Annual Report
Fall 2015

Highlights:

THE LAND INSTITUTE

About The Land Institute

The Land Institute, founded in 1976, is a nonprofit 501(c)(3) research and education organization funded by charitable contributions from individuals, families, organizations and private foundations.

Our scientists are developing perennial grain species to be grown in diverse mixtures that will require less fossil fuel, conserve soil and water, and weather the droughts and deluges that will become more frequent with climate change.

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Leadership

Wes Jackson, President and co-founder
Tim Crews, Director of Research
Jayne Norlin, Director of Institutional Advancement
Scott Seirer, Managing Director

Spreading the word

Web site: www.landinstitute.org
Facebook: www.facebook.com/TheLandInstitute
Magazine: Land Report (published 3 times a year)
E-Mail newsletter: Scoop, Signup at our web site
Annual event: Prairie Festival, Sept. 23-25, 2016

Board of Directors

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Selected presentations

October 2014: AACC International Annual Meeting. Special Session Presentation. Perennial Grasses: Can they Replace Annual Grains in the Future? "Grass to Grain: Sustainable food by design." Providence, RI (DeHaan)

New Roots for Ecological Intensification, Estes Park, Colo. (Cox, Crews, DeHaan, Nabukalu, Damaraju, Van Tassel, Wang)

November 2014: American Society of Agronomy meeting. "Perennial Rice Development," Long Beach, Calif. (Van Tassel, Hu)

Green Lands Blue Waters Annual Meeting. Bioenergy and Sustainable Agriculture. "Kernza®: Perennial Grains are Coming to Farms and Tables." Richland Community College, Decatur, Ill. (DeHaan)

January 2015: 6th Annual Agroforestry Symposium Climate-Smart Agriculture: Role for Agroforestry. "Perennial Grains: Climate-Smart by Design." University of Missouri, Columbia, Mo. (DeHaan)

Northeast Organic Growers Association-New York Conference. "Soil organic matter: Understanding the holy grail of organic agriculture." Saratoga Springs, NY (Crews)

February 2015: Experimental Cuisine Collective Monthly Workshop. "Perennial Grain: Sustainable by Design." New York University, NY (DeHaan)

March 2015: Agronomy seminar series. "Promise of Perennial crops: Breeding Silphium as a Drought Tolerant Oilseed Crop." University of the Republic, Montevideo, Uruguay (Van Tassel)

2015 University of Minnesota Plant Breeding Symposium. "Kernza: Breeding a Perennial Grain." St. Paul, Minnesota (DeHaan)

April 2015: "The Endangered Soil Resource." The Cornell Club, New York, NY (Crews)

Food Security Conference sponsored by the Institute on Science for Global Policy and Sigma Xi. "Perennial Crops Are a Key to Sustainably Productive Agriculture." Eckerd College, Saint Petersburg, Fla. (DeHaan)

June 2015: Swedish University of Agricultural Sciences Future Agriculture Seminar. "Ecological Intensification and the 10,000 Year Old Problem of Agriculture." Uppsala (Crews)

September 2015: Perennial Grains for West Africa meeting sponsored by the FAO and ICRISAT. "Land and Soil Issues in Africa—Disturbance, Succession and the Promise of Ecological Intensification." Bamako, Mali (Crews)

Department of Plant Pathology Seminar Series. "Kernza® Perennial Grain: Sustainable by Design." Kansas State University, Manhattan, Kan. (DeHaan)

Selected publications

DeHaan, L.R. and D.L. Van Tassel 2014. Useful insights from evolutionary biology for developing perennial grain crops. American Journal of Botany 101: 1801-1819.

Crews, T., T. Cox, L. DeHaan, S. Damaraju, W. Jackson, P. Nabukalu, D. Van Tassel, S. Wang. 2014. New roots for ecological intensification. CSA News Special Issue—Feeding the World in 2050, November Issue

Runck, Bryan C., Michael B. Kantar, Nicholas R. Jordan, James O. Eckberg, Richard J. Barnes, Clarence L. Lehman , Lee R. DeHaan, Robert M. Stupar, Craig C. Sheaffer, Paul M. Porter and Donald L. Wyse. 2014. The Reflective Plant Breeding Paradigm: A Robust System of Germplasm Development to Support Strategic Diversification of Agroecosystems. Crop Science 54: 1939-1948.

Wang, R.R.C., S.R. Larson, K.B. Jensen, B.S. Bushman, L.R. DeHaan, S. Wang, and X. Yan. 2015. Genome evolution of intermediate wheatgrass as revealed by EST-SSR markers developed from its three progenitor diploid species. Genome 58: 1-8.

Crews, T.E. and L.R. DeHaan. 2015. The strong perennial vision: A response. Agroecology and Sustainable Food Systems 39:500-515.

Cover photo

Intern Mohammed Alawala holds a metal funnel as a co-worker stuffs perennial wheat, freshly harvested by hand, into a paper bag. The sample later will be analyzed in the lab.

Annual Report photography by Managing Director Scott Seirer

Interns load silphium plants on a trailer for a trip to the field.

Many hands needed

By JAYNE NORLIN
Director of Institutional Advancement

There is a photo I like to use on thank-you notes, because it illustrates so much that's true about The Land Institute. It depicts several of our younger staff members hand-carrying flats of silphium, one of the crops we're working on, to an old trailer for transport to fields for planting.

Jayne Norlin

It's important work because oilseeds are versatile sources of human nutrition, and silphium is proving to be an especially resilient member of the oilseed family. It's capable of surviving — even thriving — in times of severe drought.

In the simplest of terms, the picture brings to mind the old saying "many hands make light work." Several can do in a short time what would take many hours for one to accomplish alone.

It's an important concept with labor-intensive work such as ours. In the case of silphium, seeds from the most promising plants in the fields are gathered, and grown out in our greenhouse. The best of those seedlings are then selected and grown out in the fields, where they must be painstakingly evaluated again. Only seeds from the strongest, most promising plants will make the trip back to the greenhouse to continue the cycle. The process requires many eyes and many hands.

The same concept applies to fundraising.

Just outside the frame of the photo is the almost-state-of-the-art greenhouse where silphium and many other plants get their start. There, sophisticated instruments monitoring temperature and moisture ensure the seedlings get what they need to survive until they're big enough to demonstrate their potential hardiness for life outside the greenhouse. Beyond the greenhouse is the Research Building, where some of the top plant breeders in their fields are working on intermediate wheatgrass, sorghum, perennial wheat, silphium and other oilseeds, as well as the polyculture arrangements in which they can be sustainably grown.

Truth be told, renovation of the greenhouse and construction of the Research Building could not have been accomplished without a handful of supporters who stepped up to make disproportionately large gifts. The same can be said of the new research initiatives described throughout this report – a single large grant supports a great deal of that work

But those who've stepped up in a major way for special projects would not have done so had they not known that our core programs had the solid support of many other donors at all levels.

Many hands, holding gifts, inspired their confidence.

As we transition into a new era at The Land Institute, with a new president, we hope you – and many other friends we haven't yet met – will continue to demonstrate your faith in our work with your support and interest. When we say that support makes a difference – we mean it.

Wes Jackson: Perennial polycultures are a key to soil protection.

Soil erosion tolerated too long

By WES JACKSON
President, The Land Institute

On a global basis, soils are in trouble. Therefore, the United Nations Food and Agriculture Organization has declared 2015 as The International Year of Soils. Soils are in danger, the FAO says, "because of expanding cities, deforestation, unsustainable land use and management practices, pollution, overgrazing and climate change."

"The usual rate of soil degradation threatens the capacity to meet the needs of future generations," the FAO says. "As long as soils are at risk, sustainable agriculture, food security and the provision of ecosystem services are compromised."

To what extent will FAO's efforts succeed? It has regional offices in Africa, the Pacific, Central Asia, Latin America, the Caribbean, Near East and North Africa. In the U.S., the Natural Resources Conservation Service has county offices to help protect soil. Will this global effort be enough? Few to none of past efforts have been adequate in spite of countless warnings from ancients including Plato; Patrick Henry, who said that the greatest patriot is the one who stops the most gullies; and practitioners such as George Washington, who "informed his overseer in 1795 that immediate profit was not so much an objective as the bringing of worn-out and gullied fields into condition to produce grass."

Ecologists weighed in, not the least of which was Aldo Leopold who in 1921 wrote, "…the destruction of soil is the most fundamental kind of economic loss which the human race can suffer. With enough time and money, a neglected farm can be put back on its feet – *if the soil is still there*. With enough patience and scientific knowledge, an overgrazed range can be restored – *if the soil is still there*. By expensive replanting and with a generation or two of waiting, a ruined forest can again be made productive – *if the soil is still there*. With infinitely expensive works, a ruined watershed may again fill our ditches or turn our mills – *if the soil is still there*. But if the soil is gone, the loss is absolute and irrevocable."

> "… if the soil is gone, the loss is absolute and irrevocable."
> *– Aldo Leopold*

Our national effort to conserve soil had to wait until 1933 when Franklin Roosevelt took office to address especially the private lands of farmers. Hugh Hammond Bennett was named the first director of the new Soil Conservation Service (now the Natural Resources Conservation Service). Five years before his

(Continued on next page)

The roots of a perennial prairie plant, grown in a 10-foot section of PVC pipe, are pulled from the ground at The Land Institute. This specimen was one of several TLI provided the U.S. Botanic Garden in Washington, D.C., for a display titled "Exposed: The Secret Life of Roots." The display was in recognition of the International Year of Soils declaration of the United Nations Food and Agriculture Organization.

(Continued from previous page)
appointment, Bennett wrote "What would be the feeling of this Nation should a foreign nation suddenly enter the United States and destroy 90,000 acres of land, as erosion has been allowed to do in a single county?"

Despite the 80-year history of the Natural Resources Conservation Service, soil erosion in the United States still continues at an unacceptable level over most of our grain-producing acres.

Why have we not solved this most urgent problem? Some believe we can renew any degraded soil on Earth, not realizing that on a global basis soil is as much of a non-renewable resource as oil. This is sometimes hard to understand because it requires thinking of where and how soil evolves over the entire ecosphere and that it happens in geologic time.

When it comes to conserving soil in nature's way, tried and true over millions of years, our work in developing perennial polycultures commands attention. The FAO is the appropriate organization to make soil conservation and quality an issue on a global basis. FAO knows of our work, has endorsed it and has invited our scientists to the last two of their annual meetings.

Of course, every year since 1977 has been the International Year of Soil for us at The Land. It was then when we set ourselves the task to solve what we call the 10,000-year-old problem of agriculture. I wrote then that the task would take 50-100 years. Well, we're ahead of schedule, far ahead, because of the support of people like you. That goal once was considered crazy, but now is becoming increasingly regarded as necessary and doable.

A roots specimen is loaded into a rental truck for transport to the U.S. Botanic Garden in Washington, D.C.

John Head, a professor at Kansas University, makes a point at the ecosphere education conference.

News Briefs

Wes Jackson to step down as president next summer

Wes Jackson, co-founder of The Land Institute, announced this fall that he will step down as president next June. That point on the calendar marks his 80th birthday and the 40th anniversary of the institute devoted to developing perennial grains to be grown in mixtures.

Wes Jackson

The Land Board has named a five-member committee, headed by Board Chairman Angus Wright of Sacramento, Calif., to search for a successor.

"As Wes at age 80 is ready to turn over the presidency to someone else," Wright said, "we on the board are searching for a person who is ready and able to pursue the vision of natural systems agriculture and perennial polycultures with the same energy, insight, and dedication as Wes has done for 40 years."

Jackson said his resignation as president should not be seen as full retirement. He plans to continue working with The Land Institute and promoting natural systems agriculture and other environmental issues.

Teaching the ecosphere explored at conference

In June, about three dozen people from across the nation, many of them educators, came to The Land Institute to brainstorm ways to transform education to portray Earth as an ecosphere of interconnected elements that we must value and protect.

The present, industrial thinking that treats the Earth as a mine won't do, said Wes Jackson, president of The Land Institute.

The Institutionalization of an Ecological World View conference, conducted in The Land Institute's Big Barn, explored ways to see that students are taught the need for people to become an interdependent part of the planetary whole, to preserve and protect soil, to make wise use of energy and to adopt better food systems.

New joint project expands perennial grain research

The Land Institute's work on establishing agriculture based on perennial polyculture was given a boost with the establishment of a joint project with the Denver-based Malone Family Land Preservation Foundation.

The Perennial Agriculture Project is an independent entity funded solely by the foundation to augment Land Institute research. Tim Crews, director of research at The Land Institute, also directs the Project.

The foundation has committed $1.5 million annually to the 15-year Project. That money does not flow into The Land Institute's budget, but the Project amplifies the institute's mission of developing perennial crops to be grown in mixtures. Under the Project agreement, the institute and foundation will work together to coordinate research strategies.

Too-eager hybrids face danger

Shuwen Wang is searching for a plant that remembers its need for cold weather.

All living things are highly vulnerable in their infancy, and plants acquire traits that help ensure they start flowering at a time of year when they are most likely to survive. At The Land Institute, Wang is breeding perennial wheat by crossing Kernza® (intermediate wheatgrass), a perennial, with annual wheat. He discovered that although Kernza that has been harvested in the summer waits until spring to flower again, the hybrid produced by crossing it with wheat isn't so patient. It flowers almost immediately, and consequently doesn't survive the winter.

Jeffrey Michel harvests perennial wheat by hand in a Land Institute plot.

Why does perennial wheat not wait? Wang believes he may know the answer to that question. Out of literally thousands of perennial wheat plants he found one that waits until spring to put out its heads. Careful examination of its DNA suggests that the difference between this plant and all its relatives is that this one, like regular Kernza, won't send out tillers until it has been through a cold period. In virtually all cases, crossing Kernza with annual wheat produces a hybrid that fails to recognize that it needs winter before producing seed again.

Now Wang has some plants growing in test plots to test that hypotheses. If what he posits is true, the next step will be to figure out how to preserve that trait in every cross.

He isn't tackling this regrowth question alone. Collaborators include researchers at Oklahoma State University, in China and in Germany. The Land Institute is also participating in a global experiment that involves growing 20 lines of perennial wheat in nine countries. The experiment is now in its second year. Five of the lines came from The Land Institute.

"We want to find the best perennial line for a particular location," Wang says.

Scientist Shuwen Wang displays a perennial wheat sample during a Prairie Festival tour.

To be successful, a perennial wheat hybrid must wait for a cold-weather signal before attempting to produce seed again.

A field of Kernza interspersed with alfalfa, a legume, is part of a continuing study of the polyculture concept. This scene is in early spring.

Perennials could be key in rebuilding depleted soils

In the long run, less can be more.

Or, to put it more concretely, annual plowing of the soil can help grow a lot of grain in the short term, but can easily rob the soil of its capacity to grow crops in the future.

Tim Crews, ecologist and director of research at The Land Institute, is the lead author of a paper that emerged from the gathering of scientists he arranged in Estes Park, Colo., last year. The paper examines how soils build organic matter when colonized with perennial plants and left undisturbed during ecological succession. When Crews and Land Institute sorghum breeders Stan Cox and Pheonah Nabukalu were in the West African country of Mali in September, they saw soils that had lost almost all their organic matter due to intensive annual crop production. They realized the potential value of perennial polycultures for helping to boost soil productivity.

"One of the few ways to get out of this condition is to try to build back a little soil organic matter," Crews says. "If you can get it back to a point, it can function again as an ecosystem."

A Land Institute intercrop experiment, now in its third year, provides insights into how this might be achieved. The plots feature a combination of arrangements – monocropped Kernza®, with and without fertilizer, and Kernza intercropped with alfalfa. One objective is to better understand how Kernza responds to different sources of nitrogen.

"The alfalfa/Kernza plots are looking a lot more like the Kernza fertilized plots this year," Crews says. "There are yield trade-offs. Kernza planted at 15 inches and heavily fertilized is probably going to produce more than Kernza planted at 30 inches with an alfalfa strip down the middle. But that's not necessarily the best way of looking at it. What we're looking at is, can this ecosystem sustain itself? If the system is having to use some of its energy to accomplish ecosystem services like fixing nitrogen, then that energy will not end up in grain. But you end up having a sustainable agriculture."

One of the advantages perennials have over annuals is their greater ability to produce biomass. The Land Institute is collaborating with several institutions in experiments that examine the effect of simulated spring and fall grazing of Kernza to take advantage of the high biomass production.

"If it could be grazed as well as produce grain, Kernza could become economically viable sooner," Crews says.

Tim Crews lectures on ecology.

Scientist Lee DeHaan checks the combine bin to gauge the harvest bounty of an 8-acre Kernza field.

Partnerships boost Kernza work

If you think the blind men with the elephant faced a daunting task, consider what geneticists are up against.

"Some traits can be hard to measure," says Lee DeHaan, who heads our efforts to domesticate intermediate wheatgrass (Kernza®). He offers bulls and milk production to illustrate.

Lee DeHaan

"Bulls contribute as much to that trait as cows but the bull itself never produces any milk, so it's only by genetic prediction that you know how much capacity that bull transfers to its offspring," DeHaan says. "If you measure all the relatives – all the mothers and grandmothers and aunts and daughters and cousins – if you put all that into a model you can say this bull has a breeding value of so much milk production even though the bull never produced a drop of milk."

Domesticating a wild species entails encouraging or discouraging many traits. Even if a set of genes is thought to be associated with the expression of a trait, there's usually much more that needs to be known.

"You usually don't know how many gene forms there are, or where they are located, or how they are related to each other," DeHaan says. "We would need to sequence the whole genome for that."

Using current technology, that still could take years to complete.

So although many of the challenges are daunting, DeHaan has nevertheless made substantial progress with some traits. For example, in 10 years he has nearly tripled the size of Kernza seed.

"If you select only for bigness, it's surprising how much progress you can make," he says. "When I started, the biggest seeds I had were less than 6 milligrams. Now the whole population is bigger than the biggest seeds we had."

DeHaan sees the combination of genomic data and phenotypic information as a potent combination for advancing the species.

"It could mean that instead of growing 30,000 plants a year, which I'm planting right now, we could grow 2,000 plants a year but still have selection comparable to growing 30,000," he says.

Perhaps the most promising development of the past year has been the forging of new partnerships and collaboration. One example is a paper that has been accepted but not yet published that shows how mixing quality – a key trait contributing to baking quality – is highly correlated with certain proteins. Testing for those proteins is inexpensive and can be done with as few as five seeds. Identifying the trait genetically is expected to follow.

"I'll be able to say, of the families that we have, these are the best," DeHaan says. "I can take plants from those families, cross them together, and hopefully get a population of higher baking quality."

Clipboard in hand, sorghum breeder Pheonah Nabukalu inspects plants in the field.

Day length crucial to sorghum

Most humans barely notice as summer whittles daylight from 14 hours to 13 hours to 12.

For plants, it can be a life or death matter.

"Sorghum grown in the tropics is very tightly attuned to day length, almost to the minute," says Stan Cox, who heads perennial sorghum research at The Land Institute. "The flowering kind of sorghum is very dependent on the length of day, or, more technically, the length of night."

Stan Cox

Sorghum grown in the United States is typically planted not long before the summer solstice, when days are approaching their longest.

"Once the sorghum is planted, it isn't triggered to flower until the days get short enough after the solstice," he explains.

This presents an interesting challenge if lines grown at one latitude in one climate are to be useful in another latitude with another climate.

"This will require – and we've been saying this from the beginning – taking our lines and crossing them with locally adapted ones," Cox says.

> Encouragement found in Mali: "Here were our plants flowering right in the midst of the monsoon."
>
> *– Stan Cox*

So last year we sent a team to Africa to plant test plots; this year a team returned to see how sorghum grown in Kansas fared in Uganda (900 miles south of Miami) and Mali (1,750 miles south of Miami).

"I expected to see bare ground," Cox says. "I had no expectation those rhizomes could withstand that degree of desiccation and heat, but they did. Here (in Mali) were our plants flowering right in the midst of the monsoon. In Uganda, they were clobbered with just about every disease Africa has to offer up."

All of which is most encouraging.

"A lot of that can be addressed by crossing with locally adapted material that has the right day-length sensitivity and has gone through a lot of selection over the years for resistance or tolerance to those diseases," Cox says.

Trays of silphium seeds are prepared for germination in the hoop house.

Plant traits worth a closer look

It has been something of an article of faith that annual plants grow quickly and rapidly consume resources during their short lives, whereas perennials live more thriftily, growing with deliberation through the efficient use of resources.

David Van Tassel

But is that necessarily so?

No, actually. A study by scientists in Argentina who are working with The Land Institute found perennials that grow faster than some annuals, and annuals that grow more slowly than some perennials.

"It sort of challenges this clean-and-neat characterization," says David Van Tassel, who heads oilseed research at The Land Institute. "The question is, how many of these clusterings of traits are by accident or for historical reasons that may no longer apply?"

This question goes to the heart of The Land Institute's work. Perennials can do more work than annuals because they process sunlight more days out of the year, so shouldn't they have enough energy to produce more seed than annuals?

It has already been shown that selectively breeding a perennial plant for seed yield can eventually turn it into an annual.

"Is that always going to be the case?" Van Tassel asks. "Is that necessarily what happens? If we can figure out which plant traits are associated with high yield, but are not associated with either reduced life span or some other negative thing, like profligate use of water, then we would want to focus on those traits."

The connection with the Argentinian scientists has been enhanced by a Fulbright scholarship awarded to Van Tassel last year that gave him time to work in South America, where he launched several experiments with silphium, a perennial member of the sunflower family.

"There are people in several different places that have begun research projects using silphium, and that really was not the case a year ago," he says.

In one case, three graduate students have extracted RNA from three-dozen plants Van Tassel sent, and they've initiated sequencing of that RNA. That's something that has never before been done.

"That's huge," Van Tassel says. "RNA is a very small subsample of the genome, but it's very important because that's what gets turned into proteins and enzymes."

Intern Marshall Berry counts seedlings in the hoop house.

Pursuing Research

A paper bag containing a freshly harvested head of a Maximilian sunflower plant is heaved by intern Andy Webster to the edge of the field for pickup.

Research work: Tossing, counting, bagging

Silphium plants, their heads harvested, are shrouded in plastic as part of an experiment to see if the plants gain strength through photosynthesis in late fall after harvest.

Left: **Silphium plants grow in the hoop house.**

Campers attending the Prairie Festival in September rise to greet a bright day.

A hope for environment: Ethics

The need to value nature and practice environmental ethics was a common thread among speakers at The Land Institute's annual Prairie Festival in September.

Among the speakers, Mary Evelyn Tucker, a Yale University research scholar, said that although the Earth's cries are becoming more dire the challenges we face are pulling us into a new period of understanding that we are together in a vast, changing universe. It is our religious, spiritual and ethical cultures and worldviews that will lead us to common good, she said. She sees a new era dawning as our energy and creativity are sparked to question "what are we as humans trying to contribute toward a flourishing planetary civilization."

John Cobb, theologian, philosopher and author, struck a similar theme, saying we are coming to understand that interdependence is at the heart of everything.

The festival drew an audience of 705, virtually unchanged from the previous year. Besides the speeches, events included art and music, tours of plant breeding fields, yoga, a prairie walk and the traditional bison stew dinner.

Next year: A special festival

The festival next year, set for Sept. 23-25, will be a celebration of The Land Institute's 40th anniversary and a tribute to Wes Jackson, the institute's co-founder who plans to step down as president in June. Mark your calendar.

Bison stew is featured at the festival dinner.

Mary Evelyn Tucker is greeted by well-wishers following her Prairie Festival talk.

Our financial report is solid

By SCOTT SEIRER
Managing Director

We report a stellar year on the financial front. Total revenue for fiscal 2015 was $4.7 million, sharply higher than the $3.0 million we set as the target when the budget was drawn. That increase in funding, and our expectation that we can continue to build our funding stream, has led us to ramp up the scope of our work and increase our operating budget this fiscal year to $4.6 million.

Scott Seirer

Our financial strength is reflected on our balance sheet. We began the new year on July 1 with the books showing $16.9 million in assets, up 18 percent from $14.3 million a year ago. Our financial strength has allowed us to add new equipment and facilities. During the fiscal year, for example, we renovated our vernalization chamber (where plants can experience an artificial winter), and added another equipment storage building. Our equipment fleet has been expanded, and the additions include a sophisticated seed planter that allows computer-controlled planting precision in our test plots. Such investments are key to expansion of our research capacity. And, to literally power our work, we recently added solar panels to the roof of our Research Building to draw electricity from the sun.

We begin the new year with much optimism. As usual, we have no debt. We have cash on hand and contributions in the pipeline. We have money set aside for capital expenses. Our operating budget is growing at a healthy, yet manageable rate, and with it our capacity to pursue our mission is expanding.

We invite you to take a closer look at our financial strength by reviewing our audit, which is posted on our website (www.landinstitute.org).

Volunteers from the Flint Hills Renewable Energy Co-op and the Salina community help with the placement of solar electric panels on the Research Building roof.

Technician Sheila Cox threshes sorghum on the back patio of the Research Building.

Wes Jackson on soil degradation:

"… the soil's nutrients are pulled downward relentlessly toward the sea and downward through nutrient leaching, beyond the reach of plant roots. We have not been given a license to accelerate this loss of useful atoms at a rate faster than geologic recharge. But we have been doing it for 10,000 years primarily with annual grain agriculture."

– From his Prairie Festival address, Sept. 27, 2015

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