.
H. N. PATTERSON.
July 4–9, 1892.
NO.
Aristida longiseta Steud
DETERMINED BY MRS. AGNES CHASE.
H. N. Patterson's
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Herbarium.



answer some of the most elegant questions in biology.

- Ed Buckler, a programmer/geneticist who now regularly finds himself planting corn, wants to bring the incredible advances in DNA sequencing technology to bear on the problem of perennialism.

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**Wes Jackson**

In 1940, U.S. wheat growers could expect to produce about 14 bushels per acre harvested. Decades later, that figure has tripled. The increase in corn yields is even more impressive: 10-fold since the 1930s. The success of plant breeders' efforts to increase yield is abundantly clear: Food production has kept pace with vigorous population growth. It has come at the cost, however, of extreme demands on the land itself.

Wes Jackson was born in Kansas in 1936, so he has observed many of these changes, good and bad, firsthand. His epiphany came in the late 1970s, while comparing present-day erosion with that of the Dust Bowl years. Despite measures undertaken to fight erosion over those intervening four decades, improvement was minimal. Perhaps, he realized, the problem wasn't something that farmers had actually tried to fix during those decades. Perhaps the problem was a much older, more fundamental one.

In Jackson's view, our most essential nonrenewable resource is not oil, but soil, and our present agricultural system is destroying it with industrial efficiency. When he talks about the "10,000-year-old problem of agriculture," Jackson's enthusiasm is captivating. As he describes the glaciers of the last ice age receding, and the planting of the first wheat crops near the Tigris river, it's easy to feel that agricultural history holds important secrets. When you grow annual monocultures, Jackson explains, as we have ever since those first wheat crops, you have to destroy the local ecosystem "to stay ahead of the weeds." And in fact, soil erosion has been around as long as farming; the Fertile Crescent today is a far cry from what it once was. For more than three decades now, Jackson has been working to raise awareness of this issue and to promote an alternative vision of how we should, or perhaps must, learn to farm if we want to feed the world without destroying it.

In 1976, Jackson founded the Land Institute in Salina, Kansas, to "develop an agricultural system with the ecological stability of the prairie and a grain yield comparable to that from annual crops." The prairie is held up as an ideal, at least in part, because it's where Jackson grew up and lives. "If you look out at the prairie," Jackson says, "whether it's tall-, mid-, or short-grass prairie, you don't have soil erosion beyond natural replacement levels. The only thing the prairie doesn't produce is nice big seeds."

Jackson, who holds a Ph.D. in genetics, advocates for a system of cultivation that evolved over millions of years: nature's. Instead of planting monocultures, he argues that we should plant multiple crops together in mutually beneficial combinations, or polycultures. And instead of replanting annual seeds every year, these polycultures should feature perennials with the potential to produce for three years or more. He calls this system perennial polyculture. If we're willing to mimic nature, we will, he believes, find inherently sustainable ways to farm, and the development of perennial grains is the scientific key to this task.

The Land Institute has been building support for this vision for 35 years, through advocacy and collaboration with scientists. In the past decade, though, frustrated with the slowness of progress, the organization has turned to doing plant breeding itself. Its staff scientists and fellows have since made significant strides toward perennialization, working with crops ranging from wheat to sunflowers to sorghum. Jackson's colleagues are now making baked goods from Kernza (the name is a play on Kansas kernels), a perennial intermediate wheatgrass they've developed. And Jackson playfully describes a field of annuals planted in polyculture that were harvested together as "instant granola." Designing machines to separate crops harvested together would be a straightforward engineering problem, Jackson says, so no need to worry if granola isn't your thing.

Today, the Land Institute's work is at a tipping point. With increased press attention over the past few years, public interest in the project of perennialism is beginning to build. And in the past year, Deputy Secretary of Agriculture Kathleen Merrigan has brought up the promise of perennials in several public forums, so at the moment, at least, they have a champion at the USDA. But although the Land Institute's in-house plant breeders and the academic scientists across the country who are part of their network are making real progress in developing perennial food crops, their work is small in scale and poorly funded.

The Land Institute has doubled in size since its plant breeding efforts began, but raising money is an uphill battle. When asked how the organization is supported, Jackson deadpans: "Bake sales. Church socials." Though the organization has received small amounts of federal funding via earmarks and the USDA's Sustainable Agriculture Research and Education (SARE) program, the vast majority of its support comes from foundations and individuals. Jackson is hopeful that government will play a role in making his vision a reality. He has promoted a 50-Year Farm Bill in Washington as an alternative to the existing five-year version, but his own current efforts focus on foundations, which could invest on a scale as large as his dream.

He's not the only one who thinks that foundations, rather than the government, are the most likely solution to the funding problem. Rick Welsh, a professor of sociology at Clarkson University who specializes in agriculture and food systems, agrees that "if you could convince someone at Rockefeller or Kellogg that this was really the future for the developing world or the United States, then maybe you could get a champion." Although they can sometimes be fickle in terms of their priorities, foundations do have the flexibility to think long-term if they choose. Cornell plant geneticist Ed Buckler points to the Howard Hughes Medical Institute, which supports exceptional biomedical scientists, not for a specific project but to pursue whatever research they think is most promising, however risky, for a renewable five-year term. And he observes that many leaders of recently established foundations "got wealthy by being in this high-risk venture. They think, 'Well, odds of this working? Maybe it's 10%. But if it does work, the payoff is massive.'"

Like his agricultural vision, Jackson's goal for foundation support is ambitious. He imagines a handful of big foundations partnering together to make a transformative 30-year commitment of around $3 billion. While aware that this is a long shot (at one point he assures us dryly, "I'll try not to have too much senile rapture here"), he also has a ready counter for those who might call his ideals utopian: "If you're working on something you can finish in your lifetime, you're not thinking big enough."

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**Steve Jones**

Like Wes Jackson, Steve Jones worries about soil erosion and sees perennialization as a key part of the solution. But as an active scientist and wheat breeder, his focus is more on the genetic than the societal level. Jones works in the Skagit Valley, a mild and fertile region 60 miles north of Seattle and less than 10 from the Pacific Ocean. Here, spring brings acres of tulips and autumn more than 90 different crops, from apples to zucchini, harvested on farms that are typically smaller than 150 acres. Today Jones directs Washington State University's Mount Vernon Research Center there, but he started his time with the university at Pullman, in the southeastern part of the state, a dramatically different landscape.

Eastern Washington receives so little water that, as Jones puts it, "There are two crops: wheat and dirt." It was in this dry, windy region, where farmers struggle with soil erosion across many hundreds of acres, that he first began working on perennial wheat. He arrived at Washington State in 1991,

fresh out of graduate school at the University of California, Davis, and soon started hearing from growers that they needed perennial wheat to combat erosion. Jones was vaguely aware that a professor named Coit Suneson had worked on perennialism at Davis decades before, but had no other knowledge of the subject.

It was a fortunate accident that led him, in the mid-1990s, to start thinking seriously about perennialism. Jones had been using natural crosses to transfer genes for disease resistance from wild plants to their agricultural relatives. A couple of months after the harvest, he noticed that whole regions of a field planted with these crosses were growing back. Inadvertently, he had on some level transferred the perennial nature of the wild varieties to their annual cousins.

Serendipitously, around the same time, Jones received a call from a local farmer, Jim Moore, who was serving on the Washington Wheat Commission, a growers' organization. Moore had been asking about perennial wheat for years—

he wanted something that would hold his soil down, and also be productive—but Jones was the first person not to laugh at his request. Moore suggested that Jones apply for support from the new Fund for Rural America, a USDA program created by the 1996 farm bill. Jones, who had not previously sought such a large grant, asked for $700,000 to fund four years of work on the feasibility of perennial wheat. He soon received a call congratulating him on the excellence of his proposal. The fund would support his research, but could only provide $500,000, and suggested that he do three years of work rather than four. "It was funny, given that we were working on perennial wheat," Jones notes, "but that's what we did."

Developing a new annual variety of wheat can take 10 years, but perennials have an even longer timeframe, because it takes several years, not just one, to see how they fare. Moore, who helps test Jones' experimental varieties on his farm, sees this as perennial wheat's biggest challenge: "The time horizon is just too long for people to be willing to support it." At 73, he too thinks he may not live to see perennial wheat become widely available, but he believes his granddaughter will.

Jones's work contributes to that hope. "It's a beautiful biological question," Jones muses. "We've bred wheat to be a big bang annual, which means that it dies very efficiently. What if we can tell it not to die?" One of his Ph.D. students was able to identify the gene or genes that causes annual wheat to die—the gene his inadvertent perennials seemed to lack. But simply transferring that one gene won't produce commercially viable plants. "There's tremendous work to be done there, just careers full of work," Jones says, a little wistfully.

The Fund for Rural America disappeared with the next farm bill. After that, Jones received three years of support from Western SARE, but since then he has had little success in winning competitive grants to work on perennialism. For a while, Jones and colleague Tim Murray, a plant pathologist, had a very modest federal earmark for their work, but this too dried up. Lack of funding has led Jones to terminate his laboratory genetics efforts, and he struggles to support graduate students. With additional money, Jones says, he would relaunch his laboratory work, as well as drastically expanding the scale of the perennial breeding program. "Breeding is about massive numbers, and that just takes people. Can we look at 100 lines or can we look at 50,000 lines? We have the space, we have the equipment, but it takes people to go out and do it."

To cope with limited funding, Jones has developed a different strategy for maintaining research support. He is still pursuing competitive USDA grants, but increasingly he is shifting his focus. "Our strategy is to decentralize our funding and get it locally. One of my Ph.D. students is funded by the Swinomish tribe here. He does water-quality and salmon work. A local town has given us $150,000 to fund a Ph.D. student. It's not for perennial wheat, it's for composting biosolids. So, we're being creative in that way about getting our students funded." Growers in the area are committed to Jones and to the research center. They donated the land it was built on all the way back in 1943, and they raised funds to rebuild it in 2006. The local strategy is working, in terms of supporting a productive research operation. But it means that Jones' research on perennial wheat is moving at a crawl, not a gallop.

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**Ed Buckler**

When a scientific project is too premature for industry interest, and foundations haven't stepped in, the public sector is left to stand in the gap. So far, it's fallen short in this role

with perennialism, thanks to historical tendencies in public agricultural research to fund short-term research at the expense of lengthier projects, and to focus on year-to-year increases in yield. Because funding for research on perennialism is so difficult to get, Jones no longer sees federal support as terribly promising for perennial crops.

Ed Buckler, a plant geneticist based at Cornell, has a slightly different perspective. Buckler works at Cornell, but he is also on staff with the Agricultural Research Service (ARS), the in-house research branch of the USDA, which gives him a helpful perspective on what a public servant can currently hope to accomplish. Buckler works on maize, not wheat, and was raised in Arlington, Virginia, a long drive from farm country. He's been programming since he was eight or nine, and his approach to the problem of perennialism is rooted in computational genomics. Buckler is aware of the constraints on public support for perennialism, but he's doing his best to work within them and has some suggestions for improving them.


Buckler's scientific goal is to speed up the process of developing perennials. He speaks fondly of Jackson's Land Institute: "They have been championing perennials for a really long time. The basic concepts that they spoke about a decade, two decades ago, are exactly right. But they would lay out a time horizon on the order of 50 or 75 years. That was beyond the normal attention span of what society wants to do." Today though, with the aid of genetic sequencing technology, Buckler believes that some of the Land Institute's goals could be accomplished much more quickly.

Buckler wants to accelerate the crossbreeding process by using DNA sequencing tools to identify the most promising naturally occurring variations. The technologies used to sequence genomes have advanced by leaps and bounds over the past few years. Sequencing the first human genome in the 1990s cost $3 billion; today, the price to sequence a genome will soon approach $1000. A project that would have been "a moon shot" fairly recently is now, Buckler explains, "something that could be done with a couple of million dollars a year." This shortened timeline opens up more potential for doing the work with federal funding. "I think we're at a point now where in one five-year chunk we could figure out the genes that are important for perennialism, and in another five-year chunk we could start putting those together to put a perennial out in the field. Not one that a farmer would care about, but one where biologists would say, 'Yes, that's a perennial, that looks like corn.' *If* we were successful." From there, it might be five more years to a plant that farmers might actually want to grow.

Still, even that plan assumes that five-year grants are avail-

able. But it's only recently and in a handful of areas that the USDA has given grants longer than three years. Reflecting on perennialization, Buckler says, "I think it will be interesting to people. I personally am definitely interested in doing this. But I know of [only] one source [the National Science Foundation's plant genome program] that would fund five years on something like this. Out of all the federal research portfolios that are likely to support something like this, there's one program. And that's kind of the problem."

Even a five-year time horizon is challenging for plant breeders, whether they're working on perennialism or other traits. "A realistic number?," asks Buckler. "For a plant breeder, it probably should be a 10-year grant, and maybe at two intervals you provide rigorous peer-reviewed progress reports. But nobody has 10-year grants."

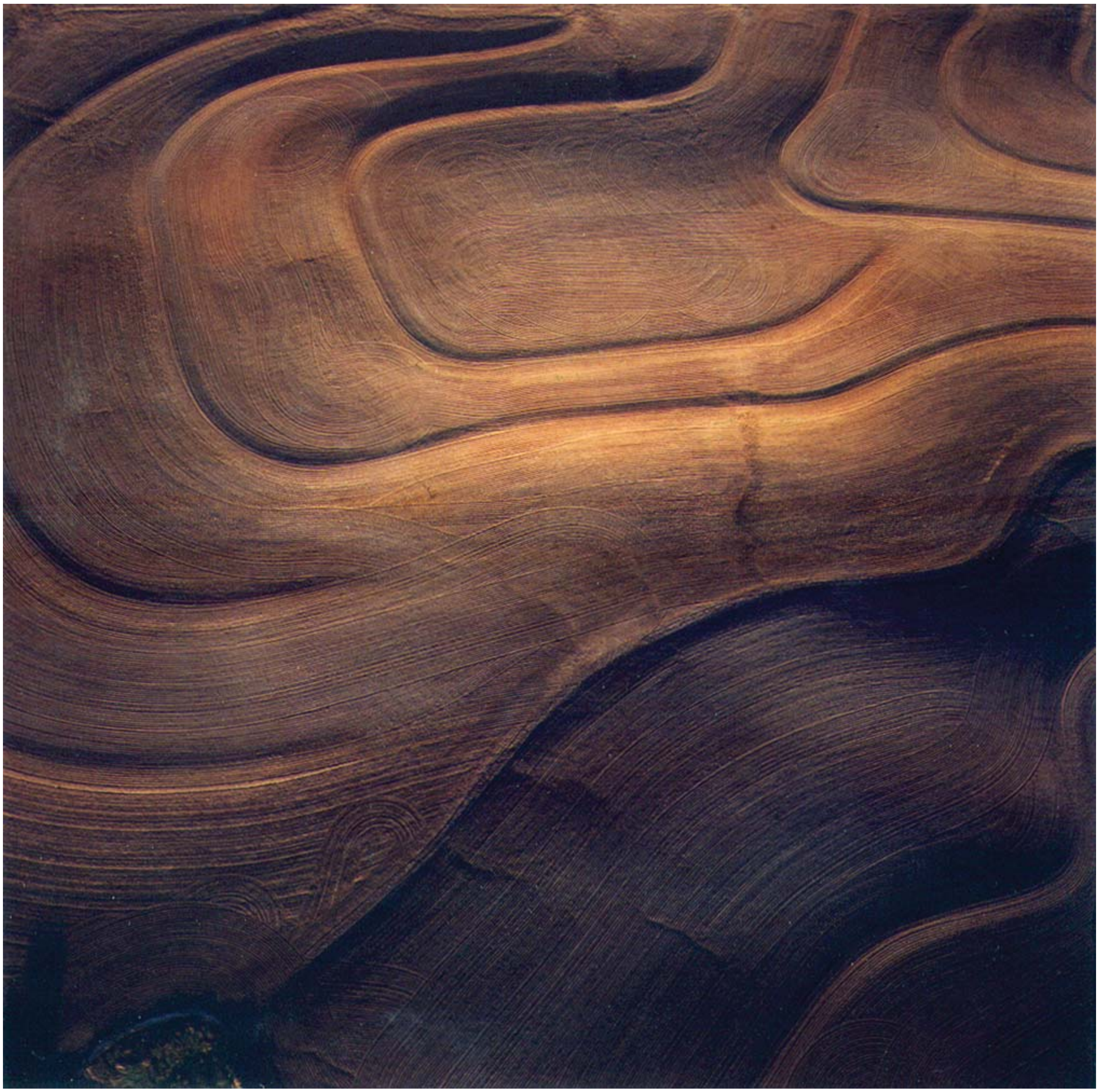
Buckler's own work bears out the point that plant breeders need more than three years. "Some of our most successful and highest-profile projects actually took about eight or nine years to do," he notes. He credits his status as an ARS employee with allowing him to undertake such projects. His position "provides a core level of basic support—enough to hire a field manager, and a lab manager, and a couple other people. Compared to a regular academic position, that's a real advantage." That core funding has been critical to his research. "We used our hard money support from the ARS to set up the experiment over several years, and then we wrote a grant saying, okay, in five years we're going to finish this thing off." Scientists employed solely by universities, of course, cannot use this strategy.

**The question of yield**

But even in a world of 10-year grants, proponents of perennials would still have to address the second of these twin problems: yield. Even some supporters see perennials as unlikely to ever yield as much as annual crops. Bill Beavis, a geneticist at Iowa State University with an industry background, would like to see perennials succeed. But with seed companies investing hundreds of millions of dollars in improving their product each year, it's hard for him to imagine perennial corn ever catching up. For Beavis, the most difficult task will not be the scientific one of developing the corn, but the economic one of creating incentives for industry to invest in improving perennials' dollar-per-acre return.

But Buckler has higher hopes. He thinks perennial yields could potentially surpass those of annuals. "Some of the best data now comes from the biofuel efforts. In central Illinois, if you grow perennial biofuel grasses side by side with corn, the biofuel grasses fix 61% more carbon per year than the corn does," largely because of their longer growing season. "If we can divert that carbon not just to stalks but to kernels and ears, which I think genetically is totally doable, then you could make an argument that we should be able to beat the yield of modern maize by 60%."

In the long run, Buckler thinks industry will find a way to profit from perennials. "Seed companies spend a lot of money actually making seed, about a third of their costs. And



so they could perhaps have better profit margins if they were on a perennial system that rotated seed every five years." He adds, "If we do our job right as geneticists at making perennials, they'll be so attractive that a lot of people in industry will take them up. But there needs to be enough basic research to push it to the point where we can say, 'Now we're within a five-year time horizon to take this to commercialization.' "

Only time will tell whether perennials can approach or surpass the yield of annuals. But Steve Jones also offers a reminder: "If it doesn't yield as well as annual wheat, especially at first, we're not all going to starve."

Admittedly, it's hard to see increasing yield as a bad thing. Agricultural land is finite; the global population is large and growing. Feeding the world is going to require us to produce more food, and proponents of perennials quickly run into this reality. "There's almost an obsession with yield," observes Leland Glenna, associate professor of rural sociology at Penn State. "Getting X bushels per acre can even matter more to agricultural scientists than the money the farmers can make." Perennials have many advantages, but as of yet yield is not one of them. Other benefits, like reduced inputs and erosion control, are less resonant. Rick Welsh, Glenna's collaborator, adds, "It can be hard for plant breeders to find funding or private sector collaborators if their innovations don't increase yield, even if they have other benefits."

The problem here isn't that yield is unimportant, it's that we think about yield on too short a timeline. Jim Moore points out that much of his land in eastern Washington is so dry he can plant wheat only every other year. "The question is," he says, "what would you accept in order to be able to plant perennial. Forty bushels? Thirty?" For him, 30 bushels every year would be coming out ahead.

And that's with a shift to a two-year horizon. Over a period of decades, as fertile topsoil blows away or runs off, damage to farmland can be irreparable. The strategy that maximizes yield over the next year, or even decade, may look very different from the one that maximizes it over the next 50 years. The United States is blessed with an abundance of fertile land, but even here erosion and constant cultivation are steadily degrading soil health. In countries where a significant portion of cultivation already occurs on marginal land, the situation is even more acute. To use an agricultural analogy, focusing too exclusively on short-term yields may be akin to eating the seed corn.

**The long view**

Scientists interested in perennialism cope with the current funding situation as best they can, patching together bits and pieces of support or doing a little work on perennialism on the side of their main projects, as Jones has done. Limited resources do encourage deep thinking about what research is most meaningful and how to carry it out most efficiently, leading to efforts such as Buckler's. And even in this challenging environment, researchers are making progress: Jackson's Kernza could be commercially viable within a decade. Perhaps, particularly as rapidly improving DNA sequencing technology speeds things up, they'll pull this off even without easy access to funds.

Right now, though, funding priorities mean scientists are turning their energies in other directions. Steve Jones can't support laboratory research on the genetics of perennialism. Ed Buckler would like to work more on it, but already has a major grant from the one source he knows might support such research and can't apply for another. And when researchers turn away from a project, continuity, which is critical to plant breeding research, is lost. Jones recalls the work done at UC Davis: "When Coit Suneson retired in '61, a little of his material was saved, but the rest of it was thrown away. And then you start from scratch."

Some of the problems hindering perennialism's progress can't be solved. Sometimes there are simply more quality proposals than available funds. And in times of economic uncertainty, scientific research is not immune to budget cuts. The argument for perennials, however, is clearly strong. And it's made stronger when one realizes that perennial research has significant implications for annuals as well. Buckler explains: "Even if we fail at figuring out the genetics of perennialism, we would at least learn how cold tolerance works, and how drought tolerance works, and flooding tolerance, which would all be great traits to get into annual corn."

Wes Jackson, who has carefully pondered our aversion to thinking long-term, jokes that he's considered selling an American doll—you wind it up, and it gets bored. (All proceeds would go to the Land Institute.) Currently, though, interest in perennial crops is building, and there are a number of ways policymakers could act decisively to capitalize on this. First, Congress could simply name perennial crops a high-priority area for competitive grants in the next farm bill. Second, even without congressional action, the ARS could prioritize them as a research area. Welsh observes, "The USDA, through the ARS, has the resources and expertise. It makes sense for them to put money into this sort of public good. That's where you traditionally have seen research and varieties produced that are not necessarily going to be driven by the private sector."

Jerry Glover, a Science and Technology Policy Fellow of the American Association for the Advancement of Science and veteran of the Land Institute, acknowledges, however, that there is a challenge here: "ARS scientists, I think, would greatly welcome the opportunity to work on perennial grain crop development given more funding. But of course we know what the budget situation is. When you have to make difficult choices the public is in general going to support the more charismatic or compelling research programs versus food. Hopefully we can communicate the linkages between farming, the environment, and our own national security needs."

More broadly, a government reinvestment in plant breeding would benefit not only perennials, but a host of other projects that are too long-term to be on industry's radar, or that are of public value but not commercially viable. For a decade, agricultural scientists in the public and private sectors have been decrying the decline of public plant breeding. USDA support for plant breeding declined slightly in real terms between 1985 and 2005; the budget of the National Institutes of Health (NIH), by contrast, tripled during the same time period. Glover emphasizes just how critical such an investment is: "The number-one thing the public could do to adapt to and help mitigate climate change, and to ensure a food-secure future for the planet, is to reinvest in publicly funded plant breeding programs."

And at the most general level, both science and society would benefit if funding agencies prioritized identifying and supporting high-risk research of long-run importance. Academics can be a surprisingly conservative group when it comes to making grant decisions. Funding panels often go for the sure project over the unfamiliar, riskier, but potentially higher-payoff proposal.

Federal agencies are, of course, aware of this and slowly making efforts to counter it. The National Science Foundation, for example, has recently worked to identify and encourage "potentially transformative research" by establishing its Emerging Frontiers in Research and Innovation program. NIH has the Pioneer Award program to support innovative high-risk research by exceptionally creative scientists. At the USDA, a few large, five-year, multi-institutional projects are being supported. Expanding this approach would benefit not only perennial crops research but also other risky but high-impact research areas that are currently being neglected.

The main problem the scientists interested in perennialism face is clear enough: lack of funding and particularly of long-term grants. For the time being, industry isn't going to pay for the development of perennial grains. And although foundations could be the solution, so far they haven't seriously invested. But both the possibility and the need are clear. Occasionally, we need to leave the confines of our workaday lives, step outside, and join Wes Jackson in peering toward the horizon. The federal science enterprise should draw on this sort of vision and provide support for some bold long-term projects such as the breeding of perennial crops. The United States is a large country, and it can afford to spread out a bit of risk across so many amber fields of grain—especially when the payoff is protecting the fertility of those fields for generations to come.

*Recommended reading*

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