ATTAINABLE
VISION
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POSSIBLE

NOBLE RESEARCH INSTITUTE ANNUAL REPORT | 2017


“The only degree to which we have reached the end of the road of
OPPORTUNITY
is the degree to which we have exhausted the imaginative capacity of the human mind.”
LLOYD NOBLE | 1948

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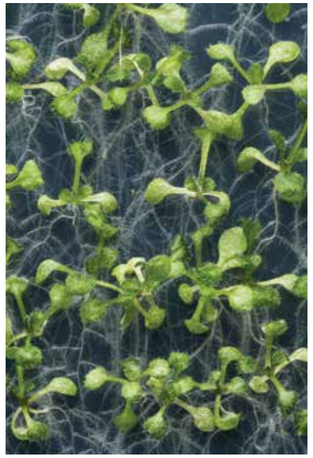

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Improving a Solution

Advanced gene editing techniques offer new hope for scientists seeking to provide farmers and ranchers with new tools that advance land stewardship.

ALSO INSIDE:

More than 2.5 million people fled their homes and farms in search of better lives as a result of the drought and dust storms of the 1930s. In 1945, Lloyd Noble formed the Noble Research Institute (then known as The Samuel Roberts Noble Foundation) as a permanent resource to help farmers and ranchers rebuild the soil and improve agricultural productivity.

INTRODUCTION

Making the Impossible Possible

The lens of history often blurs the reality of a moment. Viewed from the technological age, the great Dust Bowl of the 1930s has diminished from unprecedented natural disaster to mere lore, a Steinbeck novel, a Woody Guthrie ballad, a sepia tone backdrop for a tale about humanity's enduring spirit.

The slow ebbing of nine decades has mostly erased society's connection to this era and with it the underpinning lessons, the faint echoes of conservation. Today's generation often forgets that while man ultimately fashioned solutions to the Dust Bowl he also contributed to its genesis. Farming methodology of the time sprang from limited knowledge, even superstition. The resulting practices were unsustainable and **inefficient**.

Ignorance of soil conservation and proper stewardship left the land susceptible to nature's caprices. For much of the 1930s, the region endured a historic drought — one of the worst in 300 years, scientists now say — that pushed the land beyond its capacity. Sun-baked fields could no longer sustain a crop. The land stood unguarded and **uncovered**.

Bare earth inevitably became prey to the invisible talons of the prairie winds, which stole more than could be imagined. On "Black Sunday," 300,000 tons of life-giving topsoil — twice as much as removed from the whole of the Panama Canal — swept eastward toward the Atlantic Ocean in one afternoon. With it, went the hope of a generation. Man's unity with the soil, a dependence that stretches back to civilization's origins, found a sudden and violent **division**.

For years, dust storms blotted out the sun, forcing families to huddle in their homes — wet sheets and clothes shoved under doors and around windows. But the dust from these black blizzards still found its way in. Into homes. Into lungs. Dust pneumonia claimed lives, and a fractured economy swiped the viability of countless families. No way to grow food. No way to sell food. The people and land stood **disconnected**.

Rebuilding the Southern Great Plains was a task of such enormity it defies understanding by modern observers. Almost 35 million acres — a plot of land the size of Arkansas — were deemed completely useless with another 125 million acres experiencing rapid depletion of its topsoil. More than 2.5 million people fled the Dust Bowl states seeking a more fertile future. The wind blew their soil east, so thousands headed west in ramshackle rigs. Pulling life from the barren earth was deemed by pundits of the time as simply **unattainable**.

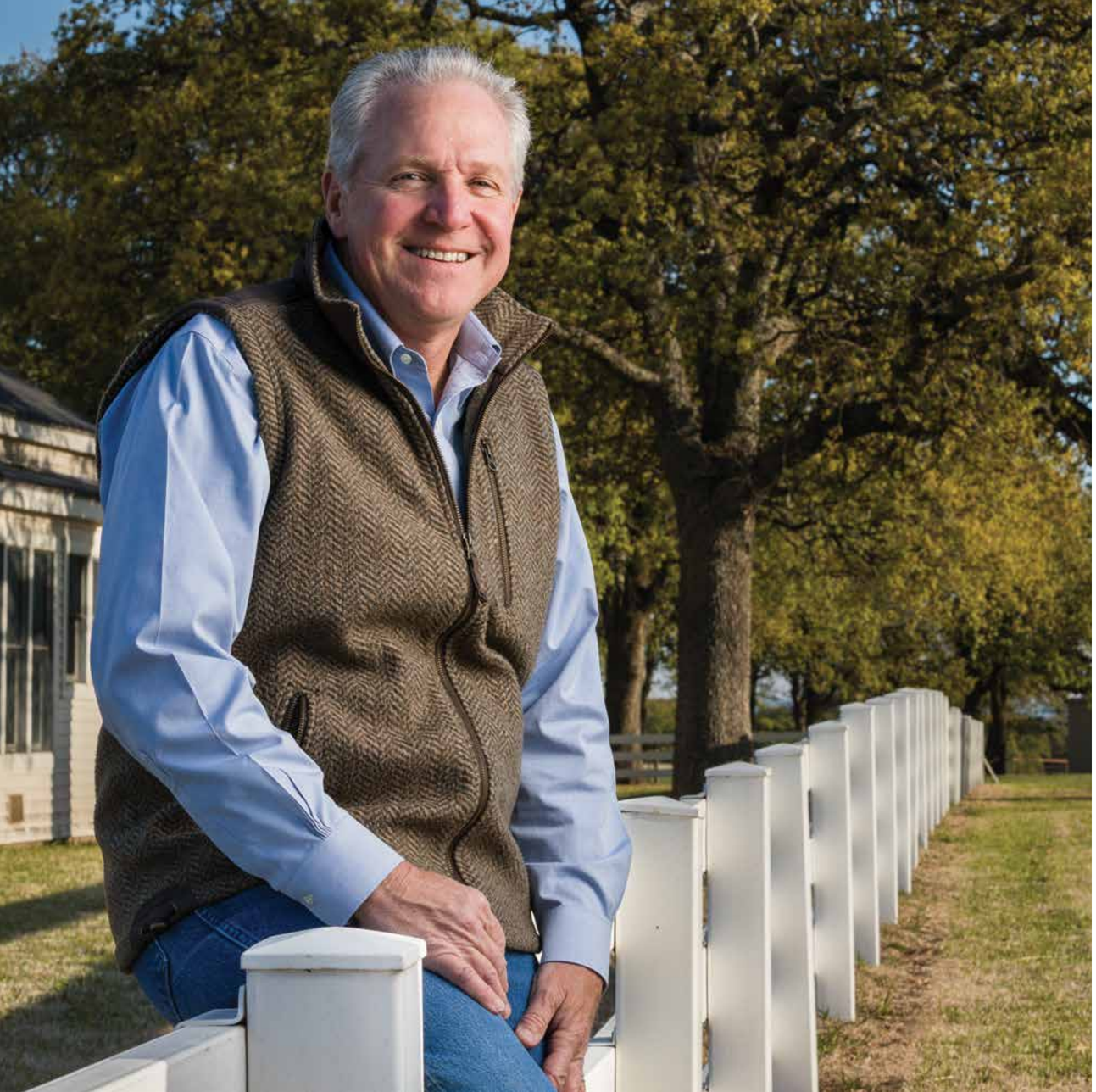
Only an uncommon few saw past what was and believed in what could be. Oklahoma philanthropist Lloyd Noble understood the width and depth and length of the scar left by the Dust Bowl on the land and the society that depended on it. Oklahoma was his home, the birthplace of opportunities that gave rise to his great fortune. He felt the burden of its recovery. He sought new methods to once again make the land **efficient** and the soil **covered**.

Noble, along with a band of soil conservation pioneers, assumed the mantle of jumpstarting a region. Speaking. Educating. Rallying converts to the banner of land stewardship. They declared the soil to be man's most precious and valuable resource. They brought hope that dispelled the fear of a generation and cast a new **vision**.

Noble went further. He established a permanent resource to assist agricultural producers eager to continue the recovery from one Dust Bowl and implement practices that could prevent another one. He formed the Noble Research Institute (then known as The Samuel Roberts Noble Foundation) to provide solutions to agriculture's greatest challenges. He knew the Southern Great Plains — and all of agriculture — would face a conveyer belt of challenges be them economic, natural or man-made. Endless tests would require ongoing solutions and a place where like-minded advocates could **connect**.

For 72 years, the Noble Research Institute has been a constant companion for producers, offering counsel and education. Knowledge generated in Noble's laboratories, greenhouses and research ranches flow into the agriculture sector. Innovation and technology seek to answer questions in ways never before dreamed, making seemingly insurmountable challenges suddenly **attainable**.

This annual report bears witness to the legacy of a man who survived the Dust Bowl and planted a seed that has reaped generations of healthier land and more productive farmers and ranchers. Within these pages are stories of men and women who are the standard-bearers of a fundamental truth that unity and boldness can shape history. They share an unflinching courage to explore, a daily devotion to rolled-up sleeves and a tenacious belief that countless small steps finally make the impossible **possible**. ■



TO OUR READERS:

Never Fear Challenges

There will always be reasons to avoid a challenge.

Maybe no one has ever attempted it before. Maybe the cost is too high or the timetable too short. Maybe the obstacles to success line up like an endless hurdler's lane. How many groundbreaking ideas have died seconds after inspiration merely because of the internal roll call of self-doubt?

Within the Noble Research Institute core values exist three simple words: "Never fear challenges." We will not let the threat of failure or the perceived size of a task deter us from venturing into the unknown. This perspective changes how we approach problems and unleashes our ability to solve them.

Throughout the pages of this annual report, we display the intrepid spirit that makes the impossible possible. Be it pioneering new CRISPR technology or leading a national cover crop initiative, we strive to attain the unattainable. This organizational ethos is not merely written on paper; it's etched into our actions.

In the last six years, Noble has led the Soil Renaissance, which brought together experts from all corners of the soil conversation to generate new ideas and lasting solutions. Success was not assured; but we walked into the unfamiliar, and our determination resulted in the creation of the Soil Health Institute, an entity with the sole focus to safeguard and enhance the vitality and productivity of the soil.

We also helped create agricultural research organizations (AROs), a new type of 501(c)(3) that offers the next generation of philanthropists a new vehicle for using private resources to advance agriculture. And as a course of our conviction, we became the nation's largest ARO.

Noble will never fear challenges. We will continue to convene unlikely collaborators. We will seek innovations through research and technology. We will carry the banner of agriculture. This is why I am confident as we once again pioneer new territory.

In March 2017, we assembled a series of meetings with multisector stakeholders to explore and assess the potential for creating a radical new solution that would jump-start the adoption of soil health practices across the country.

The group assessed the challenges and risks of developing a new type of market, one focused on farmers and ranchers. They created lists of pros and cons, obstacles, and opportunities. The question was then posed: Could we build a large-scale program to create and sell ecosystem service credits from working agricultural lands?

Walking away would have been easy. It's always easier.

Then the words of our founder, Lloyd Noble, echoed from the past: "The only degree to which we can make real progress is the degree to which, when we have ideas, that we can get those ideas motivated into action."

The prospect of creating a new type of market was daring. The only missing component was the desire to try, and that is a characteristic we are never short on. So we have embarked on an ambitious national effort to develop a market-based ecosystem services program that incentivizes farmers and ranchers to voluntarily implement soil health practices. A market such as this supports the agricultural producer with the grander goal of benefiting society at large.

Healthy soil can sequester and build soil carbon, enhance water quantity and quality, increase production, and decrease the cost of inputs. And these are just a few among a long and growing list of advantages that have positive generational repercussions.

At the moment of this letter, we are in a steeplechase of obstacles and work. We know that success is not assured, but the possibility to transform agriculture is too great of an opportunity to not try.

So we will walk forward with our team. We will put forth our full effort. We will be driven by hope. Ultimately, we can be proud of the outcome because no matter the result, we never feared the challenge.

Sincerely,

PRESIDENT AND CEO

For more information on the Ecosystem Services Market, visit noble.org/market.

Lloyd Noble's vision to care for the soil and the people who depend upon it continues through the organization he founded, which became known as the Noble Research Institute in May 2017.

UNATTAINABLE

Lloyd Noble's vision to care for the soil and the people who depend upon it continues through the organization he founded, which became known as the Noble Research Institute in May 2017.

Lloyd Noble established The Samuel Roberts Noble Foundation on Sept. 19, 1945, as a resource to encourage farmers and ranchers to adopt practices that would benefit the land, increase agricultural productivity and improve quality of life. He named his organization in honor of his father, who he described as the most charitable man he knew. In May 2017, the Noble Foundation became known as the Noble Research Institute.

"The obligation that rests squarely on the shoulders of each generation is not what they inherit, what they have handed to them, or what they acquire from the standpoint of wealth or position, but what they do with the wealth or power that they have in their hands."

LLOYD NOBLE | 1933

ATTAINABLE

Great need begs for big solutions. For an inspired, well-equipped generation of people for agriculture and the world. Ideas must come from every corner of the mind to grasp the unattainable. Add a thorough plan and determination. Draw people together with a shared vision. What once seemed lofty can become reality.

~~UN~~ATTAINABLE

Serving a Greater Purpose

Lloyd Noble's legacy continues with a bold step for his organization and new opportunities for funding agricultural research that benefits all of society.

The prelude to a new beginning unfolded in front of nearly 400 employees on April 26, 2017.

The all-employee meeting room, which had been silent with anticipation, boomed with applause as the announcement was made: The Noble Foundation would become the Noble Research Institute in five days.

The Noble Research Institute would continue Noble's 72-year-long legacy of research, consultation and education programs. A new nonprofit, the Noble Foundation, would continue philanthropic programs.

The moment symbolized a transformation that would create new funding and collaboration opportunities for agricultural research at the organization and beyond.

The historic moment was one many had thought unattainable.

It Took an Act of Congress

When Steve Rhines joined the Noble Foundation in 2001 to serve as intellectual property counsel, he became part of the search for a better way to steward the organization's resources and its mission to advance agriculture.

The consensus among the organization's leaders was that to remain classified by the IRS as a private foundation would limit its ability to conduct operations. The more desirable alternative was to become a public charity, but no mold seemed to fit. In 2004, Mike Cawley, president at the time, sent Rhines and others to Washington, D.C., to see if they were missing anything.

There, they sat across from legal counselors at Hogan & Hartson (today Hogan Lovells). The attorneys listened with interest to this unusual private foundation's story. Like most private foundations, the organization was initially funded by one private source (Lloyd Noble) and most of its revenue came from the investment of those funds (its endowment). But unlike most private foundations, the Noble Foundation also conducted its own direct operations: basic and translational plant science, applied agricultural research and demonstration on working farms and ranches, no-cost consultation for farmers and ranchers, and educational programs for youth and adults.

The attorneys said Noble's activities ran parallel to a lesser known type of public charity: the medical research organization, or MRO, which their firm had helped create within the U.S. tax code in the 1950s. The difference was obvious. Medical research organizations are dedicated to human health, so the MRO model would not fit unless the definition of "medical research" could be extended to include agriculture. It could not, but another idea was planted. What if a similar but new form of public charity, an agricultural research organization, or an ARO, could be created?

Pursuing the idea was not likely to be successful, the attorneys said. The pages of notes were filed away for three years, but Rhines and Noble's leadership never completely gave up on the thought.

By June 2008, Rhines, Cawley and Jeff Moen, who had joined the organization in 2007, developed a proposal to the Noble Foundation Board of Trustees. Though pursuing the ARO concept would bring many unknowns, the trio saw its potential to open up new opportunities not just for the organization but also for philanthropic giving to agricultural research on a national level.

The Board said, "Yes."

Rhines and Moen spent the equivalent of several months on the road over the next seven years. They traveled the country, explaining the concept and receiving input from deans of agricultural colleges, industry leaders, and ultimately lawmakers and their staffs. By 2015, 65 associations, universities and other nonprofits were lending their support to what had become known as the Charitable Agricultural Research Act, which had bipartisan support in both the U.S. House of Representatives and the U.S. Senate. The bill was introduced eight times from 2011 to 2015 before it was signed into law on Dec. 18, 2015, as part of the Protecting Americans from Tax Hikes Act of 2015.

The Board took a year to carefully consider how to move forward. Every piece of the organization perfectly fit as an ARO, except its philanthropic giving. In December 2016, the Board unanimously decided to split the organization's research, consultation and education activities from its philanthropy program. The former would remain with the organization and continue forward as the Noble Research Institute. A new private foundation with the original name, The Samuel Roberts Noble Foundation, carries on the Noble family's philanthropic legacy in the name of the man Lloyd Noble recalled as the most charitable man he knew — his father.

Beyond Noble, the availability of AROs to philanthropists addresses a greater challenge facing the U.S. agriculture industry: lack of public funding for research. AROs are a new charitable option for those, similar to Lloyd Noble, who want to dedicate their wealth to agricultural research for the public good.

"There were many times when it seemed this wasn't going to work, when our plans would get derailed by a multitude of things that had nothing to do with the merits of the legislation," Rhines said, reflecting on the journey, in 2017, "but we kept going back to something one of the Board members, Bill Goddard, said in one of our early meetings: 'AROs extend the legacy of Lloyd Noble. This effort serves a greater purpose.'" ■

We learned about AROs during a visit to the Noble Foundation (now the Noble Research Institute) back when the model was working its way through Congress. We were originally formed as a private operating foundation but were frequently challenged by the constraints of that structure. Because we operate more than 218,000 acres of native South Texas rangeland and research cattle ranching and wildlife conservation, the ARO structure better fit our mission. We initiated our conversion to an ARO in September 2016. In addition to better aligning our organizational structure and charitable mission, the model strengthens our relationship with the land-grant university system at Texas A&M. We are excited to see what creativity other organizations bring to the table for agriculture as they become or start up as AROs.

Neal Wilkins, Ph.D.
President and CEO of the East Foundation, the first 501(c)(3) agricultural research organization

Bill Buckner, president and CEO of the Noble Research Institute, announces the organization's new name and its plans to become an agricultural research organization, the newest form of 501(c)(3) public charity, at a special event in Oklahoma City on May 5, 2017.

Areas of Activity

The Noble Research Institute continues activities that had been in place before the name and structure changes. These activities are organized into four interconnected areas.

RESEARCH

The Noble Research Institute focuses on research that will help farmers and ranchers improve land stewardship and productivity regionally, nationally and internationally. Scientists consider the full spectrum of agricultural research, including basic, translational and applied. They study the basic molecular and genetic levels of how plants grow and interact with the microbial world around them. They develop stronger and more efficient small grains, grasses and legumes. And they evaluate how well cattle perform in various grazing systems. In 2017, Noble scientists shared their findings through

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PEER-REVIEWED SCIENTIFIC PUBLICATIONS.

PRODUCER RELATIONS

The consultation program officially formed in 1958. However, Noble employees have been working directly with farmers and ranchers since the organization's beginnings. As early as 1946, Noble field agriculturalists advised farmers and ranchers on how to boost their soil's productivity through fertilization and conservation practices. In 1958, consultation began with three farmers in Carter County, Oklahoma, and with three farmers in each of the seven surrounding counties. In 2017, consultants worked with

1,764 FARMERS AND RANCHERS, INCLUDING 88 FOR THE FIRST TIME.

APPLIED AGRICULTURAL SYSTEMS RESEARCH AND TECHNOLOGY

The Noble Research Institute is one of the largest agricultural producers in Oklahoma. The organization operates seven research and demonstration farms that span 14,000 acres in the southern part of the state. There, researchers raise forage-based beef cattle, grow horticultural crops like pecans, and manage natural resources in ways comparable to how farmers and ranchers in the region operate. In addition, these farms provide a place to apply research to real-world environments and an opportunity to test out practices and technologies so producers don't have to invest their resources in trials. In 2017,

58 applied agricultural systems research and technology projects and demonstrations were initiated or in progress.

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EDUCATION

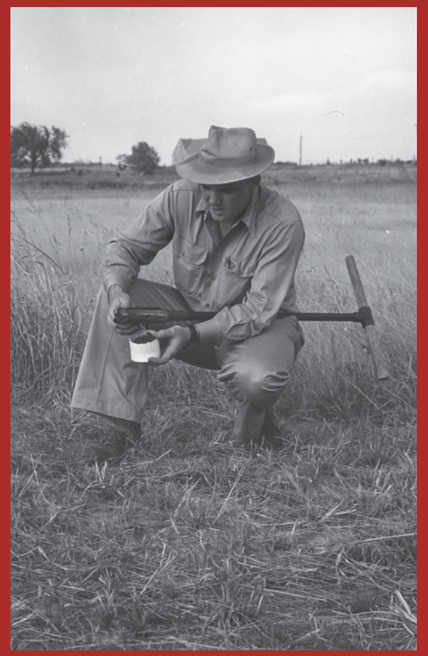
Lessons learned on the farms and ranches turn into information shared with students of all ages. The Noble Research Institute hosts agricultural seminars and workshops for farmers, ranchers and others interested in hands-on agricultural production and natural resource stewardship. All are welcome to learn the latest research-based approaches to managing cattle, forages, soils, horticultural crops, natural resources and economics. The Noble Research Institute also fosters an awareness of and appreciation for agriculture in the next generation. Youth learn about science and agriculture through interactive learning opportunities including hands-on lessons, tours, field days and internships. In 2017, educational staff hosted **1,281 people on tours of Noble's agricultural facilities** as well as **1,672 farmers, ranchers and other land managers who attended 14 agricultural education events.** They also reached

7,146 STUDENTS AND 575 TEACHERS through tours, hands-on lessons and interactive field days.

Farmers plant cover crops, such as crimson clover, between seasons of a traditional crop, when the ground would typically lie bare.

UNCOVERED

Farmers plant cover crops, such as crimson clover, between seasons of a traditional crop, when the ground would typically lie bare.



Some of the Noble Research Institute's earliest activities involved testing soil samples for farmers and ranchers and making fertilization recommendations. Noble field agricultural consultants advised land managers on how to rebuild and conserve the soil. In the 1950s, the organization expanded its agricultural research to include beef cattle production, field and horticulture crops, cropping systems, irrigation, and marketing.

"No civilization has outlived the usefulness of its soils. When the soil is destroyed, the nation is gone."

LLOYD NOBLE | 1949

Wind and water carries tons of topsoil, the foundation of life, away from farmland each year. The soil, and its ability to produce food, slowly weakens. Farmers and ranchers are increasingly adopting an old-time armor for soil: cover crops. But they have many questions that still need answered.

COVERED

UNCOVERED

No More Bare Ground

A national agricultural research initiative aims to promote soil health through the development and adoption of new cover crops across the U.S.

Beneath the surface of civilization lives another world, a microscopic one filled with fungi and bacteria so tiny that millions of them can fit in one teaspoon.

Many of these microbes make their homes along the underground highways of plant roots. They act as tollbooths, helping the roots take in water and nutrients from the soil in exchange for food and shelter. When the roots are gone, the microbes suffer. When microbes suffer, eventually the soil deteriorates.

Soil sickness is not obvious at first. But over time, mediocre soils increasingly lose their ability to hold water. They become vulnerable to wind, which carries them away in storms reminiscent of the Dust Bowl. They lose their natural fertility and ability to capture and store carbon.

Healthy soils hold the power to solve many of farmers' and ranchers' greatest challenges. But how do farmers and ranchers rejuvenate their lands? One way is to cover the soil in plants year-round with a practice called cover cropping. And today's agricultural producers are increasingly interested in the historical practice.

To Develop New Cover Crop Solutions

Jimmy Emmons stumbled upon the concept of cover cropping at a farming conference about seven years ago.

The third-generation farmer and rancher from Leedey, Oklahoma, had been searching for ways to improve his wheat, alfalfa and canola yields. Regardless of how much fertilizer Emmons applied or how much rain the land received, his production had plateaued.

At the conference, a farmer from central Ohio talked about how he had transformed his land by planting cover crops. After harvesting his primary crop, like corn or soybeans, this farmer planted a crop to grow during the season when the land would typically lie bare. Its primary purpose was to improve soil health.

"I thought, 'Man, if I could do that here in Oklahoma, that would be great,'" Emmons says.

There are costs associated with planting any crop. There's seed to buy and machinery to maintain. The risk can seem high when the crop planted is one that typically is not harvested and sold.

But Emmons found that the practice started paying off within three to four years. Today, he credits cover crops, alongside no-till and rotational grazing, with helping reduce his fuel costs by two-thirds and his fertilizer costs by half. As a result of reducing his need for inputs, Emmons has also reduced the potential for nitrogen and phosphorus runoff into nearby streams.

Based on a national farmer survey funded by the U.S. Department of Agriculture, cover crop users in 2012 were planting just more than 200 acres per farm. By 2016, that number had doubled. Still, the estimated 17 million acres of cover crops in the U.S. today represent just a small fraction of the 250 million acres of row crop fields in the U.S. as of the most recent census, from 2012.

In March 2017, the Foundation for Food and Agriculture Research and the Noble Research Institute announced a $6.6 million national research initiative to promote soil health through the development and adoption of new cover crops across the U.S.

The project will address some of farmers' practical questions: Which is the best type of cover to use for which field? How do short-term costs compare with long-term gain? When is the best time to kill the cover crop? How do cover crops affect soil moisture?

"There's not going to be one answer," says Twain Butler, Ph.D., forage agronomist at the Noble Research Institute and project leader. "It's going to be different in Oklahoma and this part of the country than elsewhere."

To answer these questions across the nation, field studies will be conducted at five strategic sites: Maryland for the Northeast, North Carolina for the Southeast, Oklahoma for the Southern Plains, Nebraska for the Northern Plains, and Missouri for the Midwest.

Most species planted as cover crops today were bred for other purposes, like forage and grain production, rather than to maximize conservation traits. In developing new varieties for cover crop use, the researchers will look to bring out plants' natural abilities to develop deep roots and to grow at times that better coordinate with primary crops' growing seasons. Species of interest include small grains (wheat, rye, oat and triticale), annual legumes (hairy vetch, winter peas and clovers) and brassicas (turnips, radishes, kale and mustards).

The network of researchers will also work with farmers and ranchers to better understand what is needed in the field as well as with seed companies to expand effective options on the market.

"Our goal is simple: to get new cover crop solutions into the hands of those who use them or will be using them," Butler says. ■

I started using cover crops about three years ago. I had been fighting disease and armyworms in my wheat fields, and it was getting difficult to get a good stand. I was looking for another crop to rotate with the wheat, hoping to grow more forage for my cattle. Jim Johnson, a Noble Research Institute consultant, suggested I try cover crops and helped me choose which species to plant. I've used a whole mix: brassicas, sorghum sudan, triticale, cowpeas, even okra. I use them as a cover in the summer between seasons of wheat pasture and as a mixed-species forage in rotation with the wheat every third year. I've also been converting to no-till. There are challenges to overcome, but these two practices are helping me be more effective with my time and resources. They're benefiting the land and my ability to feed people.

Lee Wayne Stepp
Rancher from Comanche, Oklahoma, who has received Noble's no-cost consultation since 1992

ABOVE: Jim Johnson, a soils and crops consultant, (right) explains how cover crops can help improve soil health to a group of Noble Board of Directors members, most of whom are descendants of Lloyd Noble, during a tour in 2017. Johnson has been testing various species to see how they perform in the Southern Great Plains.

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Carbon is an essential element for life on Earth. It bonds with other elements to form carbohydrates, lipids, proteins and nucleic acids, which plants and animals need to survive. Carbon is found in many forms. It moves through the global carbon cycle, which encompasses the atmosphere, continents and oceans. Carbon dioxide in the atmosphere is captured by plants and microbes and turned into food through photosynthesis. Fossil fuels are ancient carbon compounds resulting from photosynthesis hundreds of millions of years ago. Burning them releases great amounts of carbon back into the air, but agriculture can help capture some of this excess by fostering plants' ability, through photosynthesis, to store carbon in their roots and the soil.

On a Mission to Cover the Country

Farmers are increasingly interested in growing cover crops. As the name suggests, cover crops "cover" ground that would otherwise lie bare. While these crops do not usually become food for us to eat, farmers can use cover crops to boost soil health, improve water quality and sequester carbon. In some cases, they can be grazed by livestock.

COVER CROP BENEFITS

When plants (and their roots) grow, generally speaking, the land is better able to retain water and the soil is less likely to be blown or washed away. Cover crops also feed the microscopic creatures that live in soil. In turn, these microbes help future crops grow healthy and strong.

Depending on the situation, cover crops can:

- Increase crop yields.
- Fix nitrogen.
- Sequester carbon.
- Reduce pollution.
- Reduce the need for herbicides.
- Attract pollinators.
- Slow or reduce erosion.
- **Increase organic matter in the soil.**

114%

LEGUME CROPS WERE FOUND TO **INCREASE LEVELS OF SOIL ORGANIC MATTER** BY UP TO 114%

- Control plant pests, diseases and weeds.
- Increase biodiversity.
- Conserve water quality.
- Provide seasonal habitat for wildlife.

COVER CROP RESEARCH AT NOBLE

Farmers have many questions about which species to choose as cover crops and how to successfully implement the practice on their land. Currently, most species planted as cover crops were bred for other purposes, like forage or grain production, rather than to maximize conservation traits. The best species to plant will vary from location to location. The Noble Research Institute is part of several projects to help get new solutions into the hands of those who use or will be using cover crops:

Developing New Cover Crop Cultivars

In 2017, the Noble Research Institute and the Foundation for Food and Agriculture Research (FFAR) launched a

$6.6 million

NATIONAL RESEARCH INITIATIVE MADE POSSIBLE BY A $2.2 MILLION GRANT FROM FFAR.

The initiative seeks to promote soil health through the development and adoption of new cover crops across the U.S. Species of interest include small grains (wheat, rye, oat and triticale), annual legumes (hairy vetch, winter peas and clovers) and brassicas (turnips, radishes, kale and mustards). Field studies are being conducted in Maryland, North Carolina, Oklahoma, Nebraska and Missouri.

At Noble:

- **Xuefeng Ma, Ph.D.**, assistant professor, is developing rye, triticale and oat cultivars specifically for dual use as cover and forage. He is also developing genomic resources for small grains.
- **Suresh Bhamidimarri, Ph.D.**, assistant professor, is developing hairy vetch and crimson clover cultivars. He is also developing genomic resources for annual legumes.
- **Zengyu Wang, Ph.D.**, director of core research and transformation, is developing genome editing tools to identify specific genes controlling hard seed in hairy vetch.
- **Twain Butler, Ph.D.**, research agronomist, serves as project manager.

Learn more at noble.org/ffar

Evaluating Species for the Southern Great Plains

In 2014, **Jim Johnson**, soils and crops consultant, began evaluating the local adaptation of a broad suite of nearly 100 common and exotic species used as cover crops. By 2017, he and partners had completed **18 site years of observation.**

Find out what Johnson has learned at noble.org/the-great-cover-crop-test

Watch the videos at bit.ly/cover-crop-playlist

Cover Crops and Microbial Diversity

Kelly Craven, Ph.D., associate professor of microbial symbiology, is working with **James Rogers, Ph.D.**, to better understand the impacts of cover cropping and tillage on microbial communities and ultimately the **health of Oklahoma soils.**

Learn more at noble.org/cover-crops-tillage

Find the latest cover crop information at noble.org/cover-crops

DISCONNECTED

A group of industry leaders explore the story of beef production — from raising calves to selling burgers — in a new way.

A group of industry leaders explore the story of beef production — from raising calves to selling burgers — in a new way.

The no-cost consultation program was formed in 1958 to assist farmers and ranchers in applying research-based information to their operations. Consultation began with three farms in Carter County, Oklahoma, and in each of the seven surrounding counties.

"The only true happiness must come from not only understanding your own needs but an understanding and willingness to secure the same things for your fellow man."

LLOYD NOBLE

CONNECTED

The story of beef is complex. It begins with a calf born on a ranch and continues two years. Dozens of people are involved from start to finish before the story ends at dinner. Though each person depends on the others, rarely does one see the full story. Together, they seek improved sustainability. First, they must connect.

I grew up on a cattle operation, so cattle and the beef industry are in my blood. Producers in the U.S. provide the safest, most nutritious and responsibly produced food in the world. Over time, each segment of the industry has made great improvements. However, there's only so much we can each achieve on our own. The beef sustainability pilot project allows, for the first time, a flow of information throughout the entire beef value chain. Part of my role is to collect and analyze data from participants. Eventually, I'll look at how the U.S. Roundtable for Sustainable Beef metrics worked out in the real world. Most exciting to me, we'll share data with producers that can inform their decision-making at the individual operation level.

Myriah D. Johnson, Ph.D.
Economics Program Leader
and Ag Consultant

~~DIS~~CONNECTED

From Ranch to Restaurant

A two-year national project brings together representatives from each step in the beef value chain to communicate and collectively seek progress for the first time.

Squabbles in the backseat momentarily pause as a McDonald's paper sack is passed through the driver's window. Steam rises from the crinkling bag, filling the car with a savory aroma. Hamburgers are handed out, and bites are taken before the young family journeys on to piano lessons and sports practices.

It takes mere minutes to comfort a stomach's grumbles and continue on with life. In the moment, to quench hunger and enjoy flavor are primary concerns. But once the rumble quiets, the minds of many eaters continue to roar. They question how their buying decisions affect the health of their families and the planet.

A hamburger wrapper holds the culmination of the entire beef industry's efforts. There are ranchers, feeders, packers, processors and retailers who, together yet separately, move beef from pasture to plate. Each faces their own trials and triumphs. Each lives their own story of constant improvement, of doing more with less.

When a calf leaves a ranch, the rancher's story ends while the feeder's story is just beginning. When the feeder's story comes to a close, the packer's starts, and so on. Oftentimes, the lines of communication from stage to stage remain silent, and two-years-worth of effort and dedication goes unknown by the time a hamburger reaches the drive through.

"What's left is disconnect between segments of industry and between producers and consumers," says Chad Ellis, the Noble Research Institute's industry relations and stewardship manager. "But really, each party strives to do its best. We all want to make tomorrow better than today, and we can do a better job of making progress if we work together to improve and to communicate our larger beef story."

This is the aim of a two-year national industry-wide pilot project focused on identifying ways to improve sustainability across the beef value chain.

Sharing the Beef Story

About 2,300 head of cattle reached Beef Marketing Group (BMG)'s feedyard in central Kansas in December 2017.

A crew of cowboys settled the calves into their new home for the next six months. There, the calves will lounge around, eating a well-balanced diet formulated specifically to help them develop the intramuscular fat most Americans consider an essential part of a good steak. Or juicy hamburger.

This is daily work for BMG, a network of feedyards that works with local farmers and ranchers to maximize efficiency. But the cattle are part of the national beef sustainability pilot project, which began in 2017.

"Many times in our business we look at our role as feeding cattle or as raising calves and we don't look at it in a way that is connected all the way to the consumer," says John Butler, BMG CEO. "We really have a responsibility to do that."

BMG and the other project partners, McDonald's USA, Tyson Foods, the Noble Research Institute and Golden State Foods, are members of the U.S. Roundtable for Sustainable Beef (USRSB), a national coalition that first convened in 2015. For the first time, through the USRSB, producer groups, processors, retailers, allied industry and civil society have come together to discuss what they do and why along with what sustainability means to them and how they seek improvement.

"It's an important conversation and one that needs to include voices from throughout the beef industry, especially those of producers," says Ellis, who also serves as the Noble Research Institute's USRSB representative. "If we don't get involved, someone else will define sustainability for us."

The group identified six indicators of sustainability: animal health and well-being, efficiency and yield, water resources, land resources, air and greenhouse gas emissions, and employee safety and well-being. Then each sector identified ways it can measure how it keeps these resources healthy. This self-direction, Ellis says, will be what makes the effort successful.

Now, through the pilot project, they are testing these metrics and sharing information throughout the chain in ways that have never been done.

For example, producer Meredith Ellis Ulibarri, one of the Integrity Beef Alliance ranchers who raised participating calves from birth, is looking forward to receiving information from the processor, Tyson Foods, about which calves produced the most desirable yield and quality meat. This information will help her family make better breeding and management decisions for their cow herd.

Eventually Golden State Foods will turn some of the meat into a portion of the 100 percent beef patties served by McDonald's. The rest of the meat will be sold through the chain as conventional beef.

Full results are expected to be available in fall 2018.

LEFT: Integrity Beef Alliance members Meredith Ellis Ulibarri (center left) and her father, GC Ellis (center right), talk about raising beef cattle on their ranch, G Bar C Ranch, near Rosston, Texas, during a tour organized by McDonald's. ABOVE: Integrity Beef Alliance members implement best management practices and keep detailed records. They raised the calves that are part of the national beef sustainability pilot project.

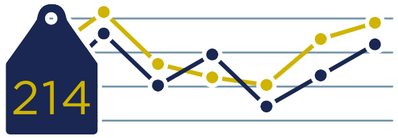
"Being able to communicate up and down the supply chain is something we've never been able to do," Ulibarri says. "Plus it will help us better communicate with consumers. I hear misconceptions people have about how we raise cattle, and I see their surprise when they learn about the ranch and realize it's not what they thought. It's a paradise here, and I see my job as caretaker of the land and animals. Being able to tell our story on such a huge platform as McDonald's opens up a lot of opportunity. Only good can come from it, from my perspective." ■

A Model for Beef Sustainability

To improve the sustainability of the beef industry, all production levels must work together. Here is how the beef sustainability project will work with its partners across the U.S.

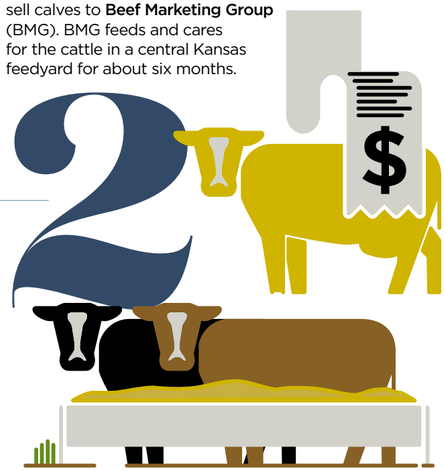
1

Ranchers who are part of the **Integrity Beef Alliance** raise the project calves from birth. The Integrity Beef program emphasizes progressive management methods, ranch stewardship and humane care of all livestock.



2

Integrity Beef Alliance members sell calves to **Beef Marketing Group** (BMG). BMG feeds and cares for the cattle in a central Kansas feedyard for about six months.



3

BMG sends the cattle to **Tyson Foods** for harvesting.

4

A portion of the meat goes to **Golden State Foods** to be incorporated into 100 percent hamburger patties. The hamburgers are sold at **McDonald's**.

Making Beef Even Better

Generations of beef producers have looked for ways to do more with less. But historically, they have made progress within their own segments, or steps, within the full beef value chain, which spans from the ranch to the consumer. In 2015, participants representing these various segments formed the U.S. Roundtable for Sustainable Beef. They wanted to start a conversation about how to improve sustainability — emphasizing social, economic and environmental considerations — on a larger scale in the U.S. The group has developed metrics for assessing and measuring progress in six indicator areas. In February 2017, a two-year beef sustainability pilot project was launched to test these metrics in a real-world beef value chain. The project also explores scalable solutions that could be applicable to beef producers across the country and creates opportunities to share information up and down the value chain.

U.S. Roundtable for Sustainable Beef Indicators:

- Animal health and well-being
- Efficiency and yield
- Water resources
- Land resources
- Air and greenhouse gas emissions
- Employee safety and well-being

INEFFICIENT

Plant scientists seek ways to minimize agriculture's environmental impact by studying legumes, including clover, which satisfy their own nitrogen needs through relationships with soil microbes.

Plant scientists seek ways to minimize agriculture's environmental impact by studying legumes, including clover, which satisfy their own nitrogen needs through relationships with soil microbes.

In the 1980s and 1990s, the Noble Research Institute (then the Noble Foundation) expanded into plant genetics and crop improvement research. The organization saw an opportunity to complement consultation services for farmers and ranchers by exploring the inner workings of plants and using the latest technologies to produce new crop varieties that would ultimately help farmers and all of society.

"Greatness can only come to any individual when they recognize that they have much to learn."

LLOYD NOBLE

EFFICIENT

Plants need to eat to live. Their food commonly comes in the form of fertilizer. But the plants rarely finish their dinner. Excess washes away, wasting time and money as well as causing environmental concerns. Scientists are looking within the plants themselves to unlock their natural abilities to more efficiently use nutrients.

~~IN~~EFFICIENT

Unlocking the Power of Legumes

Scientists gain further insight into the inner-workings of legumes in hopes of helping the plants reach their potential to advance agriculture.

Farmers and ranchers know their crops and pastures need to eat. But many plants are like 2-year-olds. Give them a full plate of nutrients, and they'll only take half. The rest goes to waste.

Excess nutrients run off into waterways. They give rise to overpowering algae populations downstream that disrupt ecosystems. Upstream, producers stand by helplessly as money and effort wash away.

To limit this cycle, farmers and ranchers look for ways to reduce their nutrient usage. They use soil tests to help them determine how much fertilizer is enough. Emerging technologies build upon these knowledge foundations to help them apply precisely the right type and amount at the right time.

At the same time, scientists are looking for solutions within the plants themselves.

They hope to coax plants into more efficiently using nutrients by their own natural abilities.

Legume Leadership

If the microscopic creatures in the soil gave a neighbor-of-the-year award, they would probably give it to the legume family.

Legumes, which include crops like soybean, clover and alfalfa, have long been used by farmers as part of their crop rotations and other soil-health-building practices. This is because of the plants' unique ability to fix nitrogen.

Unlike other plants, legumes form specialized plant organs called nodules on their roots. Within these nodules live soil bacteria called rhizobia, which turn nitrogen naturally found in the air into a form of nitrogen (called ammonia) that plants can use. In exchange for food and shelter, the rhizobia provide their host legume with this natural nitrogen fertilizer. As a result, legumes do not require farmers to apply additional nitrogen fertilizers.

Like other plants, including grasses, legumes also form mutually beneficial relationships with mycorrhizal fungi in the soil. These mycorrhizal associations help the plant acquire phosphorus and other nutrients. This is increasingly important because phosphorus resources are finite and limited to a few countries worldwide.

While nitrogen is not limited, reducing the need for costly synthetic nitrogen fertilizers would benefit farmers and ranchers, the environment, and society.

My role is to develop tools and resources for functional genomics studies that help us better understand the complex mechanisms behind genes in Medicago and other legumes. By identifying and characterizing these genes, we can better understand how legumes acquire nitrogen through symbiotic nitorgen fixation and how they carry out other symbiotic processes with soil microbes. We can also better understand their roles in plant defense and other basic life functions. One of the greatest hurdles facing the world is the growing human population and the need to produce more food with limited resources. This research is a first step in helping us develop crops that more efficiently use nutrients, are better able to survive in drought or to overcome disease, and ultimately help us more sustainably feed the world.

Raj Nandety, Ph.D.
Postdoctoral Fellow in the Molecular Plant Microbe Laboratory

Like all living creatures, the legume's blueprint for life is harbored in its DNA. Somewhere deep within its genetic blueprint are instructions for enabling it to build above-average relationships with soil microbes.

"If we can better understand what is happening at the genetic level, we will ultimately be able to improve legumes' natural abilities to efficiently acquire nutrients," says Michael Udvardi, Ph.D., chief scientific officer.

Udvardi is one of two Noble researchers who, in 2017, received a four-year, $5 million grant from the National Science Foundation to continue the exploration of legumes.

Udvardi and Noble Professor Kiran Mysore, Ph.D., have teamed up with scientists from across the country to continue work funded by the National Science Foundation: Maria Harrison, Ph.D., from the Boyce Thompson Institute; Julia Frugoli, Ph.D., from Clemson University; Catalina Pislariu, Ph.D., from Texas Woman's University; Janine Sherrier, Ph.D., from the University of Delaware; and Becca Dickstein, Ph.D., from the University of North Texas.

In previous work, the team screened thousands of plants to identify genes that allow legumes to interact with soil microbes and receive nitrogen and phosphorus from them. They'll continue to identify and study these key genes with the new funding.

This research is made even more critical when viewed through the lens of dwindling phosphorus supplies.

"It's not a question of if we're going to run out of phosphorus but when," Mysore says. "It's very important that we help plants better use nutrients like phosphorus so we can extend our supply."

It may take many years to turn new knowledge from this project into improved legume cultivars. However, in the long run, such knowledge should accelerate plant breeding efforts to improve legumes for agriculture.

"We know thousands of genes are involved in these symbiotic processes, but we don't yet know what roles most of these genes play or which ones are most important," Udvardi says. "This grant will enable us to answer these questions and contribute to advancing agriculture and reducing its environmental footprint." ■

LEFT: Legumes, such as this cowpea, form specialized plant organs called nodules on their roots. Soil bacteria called rhizobia live within these nodules and provide nitrogen to the plant. RIGHT: Barbara Nova-Franco, Ph.D., a postdoctoral fellow, (left) and Katherine Chang, a 2017 Noble Summer Research Scholar in Plant Science, prepare *Medicago truncatula* plants for further study.

~~IN~~EFFICIENT

Nitrogen is essential for plant growth. Nearly half of the planet's population would face hunger without synthetic nitrogen fertilizers, according to scientist Vaclac Smil, Ph.D. However, these same fertilizers can contribute to environmental concerns when nitrogen is not captured by plants but washes away into streams. To help overcome this challenge, Noble Research Institute scientists are working to improve legumes (plants that naturally make their own nitrogen fertilizer), identify and breed plants that are more efficient nitrogen users, and develop grasses that fix nitrogen. Learn more at bit.ly/nitrogen-ag

The Power and Problems of Phosphorus

Most people probably don't think about phosphorus very much during their day. Or at all. But in the next few decades, phosphorus will be on everyone's mind. This chemical element (with the symbol P) is essential for all life as it is part of many biological molecules. P thus plays a vital role in agriculture, supporting the growth of healthy, productive crops. Unfortunately, the world is running out of P resources.

15 P 30.97 Phosphorus

PHOSPHORUS is an element essential to both plants and animals. It is one of three nutrients commonly applied to soil as fertilizer to help plants grow. It plays roles in RNA and DNA, the cell membrane, and energy transfer reactions.

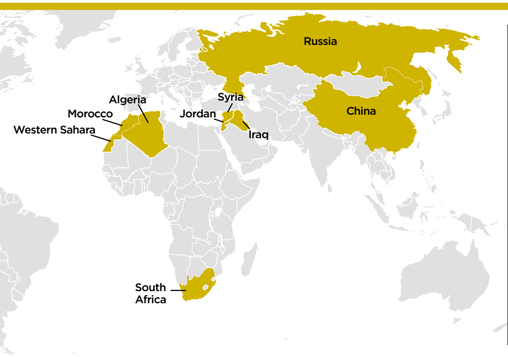
Estimates vary, but some scientists put minable phosphorus supplies at providing enough for only

30–40

more years.

9

countries control 90 percent of the world's known phosphorus reserves.



Source: 2015 U.S. Geological Survey report.

CROPS IN THE SOUTHERN GREAT PLAINS DO NOT USE ABOUT

22%

OF THE PHOSPHORUS FERTILIZER THEY RECEIVE. THE HIGHEST LOSSES WERE FROM CORN AND COTTON.

Source: 2006 Natural Resources Conversation Service report.

NOBLE PRINCIPAL INVESTIGATOR **WOLF SCHEIBLE**, PH.D., IS **EXPLORING THE MOLECULAR BASIS** OF HOW PLANTS CAN MORE EFFECTIVELY USE PHOSPHORUS.

UNABSORBED PHOSPHORUS **REMAINS IN THE SOIL,** WHERE IT BECOMES EITHER TIGHTLY BOUND OR IS USED BY MICROBES, OR, THROUGH ELUVIATION AND EROSION, IT ENTERS RIVERS, LAKES AND SEAS.

PHOSPHORUS **IS NOT AVAILABLE IN NATURE ON ITS OWN,** BUT IS FOUND IN SEDIMENTARY AND MAGMATIC DEPOSITS, MOSTLY AS MINERAL ROCK PHOSPHATE.

NOBLE PRINCIPAL INVESTIGATORS **MICHAEL UDVARDI**, PH.D., AND **KIRAN MYSORE**, PH.D., ARE **STUDYING THE GENES** THAT ALLOW LEGUMES, LIKE CLOVERS AND SOYBEAN, TO EFFICIENTLY ACQUIRE NITROGEN AND PHOSPHORUS.

Plant scientists investigate possibilities for providing benefits to farmers, animals and society by improving crop varieties through an up-and-coming tool: CRISPR-Cas9.

DIVISION

Plant scientists investigate possibilities for providing benefits to farmers, animals and society by improving crop varieties through an up-and-coming tool: CRISPR-Cas9.

In 1951, the Noble Research Institute (then known as the Noble Foundation) launched a plant breeding program to develop new small grains varieties, including oat, rye, wheat and triticale, better suited for grazing cattle on the Southern Great Plains. In March 1993, the organization became the first in Oklahoma to field-test genetically engineered crops. These crops had built-in disease resistance and other improved traits.

"The only degree to which we can make real progress is the degree to which when we have ideas that we can get those ideas motivated into action."

LLOYD NOBLE | 1949

Plant scientists see the ways agriculture can be more environmentally friendly. They have ideas for tools to help farmers and ranchers. To solve some of the planet's most pressing problems. And now they seek to overcome a philosophical division with a new vision in plant breeding.

VISION

My family grows rice and sweet potatoes in Guangdong, a province in southeast China. From the time I was 8 through my teenage years, I grew vegetables and sold them at the market to make my own "allowance." I have always loved nature. That's why I wanted to become an agricultural scientist. I want to help farmers handle their challenges and grow more, higher-quality food. Three years ago, I came to Noble and began my research with CRISPR. It was exciting to start the project, but it has been even more exciting to see our system work. It could help plants better adapt to stress and improve their yields. The possibilities are endless. It makes me happy to know this has great potential to help farmers and, ultimately, society.

Miao Chen, Ph.D.
Postdoctoral Fellow in the Transformation and Genome Editing Laboratory

DIVISION

Improving a Solution

Advanced gene editing techniques offer new hope for scientists seeking to provide farmers with new tools that advance land stewardship.

People since the beginning of time have bred plants and animals for desirable traits.

The first farmers would have propagated the largest, tastiest berries. Even man's best friend, the dog, has been bred for specific skills like hunting and protecting.

In traditional breeding, including that of the Noble Research Institute's 66-year-old small grains breeding program, the best plants in each generation are used as parents for the next.

Perhaps the best known example of traditional selection is maize, or corn, which started out as a wild grass called teosinte more than 10,000 years ago. While ancient civilizations in Mexico and Central America developed corn, no one knew until the 20th century that DNA was the secret behind this process.

DNA is the instruction code for life. It tells living creatures how to function, and within it lies potential. If plant scientists can adjust these instructions, whether through traditional breeding or more precise methods, they can produce varieties better prepared to overcome challenges faced by farmers and society at large. They can coax plants into using nutrients more efficiently, into growing longer or stronger in the face of drought and disease.

In the 1980s and '90s, genetically modified organisms, or GMOs, were born. Scientists had learned how to copy a desirable gene (a section of DNA) from one organism and insert it into another so that it could express a beneficial trait. By 2015, about 444 million acres of GMO crops were planted across the world. GMOs, which most commonly provide insect and herbicide resistance, have been associated with yield increases and the rise in conservation tillage, according to a U.S. Department of Agriculture soybean study. Conservation tillage practices, including no-till, help prevent erosion and other environmental degradation.

But, though the National Academy of Sciences has found "no substantiated evidence of a difference in human health risks" when comparing GMOs with conventionally bred crops, some people are uncomfortable with this type of breeding. GMOs have been subject to scrutiny and governmental oversight. This regulation has made it difficult and expensive to bring improved crops to market, which has limited access for smaller companies and to only a few crop species.

While traditional breeding and genetic engineering are two tools for crop improvement, another is showing great promise. Gene editing, specifically a technique called CRISPR-Cas9, is casting new vision in the timeless quest to grow plants that meet societal needs.

Zengyu Wang, Ph.D., director of core research and transformation at the Noble Research Institute, is taking the emerging technology one step further.

One Step Further

CRISPR-Cas9 has gained the interest of scientists in many fields, from medicine to agriculture. In 2013, Wang decided to integrate it into his forage research.

CRISPR stands for "clustered regularly interspaced short palindromic repeats," and refers to a biological system based on a natural defense mechanism in bacteria. Cas9 is the associated protein. While a GMO expresses beneficial traits through a process that introduces genetic information from another species, the CRISPR-Cas9 method produces beneficial traits as the result of a precise edit made within the target species' own DNA.

Typically, when CRISPR is used to improve plants, a strand of CRISPR-Cas9 DNA and a guide RNA are inserted into the plant genome. The guide RNA directs the Cas9 protein, which acts as a pair of scissors, to accurately snip out a specified portion of the plant's DNA. This tweak in the plant's instruction manual enables the plant to produce a desired trait – such as drought tolerance.

After adopting CRISPR in a variety of plant species, Wang and Miao Chen, Ph.D., a postdoctoral fellow, decided to try something new. Instead of inserting DNA as used in conventional CRISPR approaches, they inserted RNA. The outcome is the same except RNA, unlike DNA, does not integrate itself into the plant genome. By nature, it is a messenger that lasts only as long as it takes to deliver its instructions. This approach eliminates the need for later, additional steps, for example, backcrossing to remove inserted DNA material, before delivering field-ready, commercial plants for evaluation or use.

"Essentially, we are inducing a natural variation within the plant, comparable to what happens in the field, with much more precision, efficiency and reliability than we've ever had," Wang says.

Wang's variation has proven successful in trials, and he and his team will work to apply it in agriculturally important crop, like wheat.

"Farmers and ranchers need crop varieties that will help them produce food using less water, fertilizers and pesticides," Wang says. "CRISPR is one of our most exciting new tools to help us deliver these solutions to producers for their benefit as well as that of our environment and society as a whole." ■

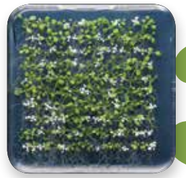
Noble Research Institute plant scientists use *Medicago truncatula* (pictured here) among other plant species to study how to use CRISPR-Cas9 to produce plants with desirable traits. *Medicago truncatula* is the model species used to study legumes, like clover and soybean.

10 Things to Know About CRISPR

Scientists are exploring new ways of improving crops for the benefit of farmers, the environment and society. CRISPR is an emerging tool with great potential.

1 CRISPR IS THE MOST PRECISE, MOST **affordable** AND FASTEST WAY AVAILABLE TODAY TO CONDUCT ADVANCED PLANT BREEDING. The crop varieties it produces could have been bred in the field as part of a traditional breeding program. But CRISPR is much faster.

2 Traditional breeding, genetic engineering (used to create genetically modified organisms, or GMOs) and gene editing (including CRISPR) are all **TOOLS FOR CROP IMPROVEMENT.**



3 When used to edit plant genes, the system essentially snips out a specified piece of DNA within the plant while the cell seamlessly repairs the site using its natural abilities. This enables the plant to generate desirable traits.

4 **CRISPR** stands for "clustered regularly interspaced short palindromic repeats." It refers to a system based on a **naturally occurring defense mechanism** in bacteria. This mechanism protects bacteria from invading viruses by enabling a scissor-like reaction that cuts and destroys the attacking virus's DNA.

5 THERE ARE DIFFERENT CRISPR SYSTEMS. THE MOST COMMON IS **CRISPR-Cas9.** The "Cas9" refers to an associated protein that acts as the scissors in the reaction. It's bundled with a piece of guide RNA that tells it where to cut.

6 A new waxy corn variety from DuPont is expected to be one of the first CRISPR-edited plant varieties on the market, sometime around 2020. Waxy corn is used in paper adhesives and food thickeners. Other potential CRISPR applications include **crops that taste better, yield more, are resistant to diseases and pests, and better tolerate drought.**

7 Conventional methods of CRISPR initially insert a piece of foreign DNA to kick-start the editing process; however, the foreign DNA is segregated out in the next generation. This means the foreign DNA is not in seeds that would be sold for planting. For this reason, **CRISPR-edited crop varieties will not be regulated as GMOs by the U.S. Department of Agriculture** at this time.

8 One of the downfalls of genetic engineering, which creates GMOs, is that it has been limited to companies that can afford to jump through expensive regulatory hoops. **CRISPR opens doors for smaller companies and nonprofit organizations, including those that work on less-funded crops like vegetables and forages, to use the technology for the benefit of a more diverse set of agricultural crops and producers.**

9 CRISPR is also being used in medical research to explore ways the mechanism can help treat, and potentially **cure, diseases in people.**

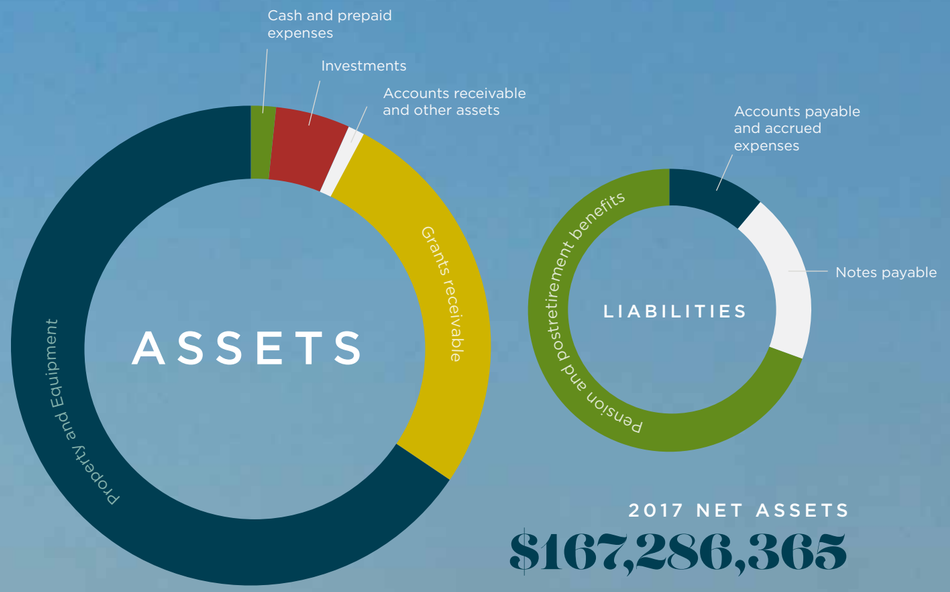
DIVISION

1

ZENGYU WANG, PH.D., AND **MIAO CHEN, PH.D.**, HAVE **DEVELOPED A CRISPR SYSTEM THAT USES RNA RATHER THAN DNA** TO BEGIN THE EDITING PROCESS. SINCE RNA IS A MESSENGER ONLY AND DOES NOT INCORPORATE ITSELF INTO THE PLANT GENOME, THEIR VERSION NEVER INVOLVES FOREIGN DNA.

FINANCIAL

REPORT AT A GLANCE | 2017



2017 NET ASSETS

$167,286,363

TOTAL ASSETS*

$198,826,860

*As of Dec. 31, 2017

Statement of Financial Position
(Unaudited)

ASSETS	As of Dec. 31, 2017
Cash	$3,088,205
Investments	9,791,528
Accounts receivable and other assets	2,113,328
Grants receivable	53,250,000
Prepaid expenses	777,108
Property and equipment, net of accumulated depreciation of $97,369,201	129,806,691
TOTAL ASSETS	**$198,826,860**
LIABILITIES	
Accounts payable and accrued expenses	$3,570,442
Notes payable	6,132,178
Liability for pension and post-retirement medical benefits	21,837,875
TOTAL LIABILITIES	**$31,540,495**
NET ASSETS	
Unrestricted	$167,286,365
TOTAL NET ASSETS	**$167,286,365**
TOTAL NET ASSETS AND LIABILITIES	**$198,826,860**

Statement of Activities
(Unaudited)

REVENUES, GAINS AND LOSSES	Year Ended 2017
Interest	$1,069,318
Dividends	2,263,400
Net realized and unrealized gains on investments	15,264,395
Grant revenue	79,250,000
Other miscellaneous program and royalty income	6,592,208
TOTAL REVENUES, GAINS AND LOSSES	**104,439,321**
EXPENSES	
Operations	57,449,866
Grants	1,706,213
Management and administrative	5,027,530
Provision for federal excise taxes	361,572
TOTAL EXPENSES	**64,545,181**
REVENUES, GAINS AND LOSSES IN EXCESS OF EXPENSES	**39,894,140**
Pension and post-retirement medical-related changes other than net periodic costs	1,912,225
CHANGE IN NET ASSETS FROM OPERATIONS	**$41,806,365**

2017 | INSTITUTIONAL

GOVERNANCE

The Samuel Roberts Noble Foundation, as the member/manager of the Noble Research Institute, and the employees of Noble Research Institute acknowledge and agree that the following principles apply to our association with and the activities we conduct on behalf of the Noble Research Institute:

1. The Noble Research Institute exists because of the vision and generosity of our founder, Lloyd Noble.
2. We are stewards of the resources and the vision of Lloyd Noble.
3. Our conduct will be fair and honest, and our activities will adhere to the purposes for which the Noble Research Institute was established.

Role of the Member/Manager

The Samuel Roberts Noble Foundation serves as the sole member/manager of the Noble Research Institute, LLC, an Oklahoma, nonprofit single-member limited liability company.

The Samuel Roberts Noble Foundation provides the leadership for the Noble Research Institute to carry out its charitable purposes, act as a good steward of its resources, and conduct and support its activities in accordance with the vision of founder Lloyd Noble. The Samuel Roberts Noble Foundation further directs management to formalize and implement the Noble Research Institute's strategic plan.

Corporate Documents

The organization's current articles of organization and operating agreement can be found at noble.org/about/governance.

Annual Internal Revenue Service Informational Return

Noble Research Institute, LLC annually files a 990-PF informational return with the Internal Revenue Service. The Noble Research Institute's current 990-PF may be downloaded at noble.org/about/governance.*

Historical returns for the Noble Research Institute are available at guidestar.org.

**The 2016 990-PF details the assets, expenditures and activities of The Samuel Roberts Noble Foundation, Inc. Noble Research Institute, LLC is the successor-by-conversion of The Samuel Roberts Noble Foundation, Inc., effective May 1, 2017.*

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1964-2017

**Advisory board member*

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Corporate Secretary and Executive Assistant to the President

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Chief Scientific Officer

A. Jill Wallace
Vice President and Chief Financial Officer

Zengyu Wang, Ph.D.
Director of Core Research and Transformation

NONRESIDENT FELLOWS | 03

The Nonresident Fellows program brings together a distinguished panel of scientists, researchers and industry leaders to assist the Noble Research Institute. These outside reviewers perform candid examinations of programs, offer objective advice and guidance, and provide fresh perspectives.

John Butler
Beef Marketing Group (BMG)

James Grimsley
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