Leading Edge

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No·till On The Plains

Ceiling Unlimited

by Matt Hagny

Tom Cannon certainly thinks differently. This gentleman farmer of north-central Oklahoma questions everything—*everything*—with the incisive mind of a skilled businessman. A few minutes with him, and you'll soon be re-examining your own deeply held conclusions. Self-proclaimed active environmentalist, an avid hunter and outdoorsman, and devoted family man are crucial aspects of the man who's also a highly successful farmer and cattleman.

The Cannon operation, Goodson Ranch, has been in the family for 4 generations, and is headquartered southeast of Blackwell along the confluence of the Chikaskia ('cheh-KAS-kee') River and Bitter Creek, and also extends on into the hills farther east and north. In the early 1900s, this farm—along with Oklahoma as a whole—grew more corn than wheat, a trend that has resurfaced in recent years on the Goodson Ranch. While the deep bottomland soils along the Chikaskia were perhaps less ravaged by a century of tillage and erosion than were the hills, long-term no-till and other new techniques deployed—and sometimes invented—by Tom are helping rejuvenate the depleted land whatever its topography.

A sizeable field near the Chikaskia prompts commentary from Tom:

Photo by Matt Hagny.

2008: Another prosperous dryland corn harvest on Cannon's farm.

Contents

"It's a Norge soil, almost gravelly underneath, but the topsoil is very tight clay. [Most of Cannon's soils are deep silty clay loams.] In '97 it had been in wheat for as long as I could remember, and as long as Dad can remember. The best wheat crop it had ever made was 28 bu/a. I went completely to no-till in '97, so I double-cropped it to soybeans, which made in the low 30s—the best crop it had ever raised. The next year I planted corn, which was pathetic—about 60 bu/a." Tom continues, "It was clear that it needed a very long break from wheat, so I went to brome plus red and rose clovers. I had trouble getting the brome to meter out with my air drill, so I added 50% wheat. The wheat grew much better than expected, so not knowing what to do, I let it go to maturity, then went and skimmed it off

"If there's sunlight and moisture, I gotta have something growing."

with my [Shelbourne] stripper head. Despite the growing brome and clover, the wheat made well over 50 bu/a! That blew us all away. And I had a fantastic stand of brome and clover." (*Editors' Note: Rose clover is similar to red clover except that rose is an annual.*)

That brome + clover mix was hayed and grazed for 6 years, without any herbicide, although it was limed twice. In '07, Tom took the first cutting of hay, then sprayed a burndown on the brome, "Trying not to kill the clover. It wasn't going to hurt anything." He seeded wheat that fall, which made in the mid-50-bu/a range. Most of the clover survived and made seed, although the field had a prosperous double-crop of soybeans on it in early Sept. '08.

A State of Play

With Cannon continually exploiting opportunities and testing new ideas, no standard crop rotation exists for the 2,700-plus acres of cropland under his management, of which about 680 acres are pivot irrigated now (he had none a mere 8 years ago). However, a typical crop sequence for Tom would be 2 to 3 years of corn, followed by wheat/ dc soys. Occasionally single-crop soybeans are grown, especially under irrigation. "It's very field-specific," he says. Sometimes cowpeas are double-cropped instead of soybeans, especially if the field has grown several soybean crops in the past and is beginning to show some disease pressure. Double-crop corn is another option he uses at times. Cannon almost never stacks wheat, and rarely plants milo anymore. Cover crops of clover and/or canola are frequently drilled in the fall after corn and soybean harvest: "If there's sunlight and moisture, I gotta have something growing." (He grew winter canola for grain harvest in '03, but hasn't since.)

In the late '90s, Cannon was using primarily a rotation of wht/ dc soys >>milo >>soys, which, Tom says, "wasn't intense enough. We usually tried for early milo, which made for a long time from milo harvest until the soybeans were planted. We needed a cover crop but didn't recognize it." Instead, beginning in '99, Cannon began growing substantial acres of dryland corn in place of milo, and seeding the wheat into the corn stalks—thereby eliminating the single-crop (full-season) soybean. (Cannon has never had a significant problem with head scab in wheat following corn, not even in cool & rainy '08; being a few degrees warmer in his region makes all the difference.)

While Tom frequently uses transgenic corn hybrids (110 – 118 day) with Roundup Ready and corn-

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No·till On The Plains

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No-Till on the Plains Inc's Mission: To assist agricultural producers in implementing economically, agronomically, and environmentally sound crop production systems.

Objective: To increase the adoption of cropping systems that will enhance economic potential, soil and water quality, and quality of life while reducing crop production risks.

borer *Bt*, he sees little or no reason to be using rootworm *Bt*, noting: "We have so little rootworm problem in this area." (And it's not that rootworms are escaping his notice, since Cannon is a keen observer and also employs a CropQuest consultant.) Tom notes the transient advantages of these technologies in the face of shifting and adapting pest populations, particularly glyphosate-resistant marestail (now in great abundance in his area) as well as armyworms that are unfazed by some types of *Bt*. Further, virtually all the Palmer pigweeds in his area are resistant to both triazines and ALS herbicides.

Yet Cannon aggressively pursues new technologies that add to his profitability. The Palmer pigweed problem has been countered with the Callisto component of Lumax, and the glyphosate-resistant marestail are being tackled with hot mixes of ET (pyraflufen) + crop oil in burndowns ahead of dc soybeans, although Cannon astutely notes that it's much easier and cheaper to use appropriate chemistries in the growing wheat, and then let the wheat canopy keep the marestail shaded out the rest of the season. For controlling marestail in his single-crop soys, Cannon has had only limited success with high rates of Synchrony, and will be going to FirstRate, metribuzin, and other chemistries in the future. Still, Tom emphasizes that there's no substitute for good crop competition—the soggy, cold '08 spring weather thinned his corn stands on bottomland significantly, letting Palmers come through the Lumax later in the season: "I relied too heavily on technology. I should've started over [by replanting]. The best weed control I have is crop canopy."

While Tom assiduously replants any drowned-out areas to keep the weeds down, he balances the weed-control urge. "Not every noncrop plant out there is bad. It adds diversity."

Lately Cannon has been addressing his fertilizer program, including many secondary and micronutrients. His area has rather high zinc levels due to widespread dust being deposited from a previous industry near Blackwell, so zinc deficits have never been a problem. Tom inherited typically high P levels from his dad's farming practices, so again, no problem, although he applies maintenance rates especially on wheat. Tom has applied abundant S in recent years, too, making way for pleasant responses to other nutrients, such as magnesium on wheat (he has been applying several trace elements as well.) The one nutrient on which Tom has been conservative is N, with his efficiency coming in at a lean 0.7 lb of N per bushel of corn, and 1.3 – 1.6 lbs of N per bushel of wheat produced. Cannon has gotten serious about plant tissue sampling, and now aims to monitor and improve his practices via those report cards.

"The best weed control I have is crop canopy."

Tom credits the more balanced nutrient program with letting him set a new personal-best on wheat in '08, with a largish dryland field making 100.5 bu/a. His five-year average for wheat is 57, which includes many acres of hailed-out wheat in '08. Cannon's 5-year corn average is 85 bu/a, which includes one year of zero yield when *all* of it was put up for hay. He says, "In hindsight, I really regret [taking the corn as hay]. I took a hit on soil quality. Financially it was a wash [break-even], but in the long run I lost money because of the N and P removed."


Photo by Laurie Cannon.

Tom usually has a cheerful outlook, but his '08 dryland double-crop soybeans are yet another reason to smile. Tom says, "If you happen to get the moisture, you want to have everything in place to take advantage of it."

Old & New

Cannon recently upgraded to a 16-row JD 1770 CCS planter, which includes row cleaners, Keetons with Mojo Wires, and Martin Spader closing wheels. For '08, the planter ran without any fertilizer capabilities (remember his high soil levels of P and zinc), although that may change as he seeks to become more efficient with N application methods—trying to avoid mulch cover losses as well as denitrification. The planter is used primarily for corn, and part of the single-crop soys. Essentially all his double-crop soys go in with the drill on 15-inch spacing, and wheat on 7.5-inch. Cannon's drill is a Deere 1860, updated with 90-series boots and SDX firming wheels. Tom says, "That drill has done 40,000 acres, but it's in as good a shape as when I bought it—that's because I completely rebuilt it this last year." Tom reports that their wheat stands are a lot better than in their tillage days.

For field operations, Cannon runs RTK guidance and uses controlled traffic on his level bottomland, adding, "I would never do that on [rolling] upland." Spraying is accomplished with a RoGator. For a labor force, the Cannon operation has 2 full-time hired men as well as another part-timer who loves to run the farm's leased combine. Tom's mother does the bookkeeping. Tom credits no-till with freeing up enough time during the year for his coaching of baseball and other youth activities, not to mention time for his wife and their 4 kids.

Cattle & Land Health

Tom's innovation extends to Goodson Ranch's stockers and cow herd, and the forages to feed them. Tom exudes enthusiasm for his alfalfa / native rotation: "It's the most incredible alfalfa I've ever seen, and it was seeded directly into native sod [that was sprayed out]. The first year was a very dry year, and it still yielded over 5 tons/acre for the year—nobody else made over 4 tons/a that year. When I'm done with the alfalfa, it will go directly back into native [species] by spraying out the alfalfa." Cannon's alfalfa is put up for hay, to be fed in the winter: "That goes against what I believe. We shouldn't be hauling all this feed to the cattle." (Will Tom revamp that system too?)

As for the cropland, Cannon has done relatively little grazing recently, although he second-guesses: "I've been critical of myself for past cattle I've run on cropland. I priced myself out of the market [when doing enterprise analysis]." He explains, "I wasn't crediting anything for the manure. . . . We know for sure there are soil biological benefits to cattle manure. These soils were developed with the buffalo [as part of the ecosystem nutrient-cycling mechanism]. . . . There's so much going on in the soil that we don't yet understand."

Tom clarifies further: "Grazing dead stalks is a no-no. We only graze living plants." —which for Cannon is a growing wheat crop (this *is* Oklahoma), as well as cover crops. (Cannon previously grazed wheat, then didn't for 2 years, and now will revisit it.) Somewhat surprisingly, Tom states that his best irrigated corn yields have followed crops (or covers) that were grazed. Tom also notes that most of his fields have a grassed refuge area where the cattle can congregate when conditions get wet out in the field.

Continuous no-till and improved soil characteristics are distinctively helping Tom's crops: "In a dry spell, my dryland corn holds on about 9 to 11 days longer than neighboring tilled fields. For soybeans, it's almost 2 weeks. That's huge."

Photo by Matt Hagny.

Cannon's 2008 irrigated full-season soybeans have tremendous potential due to skillful agronomy and the field not having grown soybeans for several years.

Past & Future

As journalist G.K. Chesterton once noted, "The only way of catching a train is to miss the train before." That aptly describes the twists of Cannon's life, who had farmed for a spell, then returned to Okla. State Univ. in '95 to pursue biological engineering—Tom didn't make the grades during his first stint, due to a penchant for partying, but was a 4.0 GPA the second time around: "I had a thirst for knowledge when I went back to school that outweighed any previous thirst for beer. My thirst for knowledge hasn't been quenched. I love to read."

Photo by Matt Hagny.

The Chikaskia runs through the Cannon land, creating both challenges and opportunities. Tom loves the wildlife habitat along its banks.

Tom's career-track changed yet again when his dad was in a bad car accident in January of '97, prompting Tom to return to the farm once more (Tom's dad had a lengthy recovery, then developed other health problems that have prevented his return to being physically active on the farm). Tom attended the No-Till on the Plains conference in January of '97, which provided the final impetus for the change: there was to be no more tillage on the Cannon farm from then onward, with the exception of a few fields that were tilled one last time in '97 to smooth them. (Their tillage equipment was soon sold, or now has enough rust to be ready for the museum, Tom says.)

Tom explains that his attitude was always skeptical of tillage: "I never could understand why we did all that tillage, then packed it down again to plant wheat. We ran plows for 2 weeks, then ran the disk in 24-hour shifts to beat the clods around. We worked it into a fine powder before running packers over it to firm it up for planting." He continues, "I knew very little about no-till when I started, but I went to the No-Till on the Plains conference and saw other people who were making it work. And I never bought into the thinking that it works in those places but not over here."

The stewardship ethic runs deep in Tom: "It is very, very important to me to leave the land in much better shape for the next generation. We have the technology and knowledge to do so." Those sentiments go far beyond no-till, to encompass tree plantings each year on their land along the river, including 7,000 trees in a single year: "The river banks erode so quickly, so we're putting trees back where fifty or sixty years ago there were dozers taking trees out." (The trees also benefit the ranch's outfitter business.) Cannon also thinks differently about flood control: "Instead of these big watershed dams, which are nearing the end of their life expectancy, let's capture more of the water with trillions of tiny dams of residue in the fields."

Despite knowing that his methods are improving the cropland as well as being profitable, Tom doesn't solicit landowners in the neighborhood: "I let them come to me." And despite his incredible progress, he's still restless: "There are better ways of managing than what I'm currently doing. I'm still searching."

Photo by Tony Downs, Imago

Nutrient Export from the Land

by Matt Hagny

SCIENCE

Hagny is a consulting agronomist for no-till systems, based in Wichita, Kansas.

Farmers and ranchers generally think of production in terms of pounds or bushels to be sold, derived from a specified land area. Very few think of it as nutrient export from the land: to put it more bluntly, the 'mining' of the soil's nutrient resources.

Plant & Animal Nutrition

Because of the deep kinship of multi-cellular life, both plants and animals use certain elements as building blocks for the organism: hydrogen, (H), oxygen (O), carbon (C), nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B), nickel (Ni), and silicon (Si). A few additional elements, such as sodium (Na), selenium (Se), iodine (I), fluorine (F), tin (Sn), vanadium (V), chromium (Cr), and cobalt (Co) are essential for animals but do not appear to be essential for plants, even though plants readily take up these minerals and certain plant species grow more vigorously in the presence of some of these elements.[1]

Secondary and micronutrient deficits will continue to worsen with each harvest until something is done to correct them.

Photo by Matt Hagny.

Severely sulfur-deficient no-till wheat in central Kansas. Many other nutrient deficits can also cause crops to be paler than a healthy crop would be, although sometimes the color differences are subtle and easily overlooked. Nutritional deficits are more likely in no-till due to increasing soil organic matter sequestering nutrients, increased cropping intensity, and cooler & wetter soils during some parts of the growing season.

Apart from radioactive decay (which proceeds extremely slowly anyway), elements do not convert from one to another at the pressures and temperatures found on Earth. While hydrogen, oxygen, carbon, and (for some organisms) N and S are available from the atmosphere, all land-dwelling organisms must obtain the other essential elements from the soil, directly or indirectly. The terrestrial distribution of these elements is non-uniform, finite, and the availability (in forms suitable for uptake) often imposes substantial constraints on the viability and robustness of organisms in many environments, as well as their reproductive success.

Bio-available forms of the essential elements tend to be conserved ('recycled') in ecosystems. This was likely an adaptation. Plants assimilated elements from the soil, and eventually the plant biomass was consumed by other

[1] N.C. Brady & R.R. Weil, 2002, *The Nature and Properties of Soils*, 13th ed., Prentice Hall; A.V. Barker & D.J. Pilbeam, 2007, Introduction, in *Handbook of Plant Nutrition*, ed. A.V. Barker & D.J. Pilbeam, CRC Press: Taylor & Francis; W.F. Bennett, 1993, Plant Nutrient Utilization and Diagnostic Plant Symptoms, in *Nutrient Deficiencies & Toxicities In Crop Plants*, ed. W.F. Bennett, Am. Phytopath. Soc. (St. Paul, MN). See generally: various authors, 2005, Essential trace elements for plants, animals, and humans, in Proceedings of NJF Seminar No. 370, Reykjavik, Iceland (15-17 Aug. 2005), Nordic Assoc. Agric. Scientists. See also F.C. Nielsen, 2000, Evolutionary events culminating in specific minerals becoming essential for life, *Eur. J. Nutr*. 39: 62-66. (Vanadium may be necessary for some plant species, but its essentiality for the entire plant kingdom hasn't been adequately proven. A number of other elements are tentatively included in the list as essential for animals, but studies have been few and/or the issue lurks as to whether they are essential for only a few species or broadly across the animal kingdom; these include lead, arsenic, aluminum, bromine, lithium, germanium, rubidium, tungsten, and strontium. Lead and arsenic are often thought of as toxins due to the high exposure resulting from some industrial processes and consumer products, but these elements are essential in trace amounts. These lists of essential elements for plants [and animals and fungi] are likely incomplete: "[With improved technology] it is quite likely that additional elements will be shown to have irreplaceable functions in discrete biochemical processes that are important for plant life." —P.H. Brown, 2007, 'Nickel,' in *Handbook of Plant Nutrition*, ed. A.V. Barker & D.J. Pilbeam, CRC Press: Taylor & Francis.)

organisms while the plant was alive or dead (by foraging animals, including insects, or by fungi or microbes), to become part of the consuming organism's own body, or excreted as waste. Everything was returned to the soil, since even the mobile organisms (some animals, including insects and birds) usually died somewhere in the vicinity. The ecosystem was largely 'closed,' i.e., the nutrient elements were retained and re-used for millennia. There were slow gains to the nutrient pool, as rocks weathered and organisms pried the more recalcitrant compounds from the soil. Losses via leaching and erosion generally were extremely slow. Fertile soils were formed by the accretion slightly exceeding the losses over eons. Ultimately, as weathering proceeds, soils become less fertile as slow gains are overcome by slow losses (usually this takes a few million years).

Erosion is held in abeyance mostly by the biomass covering the soil, as well as roots and fungi binding the soil particles. These depend in large degree on the vigor of plants growing there, which can easily be limited by nutritional disorders. A vicious cycle ensues: Nutritional deficits make erosion worse, which makes crop nutrients even more scarce.

In modern times, human activities have disrupted the recycling. Feed grains and forages are hauled en masse to feedlots, poultry barns, or swine confinement. Typically, very little of the wasted feed and excrement finds its way back onto the cropland or hayland, and the animal carcasses certainly aren't returned. Nor are the eggs, milk, or other animal products. Those, along with a great many other grains and oilseeds (wheat, soybeans, canola, lentils, chickpeas, sunflower, etc.), are consumed directly by people, and almost none of the sewage waste is returned to the cropland or rangeland (some towns in rural areas may spread sewage sludge on local fields, but large cities almost always have facilities that dispose of sewage—treated or untreated—into rivers or oceans).

An enormous exporting of nutrients from cropland and rangeland occurs with each harvest of grain, fiber, hay, or animal product. The amounts may not be great for any single harvest, but they add up over the decades. Tables 2 – 6 (see pages 455 – 456) provide rough estimates of the exported quantities (the number of harvests will be much higher for regions where harvests began centuries ago, such as the eastern seaboard of the USA). For instance, a century of small grain and corn harvests can easily remove 10 – 15 lbs of Zn from each acre of soil (and while that may seem like a lot, losses of nutrients with soil erosion can be larger yet).

Whenever land around the world is first settled by agrarian civilizations, at the outset usually no fertilizers or soil amendments are needed because the agriculturalists are tapping into the supplies accumulated by the native plants and fauna over eons (the settlers always chose the most fertile land for cropland). Over time, the soils become increasingly responsive to applications of fertilizers and other amendments. However, there is a lag in reaction time—often a nutritional deficit for the crop or livestock goes on for decades before it is diagnosed and corrected. It is dependent on management, and we often don't respond in a timely or adequate manner (and I include myself in this shortcoming). Because soils vary in their native nutrient supplies, the order in which individual nutrients first become limiting will vary from place to place, creating further management challenges.

As it played out on the USA's Great Plains, the settlers broke the sod and generally grew reasonably good crops for decades without fertilizers. By the 1950s, the soils had become quite responsive to the N and P fertilizers which were becoming readily available, and farmers needed to apply those fertilizers regularly to stay competitive in their production. In the eastern USA, which was settled earlier and had more years of harvesting of crops and livestock, lime (supplying Ca and Mg) and

Photo by Matt Hagny.

S-deficient no-till wheat. (A few areas had adequate S.)

K fertilizers were also being applied fairly regularly by the 1960s, at least in some areas. By the 1990s and early 2000s, applications of S and Zn had become routine for some areas because acute deficiencies were diagnosed. But how many other deficits are being overlooked on North American cropland? And is anyone monitoring rangeland or hayland at all?

A large number of the proteins, enzymes, and biochemical reactions occurring in earthworms also occur in mammals. Therefore, nutritional requirements are likely to be similar.

For instance, the dryland no-till crops that I monitor in Kansas and nearby states often have moderate to severe deficiencies of Zn, Cu, and Mo, as well as occasional deficiencies of Mg, Cl, and even B. (The deficiencies often have distinctive visual characteristics, and are confirmed by plant analysis and/or responses to fertilizer application. Another clear warning that many no-till crops have inadequate nutrition is their more pale color, which can be caused by inadequate N, P, S, Mg, Mn, Zn, Cu, or Mo. No-till crops will generally grow more slowly than crops in tilled soil, which is an effect of temperature and completely normal; however, pale color isn't normal—anything less than the super dark green of the best crops in the region should be investigated, as well as any color variations within the field.) These deficits will continue to worsen with each harvest until something is done to correct them. Unfortunately, almost no one is looking.

Acute zinc deficiency in corn, north-central Kansas. Note the paleness when observed from a distance. In the close-up, the symptoms are distinctive. The deficiency is worst where the wheat residue was concentrated behind the combine. Some observers would blame no-till, or the straw, but the reality is that it was a failure of management to supply adequate zinc to the crop. The field didn't even make decent silage due to the zinc deficiency.

Photos by Matt Hagny.

Implications

Obviously, yields of crops and rangeland are being affected by these deficits.[2] That is often incentive enough for the keen manager to take corrective action (if only he or she knew to monitor for the deficits). But other effects are more insidious.

First, the nutritional value of the foods consumed by people is declining accordingly. This is well-documented, even if not widely known. Severe nutritional deficits in humans result in all sorts of maladies including reproductive and growth disorders, which we think of as Third World problems.[3] After all, we have our vitamins. But sub-acute deficits can occur in denizens of the Developed World too.[4]

Nutrient deficits (and wholesale exports of nutrients) also create many implications for the long-term productivity of the land. Soil erosion is held in abeyance mostly by the biomass covering the soil, as well as the roots and fungi binding the soil particles—these depend in large degree on the vigor of the plants growing there, which can easily be limited by nutritional disorders. A vicious

[2] "Most nutrient deficiencies inflict significant damage and loss before deficiency symptoms appear." —M.V. Wiese, 1993, Wheat and Other Small Grains, in *Nutrient Deficiencies & Toxicities In Crop Plants*, ed. W.F. Bennett, Am. Phytopath. Soc.

[3] R.M. Welch, 2006, PowerPoint presentation at No-Till on the Plains Winter Conf. (Salina, KS, 30-31 Jan. 2006).

[4] D. Thomas, 2003, A study on the mineral depletion of the foods available to us as a nation over the period 1940 to 1991, *Nutr. Health* 17(2): 85-115; various authors, 2005, Nordic Assoc. Agric. Scientists. See also Welch, 2006. *Cf.* D.R. Davis, M.D. Epp & H.D. Riordan, 2004, Changes in USDA Food Composition Data for 43 Garden Crops, 1950 to 1999, *J. Am. College of Nutr.* 23: 669-682 (selective breeding for yield rather than nutritional content no doubt explains part of the decline of secondary and trace elements in foods).

Table 1. Soybean Response to Molybdenum

	Yield bu/a
check	35.4
+ moly	41.1
Response	**+ 5.7**

Trial conducted by Matt Hagny in Harvey County, Kansas, on upland clay loam in 2007. Check had 4 gallons/a of 9-18-3 as pop-up. Moly treatment was 4 fl. oz. of Liquid Moly 5% added to pop-up. (Hagny doesn't advocate N-P-K fertilizers in the seed furrow for soybeans, but this is what the producer was doing. Further note that *soil applications of moly appear to be totally ineffective unless mixed with P fertilizers*—this may not be universally applicable, but apparently is the case for the types of clays found in much of Kansas.) 2 replications for moly treatment, 3 replications for check. Plant analyses of soybeans growing adjacent to the plot indicated severe deficiency (0.01 ppm Mo); a sample from the 2008 wheat crop in the plot area also tested 0.01 ppm Mo. Source: M.P. Hagny, unpublished data.

cycle ensues: Nutritional deficits make erosion worse, which makes crop nutrients even more scarce.

Feeding the soil biology is also critical. Very little is known about the nutritional requirements of the soil's inhabitants, but some reasonable estimates can be made. Earthworms are generally considered one of the best benchmarks of soil health,[5] partly because they are conspicuous (as compared to bacteria, protozoa, fungi, or mites) and because their activity almost always dramatically improves water infiltration into the soil, as well as improving drainage, aeration, and plant-available nutrients. Earthworms are actually fairly complex organisms, with physiology that includes a heart and circulatory system, a nervous system, a mouth, gut, and anus, and bilateral symmetry. A large number of the proteins, enzymes, and biochemical reactions occurring in earthworms also occur in mammals.[6] Therefore, the nutritional requirements are likely to be similar.

In the future, we may be testing crops or rangeland plants for elements such as selenium or chromium, and correcting the deficits, not only for the nutrition of livestock or humans eating those plants, but also because of earthworms and other soil inhabitants needing those elements.

Molybdenum, for instance, is known to be essential for plants, being a component of a 'pterin' cofactor complex (MoCo) that is critical to the function of several enzymes.[7] Molybdenum is also essential for vertebrates (including mammals such as cattle and humans) as well as invertebrates and fungi, and is necessary even for bacteria.[8]

Zinc is universally used by eukaryotes,[9] which is to say the entire plant, animal, and fungi kingdoms (all eukaryotic cells have a true nucleus, as well as organelles such as mitochondria; the other domains of life are bacteria and archaea, both of which lack mitochondria and a nucleus). Copper is also essential for all eukaryotes. One reason is that copper and zinc are used in the Cu/Zn superoxide dismutase (SOD) enzyme, part of the antioxidant defense system, with SOD playing a critical role in 'defusing' the extremely high levels of free radicals resulting from oxidizing reactions in the mitochondria, the 'power plants' of all eukaryotic cells.[10] Copper and zinc are also necessary for many other enzymes crucial to eukaryotic growth and function.

While earthworms are mobile, and ingest large volumes of soil and organic material to meet their bodily nutritional needs, it is quite plausible that if the vegetation on a parcel of land is severely deficient in Zn, Mo, or Cu, the earthworms will also have difficulty obtaining adequate amounts of these elements, so their growth and repro-

5 Several earthworm species were introduced to North America by Europeans along with transplanted trees, vegetables, and ornamentals. In some of the more recently settled lands of North America, the earthworm species may not have had sufficient time to 'invade' all available cropland or rangeland. Across much of Kansas, hedgerows and farmsteads and 140 years of settlement by Europeans have allowed grey worms to be found in nearly any cropland.

6 See generally N. Lane, 2002, *Oxygen: The Molecule that made the World*, Oxford Univ. Press. See also S.B. Carroll, 2006, *The Making of the Fittest: DNA and the Ultimate Forensic Record of Evolution*, Norton. (According to Carroll's sources, roughly 500 proteins are so essential to life that the DNA instructions for making these proteins have been conserved in *all* living organisms.)

7 "Moco is present in almost all living beings, taking part, as a prosthetic group, in the active site of key enzymes such as nitrate reductase, aldehyde oxidase, xanthine dehydrogenase, and sulfite oxidase. These enzymes participate in crucial processes for life such as nitrate assimilation, phytohormone biosynthesis, purine metabolism, and sulfite detoxification in plants, animals, and microorganisms." —M. Tejada-Jiménez, Á. Llamas, E. Sanz-Luque, A. Galván & E. Fernández, 2007, A high-affinity molybdate transporter in eukaryotes, *Proc. Natl. Academy Sci.* 104: 20126-20130 (citing B.N. Kaiser, K.L. Gridley, B.J. Ngaire, T. Phillips & S.D. Tyerman, 2005, *Ann. Bot. [London]* 96: 745-754). See also B. Stallmeyer, G. Schwarz, J. Schulze, A. Nerlich, J. Reiss, J. Kirsch & R.R. Mendel, 1999, The neurotransmitter receptor-anchoring protein gephyrin reconstitutes molybdenum cofactor biosynthesis in bacteria, plants, and mammalian cells, *Proc. Natl. Academy Sci.* 96: 1333-1338.

8 Stallmeyer et al., 1999.

9 L.A. Gaither & D.J. Eide, 2001, Eukaryotic zinc transporters and their regulation, *BioMetals* 14: 251-270. See also Nielsen, 2000.

10 S.J. Picco, M.C. Abba, G.A. Mattioli, L.E. Fazzio, D. Rosa, J.C. De Luca & F.N. Dulout, 2004, Association between copper deficiency and DNA damage in cattle, *Mutagenesis* 19: 453-456 (citing R. Uauy, M. Olivares & M. Gonzalez, 1998, Essentiality of copper in humans, *Am. J. Clin. Nutr.* 67 [suppl.]: 952S-959S). See also Lane, 2002.

Photo by Matt Hagny.

Perennial pasture showing distinctly better growth and color in areas with urine or dung. Nutrient deficits elsewhere are dramatically reducing production.

duction will be hindered. While low levels of trace elements may not force an earthworm population to extinction in any given soil, nutritional deficits are quite likely to inhibit earthworm populations.

There is some evidence for this, since earthworm numbers often increase following manure applications.[11] Whether this occurs due to increased food supply (e.g., carbohydrates in the manure) or due to improved nutrition isn't known, but these are often intertwined anyway (especially if we think of carbon as a nutrient). The maximum total biological activity in and on a tract of land is usually constrained by available nutrients, whether we're talking about nutrients available for the photosynthesizing organisms (plants, cyanobacteria) or the consumers of the photosynthesizers.[12] However, deficits of certain elements (e.g., selenium, chromium) might severely curtail earthworms or other soil-dwelling organisms, but not plants. So in the future we may be testing our crops or rangeland plants for elements such as selenium, and correcting the deficits, not only for the nutrition of the livestock or humans eating those plants, but also because of earthworms and other soil inhabitants needing those elements.

Plant species differ in their ability to extract any given nutrient from the soil (as well as their internal uses of the nutrient). Brassicas excel at liberating P, for instance. While this holds great potential to improve crop nutrition (and on up the food chain), it doesn't alter the underlying premise: When soil nutrient levels become too low for optimal plant growth, nutrients must be replenished by importing them from elsewhere.

While some soils appear to have an almost infinite supply of certain nutrients, given enough time, the exporting of grain and livestock product will eventually cause various secondary and micronutrients to become limiting factors in the productivity of many soils. In fact, in a great many cases, I'm convinced that we're already there. For instance, about 40% of the beef cattle in the USA have been found to be Cu deficient.[13] Similar or higher rates of Cu deficiency were found in Argentina. And 70% of cattle in western Canada were Cu deficient. Whether this is due to low levels of Cu in rangeland or in feed grains isn't well-established, but Cu deficiency certainly exists in our agricultural soils, and is growing worse with each year that it's ignored. (And note that this is occurring despite the widespread use of mineral supplements for beef cattle in the USA, so the Cu deficiencies in cattle feeds and forageland or rangeland are potentially worse than portrayed by analyzing the cattle themselves.)

In the case of rangeland, nearly all manure is being returned to the soil during grazing. Yet the animal flesh is hauled off to market each year. The composition of a

Photo by Matt Hagny.

Effect of moly applied to field peas (right side of photo; left had none). If the plants are starving for nutrients, so is the soil fauna.

[11] E.J. Kladivko, 1993, *Earthworms and Crop Management,* publ. AY-279, Purdue Univ. Extension. (Not all earthworm types exhibit population increases with manure application, however.)

[12] Maximum biological activity may also be constrained by energy supply (sunlight availability) and temperature. In the case of rangeland, the way in which the perennials are grazed can also impose a lower-than-natural limit of biological activity.

[13] Picco et al., 2004.

Photo by Matt Hagny.

You might think you've done a reasonable job of growing the crop, until you notice a fertilizer spill, overlap, or old feedlot area in a field. These provide ample evidence that the crop nutrition isn't optimal yet.

beef carcass is shown in Table 5. Multiplied out by the weight 'harvested' each year (and every year), it is a significant exportation process over time, although mild in comparison to grain or hay removal.

Importing the Necessary Nutrients

Feedlots, poultry houses, and other livestock confinement operations frequently have some difficulty getting rid of the manure being generated. It is viewed as a waste product, and often pushed into piles and forgotten, or applied indiscriminately to the nearest field or meadow.[14] Farmers and graziers are neglecting a trove of nutrients, often valued well below what it would cost for fertilizers and soil amendments containing similar nutrient quantities. Furthermore, you are getting all nutrients, including obscure ones such as selenium, cobalt, chromium, etc., as well as carbon. Manure certainly isn't going to be a perfectly balanced fertilizer source for your crops or hayland, but it is a good starting place. (For instance, if feed for the animals was grown locally, and happened to be quite low in nutrient X, and no supplemental X was given, the animals would likely remove most of the X from their feed and excrete very little, worsening the imbalance when their manure is applied to the soil.)[15] Of course, there's nowhere near enough manure to supply the nutritional needs of the world's crops and forages, which brings us to fertilizers.

Table 2. Approximate Mineral Content of Wheat Grain

Nutrient	ppm	Lbs Removed in 50 bu/a Harvest	Lbs Removed after 50 Harvests
Mg	1800	5.4	270
S	2000	6	300
Ca	600	1.8	90
Fe	60	0.18	9
Zn	44	0.13	6.6
B	4	0.01	0.6
Mn	55	0.16	8.2
Cu	8	0.02	1.2
Mo	wide variation: 0.01 to over 1.0	wide variation	wide variation
Ni	wide variation	wide variation	wide variation

Sources for Tables 2 – 4: K. Kulp & J.G. Ponte, 2000, *Handbook of Cereal Science & Technology*, CRC Press; J.R. Heckman, J.T. Sims, D.B. Beegle, F.J. Coale, S.J. Herbert, T.W. Bruulsema & W.J. Bamka, 2003, Nutrient Removal by Corn Grain Harvest, *Agron. J.* 95: 587-591. (Wide variation occurs due to soils, climate, agronomy, and crop genetics. Wheat in summerfallow systems in Montana may have less than 20 ppm Zn in the grain. [Clapperton, personal communication Aug. 2008.] One source states 12 ppm Cu in wheat grain: M.V. Wiese, 1993. Farmers can determine how much is actually being removed by testing grain at an agricultural laboratory.)

Table 3. Approximate Mineral Content of Corn Grain

Nutrient	ppm	Lbs Removed in 100 bu/a Harvest	Lbs Removed after 50 Harvests
Mg	1400	7.8	392
S	1000	5.6	280
Ca	300	1.68	84
Fe	20	0.11	5.6
Zn	25	0.14	7.0
B	5	0.03	1.4
Mn	6	0.03	0.16
Cu	2	0.01	0.5
Mo	wide variation: 0.01 to over 1.0	wide variation	wide variation
Ni	wide variation	wide variation	wide variation

Table 4. Approximate Mineral Content of Sorghum Grain

Nutrient	ppm	Lbs Removed in 100 bu/a Harvest	Lbs Removed after 50 Harvests
Mg	1500	9	450
S	1000	6	300
Ca	200	1.2	60
Fe	60	0.36	18
Zn	8	0.05	2.4
B	5	0.03	1.5
Mn	15	0.09	4.5
Cu	5	0.03	1.5
Mo	wide variation: 0.01 to over 1.0	wide variation	wide variation
Ni	wide variation	wide variation	wide variation

[14] Heavy manure applications pose problems, too, including creating imbalances in plant nutrient uptake and utilization. Excessive chloride content and traces of parasiticides in the manures can negatively impact the soil ecology. (M.) Jill Clapperton (soil ecologist, Earth Spirit Consulting), personal communication Aug. 2008.

[15] For instance, most manures and poultry litters are relatively high in P, which may actually worsen Zn deficiencies in fields due to antagonisms between those elements.

Lime, gypsum, and essentially all fertilizers other than N (which is extracted from the atmosphere), are generally mined from sedimentary deposits of compounds that fell out of solution from lakes and oceans many millions of years ago. (However, a few fertilizers and amendments are by-products of industrial processes or water treatment plants.) Luckily for our current civilization and methods of feeding ourselves, these deposits are often vast. It is simply a matter of digging them up, doing some processing, and then transporting them to cropland or rangeland for application. Unfortunately this is an energy-hungry process, with most energy prices having escalated considerably in recent years. However, returning all the sewage (as well as uneaten food, discarded cotton and linen fabric, pet excrement and carcasses, etc.) from cities to agricultural lands would also require substantial energy inputs, although the disposal of this waste instead of 'recycling' it to the land might stem more from habit than economics. Either way, cities aren't going to go away anytime soon, and I don't see much progress being made on recycling nutrients from cities. So we'd best get used to applying whatever livestock manure we can find nearby, and making up the (substantial) deficits with fertilizers of a much broader spectrum than what we are currently using.

Of course, fertilizers will need to be applied judiciously and economically. But adequate plant (and soil denizen) nutrition isn't an item where being chronically short is a good idea from a profit standpoint. It costs roughly the same dollars to pay the land rent, and to plant, spray, and harvest, whether for a mediocre crop or an excellent crop—but you will never make an excellent crop if you have nutritional deficits. It is high time we paid more attention to the full range of nutrients needed by crops and range plants, and make some strides in correcting the shortcomings. Greater productivity and profitability await those of you who do this well.

Table 5. Mineral Composition of the Bodies of Cattle

Nutrient	ppm	Lbs Removed in 100 lb/a/yr Animal Gain	Lbs Removed after 100 'Harvests'
Mg	400	0.04	4
S	1,500	0.15	15
Ca	13,000	1.3	130
Cl	1,000	0.1	10
Fe	40	0.004	0.4
Zn	40	0.004	0.4
B	0.3	0.00003	0.003
Mn	4	0.0004	0.04
Cu	3	0.0003	0.03
Mo	0.5	0.00005	0.005
Ni	trace		

Values are averages for the entire body minus the contents of the digestive tract. Extrapolated/compiled from many sources: "[T]he proportions of each mineral, expressed as amount of fat-free dry body substance, are very similar among species of adult mammals and poultry (Scott *et al*., 1982)." —L.R. McDowell, 2003, *Minerals in Animal and Human Nutrition*, 2d ed., Elsevier.

Table 6. Mineral Content of Grass Hay

Nutrient	ppm	Lbs Removed in 2 ton/a Harvest	Lbs Removed after 100 Harvests
Mg	1750	7	700
S	1500	6	600
Ca	4000	16	1600
Fe	30	0.12	12
Zn	20	0.08	8
B	10	0.04	4
Mn	75	0.3	30
Cu	5	0.02	2
Mo	wide variation: 0.01 to over 8.0	wide variation	wide variation
Ni	wide variation	wide variation	wide variation

Sources: R.C. Ward, 2007, *WardGuide*, Ward Laboratories Inc. (Kearney, NE); http://www.tennesseenutritionconference.org/pdf/Proceedings2005/JohnPaterson.pdf. (Some sources list much higher Cu contents from actual grass analyses, from 8 – 43 ppm: T.R. Turner, 1993, Turfgrass, in *Nutrient Deficiencies & Toxicities In Crop Plants*, ed. W.F. Bennett, Am. Phytopath. Soc.)

Photo by Matt Hagny.

"Drought" is often a combination of causes, and frequently is more due to nutritional disorders than to moisture deficit, especially in no-till. When the crop doesn't suffer in the fertilizer spills, this screams for you to look at crop nutrition more closely (commonly used N-P fertilizers often contain traces of more obscure nutrients, as well as sometimes stimulating uptake of secondary and micronutrients by altering pH and soil chemistry in the root zone). The second photo shows the degree of growth disparity up close. Grain yield is often 2X in those spots. Room for improvement, anyone?

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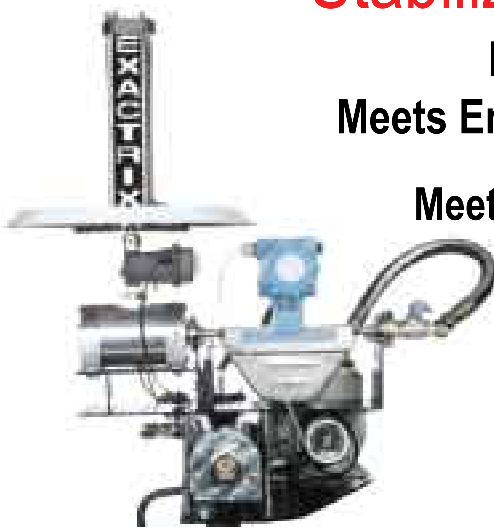

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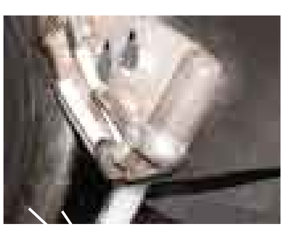

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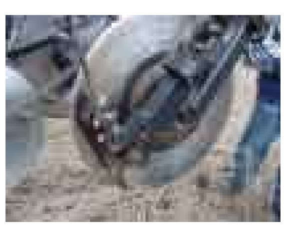

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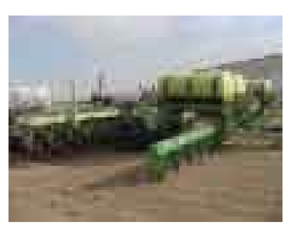

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Runoff & Erosion in Long-Term No-Till

by Matt Hagny

TECHNIQUE

Hagny is a consulting agronomist for no-till systems, based in Wichita, Kansas.

Some intense rain events in recent years have highlighted our failure to eliminate runoff and erosion in long-term no-till on many soils in Nebraska, Kansas, and Oklahoma. I had always assumed that improvements in soil aggregation and porosity would eventually take care of the problem after 10 – 15 years of continuous no-till with adequate cropping intensity and all residues retained. I was wrong—we're not even close to having the problem under control.

Photo by Matt Hagny.

Devastating erosion in central Kansas following a 4.5-inch rain in a couple hours. Several more big rains continued to damage the field that season, from which the field will never recover. The field had been low-disturbance no-till for 14 years; all residues were retained, and grass cover crops were grown nearly to maturity on several occasions. At the time of the photo, soybeans had been seeded after stacked corn, which had followed stacked wheat and double-crop proso millet. Residue levels had gotten too low during and after the 2d-year corn—a grass cover crop was badly needed. Note that the field had an abundance of terraces, which did almost nothing to mitigate the erosion.

While essentially all studies that have ever been conducted show that infiltration is improved with no-till, and that erosion by runoff is reduced by 95 – 99% with no-till (with adequate cropping intensity and residues retained), the problem is that a 'little bit' of erosion in continuous no-till creates major problems. The rills that form in continuous no-till never get smoothed or filled as they did routinely in the days of tillage (occasionally they were filled with dozers). Maybe with an aggressive coulter cart, or with hoe or knife openers, enough soil gets moved around to fill some small rills, but it's sorta like robbing Peter to pay Paul—soil is being dragged down the hill by the disturbance (Lobb's tillage erosion), and you might find the disturbance costly in other ways (too much residue loss; planting and 'banking' weed seeds). So the field gets rougher as the rills get a bit deeper with each intense rain. Eventually you find a scraper to carry in some soil to fill the deeper rills, and you just bounce across the others, cursing the whole time. Rolf Derpsch is right: Erosion must be zero.[1]

The scary aspect of erosion is that the ability to control it is utterly dependent on being able to grow enough vegetation, and this ability to grow robust vegetation declines significantly each time some of the most fertile soil slides down the hill. Eventually, you slip 'over the edge,' and no amount of management can halt the erosion—you've created a wasteland. Some will protest that erosion has been preached at them for decades, and they're still growing crops, maybe even better crops

Occasional tracts of native sod have been converted to cropland in recent decades, and the productivity advantage of these areas compared to older cropland is enormous.

[1] Or extremely close to zero. Some erosion occurred on the prairies and other natural ecosystems, although typically it was extremely slow over long geologic timeframes, and quite often soil formation outpaced erosion. Even the most skilled no-till practitioners using annual crops generally do not attain erosion rates as slow as nature's, but this must be the goal. (During some phases of the crop rotation, such as during or soon after a good wheat crop, long-term no-till with 90 – 100% residue cover and a dry subsoil usually has infiltration rates similar to the average perennial pasture, although erosion is slightly higher with annual cropping due to the absence of a fibrous perennial root system enmeshing the soil particles, as well as the presence of soil disturbance with mechanical openers during seeding or fertilizing. Also, note that the average perennial pasture is considerably degraded from its natural state.) Any cropping system involving tillage on mild slopes (or where the wind blows) isn't even close to being sustainable.

than decades ago. Yes, but what do you have to compare against? How much have genetics, fertilizers, and fungicides masked the decline in the soil's productivity? Do you realize how marginal it has become? Occasional tracts of native sod have been converted to cropland in recent decades, and the productivity advantage of these areas compared to older cropland is enormous—and remember, those areas were kept in sod because long ago people considered those soils to be *worse* than what they broke out for cropland.

Farmers have a natural tendency to be nervous about using too much water from the subsoil, but are blind to the costs of being excessively wet.

There are other reasons for controlling runoff. Almost all agriculturalists think timely rain solves all their problems, which is partly true. But are we currently doing everything we can to make use of *all* the rainfall? Obviously not, since runoff is lost to production. And if surface mulch could be further improved, so will the efficiency of water usage by the crop, since evaporation is reduced. Better soil structure from earthworms and perennial crops improves aeration and drainage, which further enhance crop growth. Diversifying rotations can reduce risk and allow more efficient usage of labor and machinery. So instead of viewing the methods of attaining zero runoff as inherently costly, it's quite feasible that these methods can actually *improve* profitability—a win/win situation. So let's look at the possibilities to further enhance water infiltration.

Grow & Keep More Residue

Your first reaction might be: "But I'm doing all I can already!" —maybe, maybe not. For instance, there's a *huge* difference between heavy wheat stubble and light wheat stubble. Even 80- to 100-bu/a stubble isn't always super-heavy, but it is more likely to be thick simply because it takes a reasonably high number of heads per acre to make those yields. So do what it takes to grow good wheat crops, and this may necessitate changes in your rotation (e.g., in drier regions, growing field peas ahead of wheat instead of soybeans, sunflowers, or milo; in wetter regions, growing a cover crop between stacked wheat crops). Planting winter wheat earlier usually causes more stubble to be produced, but sometimes at a cost to grain yield, so you will have to find the optimum planting window. Using high-vigor seed and pop-up fertilizer, avoiding damaging herbicides, and deploying other good techniques will get you on your way to higher yield potential as well as greater straw production. If two varieties yield equally well for your system, choose the taller variety to gain extra straw (the same goes for milo or corn: if two hybrids yield equally, choose the taller one).

Another aspect is to keep broadleaf crops to a minimum, since they produce a small fraction of the stubble as compared to a grass crop (e.g., wheat, corn, milo, etc.). Of course, rotational decisions are complex, and the effects ripple through the system and may not be obvious for awhile (especially if you have no comparisons). In central Kansas, some producers have been cutting back on soybeans double-cropped after wheat, and instead using proso millet on fields that will go to corn (volunteer proso can't be controlled in milo). *Pearl* millet shows promise, if the feed markets can be developed (or if grain merchandisers get serious about exporting it to Africa). Alan Mindemann, near Lawton, Oklahoma, often has used sudan after wheat, purely as a cover crop to get residue levels up for future crops. Some producers never had a broadleaf in their rotation, either going directly from corn or milo to wheat, or with a "long fallow" between them. While going quickly from corn or milo to wheat helps on erosion in the short-term, I question whether it is the optimal long-term answer since it sometimes impairs the ability to grow good wheat and milo crops because diseases such as

Photo by Matt Hagny.

Severe rill erosion along sprayer, combine, and tractor tracks in a north-central Kansas field in low-disturbance no-till for 12 years at time of photo. The growing crop is milo, seeded into stacked wheat stubble. Mulch cover was good, but the soil profile was completely saturated by the time of seeding. A cover crop or double-crop was needed. An almost universal problem with no-till adoption is failing to adjust cropping intensity upward sufficiently.

Fusarium and crown rots worsen. It is all in the art of assembling good rotations: For instance, drier regions of the Great Plains can actually grow better wheat following field peas than after chem-fallow. Having at least one broadleaf in the rotation can be beneficial for soil organisms, including earthworms; however, the frequency of broadleaf crops should be matched to decomposition rates to maintain abundant mulch on the soil surface.

One of the greatest erosion hazards is broadleaf stubble going into the springtime season of heavy rains without a crop being established (for instance, cotton or soybean stubble that isn't planted to a winter cereal or cover crop). These situations must be avoided.

Another hazard is when the soil becomes saturated, forcing additional precipitation to run off. I frequently see this in central Kansas and Oklahoma, where wheat stubble sometimes sets idle for 10 months or more and is way beyond saturation by the time something is planted. These fields not only suffer erosion, but saline seeps worsen, leaching and denitrification are greater, and crops don't grow well in waterlogged soils. Wetlands weeds such as nutsedge also get worse. Obviously, cover crops or double-cropping is needed. Sunflowers are particularly well-suited to this, since they are both drought-tolerant as well as capable of extracting lots of moisture from deep in the profile—exactly what is needed most years in the regions that often get too wet (and more of you fall into this category than you realize). Farmers seem to have a natural tendency to be nervous about using too much water from the subsoil, but are blind to the costs of being excessively wet.

Photos by Matt Hagny.

Runoff occurring soon after an August storm dropped 1.25 inches in a half-hour, on top of 3.1 inches two days prior. (Tilled fields in the vicinity suffered horrendous erosion from these events.) Mulch covered 85 – 100% of the soil surface (see inset: cover-crop sudan and sunflowers emerging). Field had been in low-disturbance no-till for 15 years with good residue production and all residues retained. Harney/Corinth soil series in north-central Kansas.

The other side of the coin is *keeping* more of the residues that are grown. Certainly this means *not* baling wheat straw, *not* cutting silage, and *not* grazing corn or milo stalks (those of you in the more forgiving glaciated soils—or under irrigation—may be able to break these rules occasionally, but they are quite disastrous on more 'fragile' soils with low OM). It also means keeping as much of the stalk standing as long as possible (if residues are lying on the soil, they decompose much more quickly). This means using a stripper head for wheat, barley, rye, and oats (note that this may require increased cropping intensity, since the field needs to be seeded before the stripper-harvested stubble rots off at the soil line, begins blowing into piles, and resists 'flowing' through a seeder). It means cutting milo as high as possible, as well as running the corn head as high as possible (preferably at faster ground speeds) and with the *least*-aggressive snap rolls (AGCO Gleaner corn heads do the least, followed by Deere, then Case-IH, then Geringhoff, etc.); note, however, that taller stalks may necessitate that you put 'stalk-catchers' on your planter or drill to lean the stalks the proper direction, and some extra securing or shielding of wires and hoses will be needed. Preserving stubble may also dictate replacing a double-crop soybean with another species (e.g., sunflowers) that doesn't require sickling off the wheat stubble at ground level.

Fertilizer application: Lots of stubble is needlessly destroyed, directly or indirectly.

Keeping the stubble standing also means using narrow gauge wheels on planters and drills, and locking up unnecessary openers on drills when seeding certain crops (the seeds should be considerably closer together, on average, *in* the row than the distance *between* the rows; for instance, beans and milo should definitely be on 15- or 20-inch rows, not 7.5- or 10-inch). Harrows and stalk shredders shouldn't be used. Eliminating unneeded duals or carrier wheels can also help (readers may note an inconsistency here, since I've previously advocated wider tires for sprayers—there are trade-offs, and sometimes the damage to the soil is so severe, as with narrow tires and heavy equipment, that trampling more stubble with bigger tires is the lesser of the two evils).

Fertilizer application is another aspect where lots of stubble is needlessly destroyed, directly or indirectly. If you're dragging a knife through the soil, you're losing a lot of residue. Even the low-disturbance designs with only a blade and a gauge or wiper wheel cause plenty of residue loss, and coulter + injection nozzles also destroy residue. From an agronomic viewpoint, there is usually no need of placing the fertilizer more than a half-inch below the surface, and actually there's not even much need for that—broadcast fertilizers left on the soil surface are highly effective if managed properly, and there's an ever-increasing array of technologies to prevent volatilization of N sources, such as poly-coated urea (ESN, etc.), sulfur-coated urea, Agrotain, and so forth. Even if some nutrients are slightly less efficient or are available more slowly when left on the surface, I'm not so sure it is cost-effective in the long run to be trying to place them subsurface. (From an environmental standpoint, it is generally better to place fertilizers subsurface, especially P.) Incidentally, ESN allows much higher rates of N to be safely applied in the seed furrow, which in some cases may eliminate the need for side-banding or surface application.

For surface-applied N, liquid sources cause much more decomposition of residues than dry sources.

As for *surface-applied* N, I'd like to point out that liquid sources cause much more decomposition of residues than do dry sources, even if the liquid is streamed in bands. The reason is that a liquid stream splatters and adheres to residues, hastening decomposition (the microbes are busily narrowing the wide C:N of grass crop residues, and a ready supply of N greatly speeds the process). I've seen wheat stubble that had UAN streamed (properly, with no excess pressure or splatter) that had utterly disappeared in the strips after about 5 weeks of wet weather, while the straw between the strips was still intact. Dry prills will bounce and sift through the straw and stalks, exposing very little of the mulch to the N required for rapid decomposition. For this reason, I strongly urge abandoning liquid streams on the surface, going instead to dry sources for surface application in regions where mulch decomposes too quickly.[2]

Finally, for durable mulch cover, make sure the crop's copper supply is adequate. Copper deficiency can reduce the lignin content of wheat straw by as much as half,[3] and lignins are among the most durable compounds in crop residues (lodging in wheat is often induced by marginally low copper levels inhibiting lignification, especially in the presence of abundant N).

Soil Properties

While residue cover undoubtedly is *the* single biggest factor influencing infiltration,[4] other soil parameters become important during extreme rainfall events. For instance, improved aggregation is a relatively slow and ongoing process in low-disturbance no-till fields (see Schumacher & Riedell, 'Soil

Photo by Matt Hagny.

Stripper-harvested wheat stubble. Keeping the stalks standing and in one piece can improve their longevity, helping reduce erosion.

[2] Even if urea costs 20% more per unit of N as compared to liquid UAN, it might still be the most economical choice for dryland if one considers the value of mulch on crop yield. For instance, UAN streams might be reasonably expected to cause 25% of the mulch to decompose 5X faster than it otherwise would. See 'Maximize Crop Residues' in the March '05 issue for estimates of crop yield responses to mulch.

[3] H. Marschner, 1995, *Mineral Nutrition of Higher Plants*, 2d ed., Academic Press.

[4] R. Derpsch, 2008, No-Tillage & Mulch Cover, *Leading Edge* 7: 422-430; R. Derpsch, 2003, Understanding Water Infiltration, *Leading Edge* 2: 140-141.

Structure Examined,' in the January '08 issue, and my 'Cropland Owner's Manual,' Dec. '05). Adding cover crops may accelerate the aggregation process, but otherwise there isn't much to be done beyond growing high-yielding crops in rotation, and retaining the residues. (Some gains may be had by choosing the more mycorrhizal crop species if two choices are roughly equal in adaptation and profitability.) However, perennial plants are a different matter entirely, largely because these plants have about 2/3 of their biomass in roots, as opposed to only about 1/3 for annual crops. This is a huge benefit to the fungi and other organisms responsible for 'gluing' soil particles into the stable arrangements we call structure or aggregation. Furthermore, perennials are quite efficient at generating as much biomass as possible for the moisture that occurs in any given year—in general, there's far less water wasted by perennials than by annuals. This is especially the case for very deep-rooted perennials such as alfalfa—leaching almost always becomes zero when alfalfa is established.

Photo by Matt Hagny.

Increased cropping intensity is absolutely essential to controlling erosion. Here, sunflowers were double-cropped after wheat harvest in north-central Kansas. Yields of subsequent corn or milo crops are rarely impacted negatively by double-cropping flowers, and will often benefit from improved planting and growing conditions (less soggy, more mellow). Plus, the double-crop can be quite lucrative some years.

Some of you already have alfalfa in rotation with your grain crops; you have the equipment and skills needed. This is a wonderful option to have in terms of making substantial improvements in soil structure, as well as halting or even reversing some problems with seeps. The extremely deep rooting of alfalfa recaptures many nutrients that otherwise would've never been recovered by other crops, plus it is a legume—so growing alfalfa and removing the biomass may actually alleviate some nutrient deficits and runoff problems for awhile; yet even established alfalfa can have erosion problems on steep slopes. Furthermore, wheat and corn crops following alfalfa almost always have significant yield advantages over other sequences, and with lower fertilizer costs.

Other avenues for using perennials would include direct grazing, which is the Argentine method: Grain crops are grown for a few years, then the field goes to a diverse mix of cool- and warm-season grasses, alfalfa, and clover to be grazed in a high-management system of small cells and high stocking rates. Eventually, the perennials are killed out with herbicides and grain crops grown again. This system works well for them, since land holdings are often contiguous in big blocks, many Argentines are expert cattlemen by tradition, and the farms are large enough to have people dedicated to livestock as well as others dedicated to crops (upper management oversees both). From a soils standpoint, the system is excellent in that substantial gains are made in soil structure during the perennial grazed portion of the rotation (occasional biting or clipping of perennials enhances their growth, but only if the plant is allowed to recover fully before the next bite; these grazing patterns maximize the gains in soil OM and structure). Because almost nothing is allowed to make seed during the grazing, a number of annual weed species that are troublesome in the grain crops are greatly reduced (a great way to combat herbicide resistance, aye?).

Copper deficiency can reduce the lignin content of wheat straw by as much as half, and lignins are among the most durable compounds in crop residues.

There are other ways of using perennials in cropping systems, including growing seed for the graziers and hay producers. There are also biomass perennials such as switchgrass, since we seem hell-bent on making ethanol from biomass as well as grain—although extensive removal of biomass runs contrary to what you're trying to do, which is to prevent erosion and to use the soil in a sustainable way. That said, it is far less detrimental to remove the biomass of a perennial versus annual crops. Properly done, biomass removal of perennials can be sustainable and keep the soil in good condition, so long as the grower doesn't get too greedy.

Of course, the soil structure and porosity are only effective if these pores are open at the surface to allow passage of air and water. Livestock hooves and mechanical implements engaging the soil surface certainly will disrupt the pore openings to the atmosphere. If the openings are disrupted faster than they are created, low permeability will result. For this reason, I do not think that most cropland soils in Kansas can tolerate livestock traffic in continuous no-till *unless perennials are added to the rotation* (and only the perennials are grazed).

Getting the water to go into the soil is only possible if there's room for it. Waterlogged soils can't infiltrate any more, so it must run off—no matter how good the porosity and mulch cover are. An almost universal problem with no-till adoption is failing to adjust cropping intensity upward sufficiently.

The problem is further compounded if the subsoil percolates water more slowly than the topsoil, which is usually the case for clayey subsoils as well as limestone layers and even gravelly subsoil. The take-home message is that it is extremely inefficient to try to store lots of water in the soil profile, and the costs can be high in terms of erosion (and weed control).

Earthworms

No discussion of water infiltration would be complete without looking at the effects of earthworms. There are two major kinds: 1) the transient-burrowing types, which make mostly lateral burrows and continuously burrow their whole lives (these are the pink or grey worms); and, 2) nightcrawlers, which live in a permanent vertical burrow—which may extend down into the soil 3 or 4 feet—and come out at night to gather food (mulch) which they pull back into their burrow. Both types go into a dormant state if conditions become dry. Neither type likes tillage, although nightcrawlers are particularly fussy about not having their 'house' disturbed. Some species can live in pure sand.[5]

Soil structure and porosity are only effective if these pores are open at the surface to allow passage of air and water. Livestock hooves and mechanical implements engaging the soil will disrupt the pore openings to the atmosphere. If the openings are disrupted faster than they are created, low permeability will result.

The transient-burrowing grey worms are the most common type of earthworm across North America (some are native, others are introduced), and their populations usually rebound in cropland once tillage is eliminated. However, even in long-term no-till of annual crops, the numbers are only about 1/3 to 1/10 of what is found in perennial pastures,[6] or, for that matter, your lawn. The main reason probably is amount of food available—these creatures engulf soil and attempt to digest everything in it, although relatively little of the bulk soil does them any good. They are extracting

Photo by Matt Hagny.

Soybeans emerging in cover-crop oats. Winter oats or winter barley are excellent cover crops that can be seeded in the fall, thus avoiding the spring mud and allowing more time for growth. In areas that grow wheat infrequently (or never), cover-crop cereal rye is a top choice ahead of soybeans, cotton, or similar crops.

5 (M.) Jill Clapperton (soil ecologist, Earth Spirit Consulting), personal communication Aug. 2008. (The pure sand was a half-mile from the coast in Tasmania; the species was *Aporrectodea longa*, a deep-burrowing type introduced in Tasmania that is also present in North America where moisture is adequate.)

6 E.J. Kladivko, 1993, *Earthworms and Crop Management*, publ. AY-279 (Agronomy Guide), Purdue Univ. Extension. (Highest earthworm numbers occurred in perennial pasture with "heavy" manure applications from the barnyard.)

carbohydrates from dead roots, dissolved organic matter, particulate organic matter, and dead (or soon to be dead) fungal hyphae, bacteria, and protozoa. Ultimately the quantities of these are proportional to sunlight photosynthesis by plants and free-living organisms. Total biomass (aboveground and belowground) of annual crops is typically much less than perennials, so there goes

It is extremely inefficient to try to store lots of water in the soil profile, and the costs can be high in terms of erosion and weed control.

part of the earthworms' food supply. Throw in some fallow or non-crop periods, and some occasional residue removal (silage, straw, etc.), and you'll soon have the explanation of why earthworm numbers stay so low in land dedicated to annual crops versus perennial species.[7] Add a few nutritional deficits,[8] or some attrition by occasional insecticide application,[9] and the earthworm population declines further.

Earthworms such as the transient-burrowing grey worm have long been considered the ultimate benchmark of the health or fertility of the soil, and indeed there is a correlation (however, some highly productive soils of the world don't have earthworms, although usually some other organism performs similar roles). Soil passing through the earthworm gut is more enriched in plant-available nutrients, particularly phosphorus. This in turn can maintain or gradually improve crop growth in that soil (so long as erosion is minimized and other agronomy is adequate, including fertilizer applications). But for the subject at hand—infiltration and erosion prevention—the burrows are important in that they are relatively durable, and readily conduct water from the surface downward as well as allowing gases to permeate. It takes fairly high grey worm numbers to have a major effect on infiltration, but some long-term no-till soils (with abundant mulch cover and other characteristics favorable to earthworms) do have populations that significantly influence permeability. On high-clay, low-OM soils that become wet, earthworm burrows become quite important for conducting water.

In the U.S. & Canadian Corn Belt and portions of the southeastern U.S., nightcrawlers are prevalent, having been introduced by European settlers bringing potted plants and trees with them. With their largish (3/8-inch diameter) burrows going straight down 3 feet or more, these have *enormous* potential to alter the infiltration rates of cropland. This can readily be seen at Dakota Lakes Research Farm, southeast of Pierre, SD, where lateral-run irrigation sprinklers apply 2 inches of water in 20 minutes, yet you can walk in immediately behind where the sprinklers have run and not get mud on your shoes! (A thick mulch helps, too.) Dwayne Beck and staff 'seeded' those fields to nightcrawlers in the early '90s, after Beck had previously noted their dramatic effect on infiltration rates on the irrigated portion of the Redfield, SD, university research station (now defunct). At the Redfield site, the nightcrawlers were accidentally 'seeded' while drawing irrigation water out of the James River (they get washed out of city lawns at times).

As intriguing as that is, nightcrawlers don't do so well under drier conditions, so we didn't know the applicability for non-irrigated fields in regions drier than the Corn Belt. I suspected they

Ultimately the quantity of food for earthworms is proportional to sunlight photosynthesis by plants and free-living organisms.

would survive in no-till cropland on Kansas' better soils, based on their survival in the grassy areas of industrial parks and undeveloped areas of Salina, KS (no sprinklers there, unlike watered lawns). (I attempted to transplant some to a no-till field in the area in '94.) We also didn't know if they would be a benefit to crops in dryland conditions, since they do consume a great deal of surface mulch. Since we didn't want to

7 Earthworm populations are often higher following corn, legumes, and especially brassicas as compared to wheat. Clapperton, personal communication Aug. 2008.

8 There are a great many undiagnosed and uncorrected deficiencies in Nebraska, Kansas, and Oklahoma cropland, including Mo, Zn, Cu, and S, all of which are absolutely essential for eukaryotes such as earthworms. Starving crops equals starving earthworms. It gets more complicated when we consider some elements that are likely essential for earthworms, but not for crops, such as selenium or chromium. Not even the soil food-web analysts or soil ecologists do much to monitor this stuff. Not yet anyway.

9 Carbamate and organophosphorus insecticides are the most damaging (e.g., endosulfan is one of the worst); synthetic pyrethroids aren't much of a problem for earthworms, at least not directly. (Kladivko, 1993; Wayne Smith [consultant, Agronomic Acumen, W.Australia], personal communication Aug. 2008.) Some herbicides, fungicides, and fertilizers can also be harmful to earthworms (fungicides are particularly rough on earthworms when applied as a liquid stream in the soil). Tillage and crop residue removal are generally much more damaging for earthworm populations than most of these other inputs, singly or in combination.

incur the expense of 'planting' nightcrawlers if they wouldn't survive, or if they would hurt crop yields (in which case they'd be impossible to eradicate), we put the idea on the back burner.

We now have enough information to answer those questions. In north-central KS, a hundred-acre creek-bottom field of Jerry Burger's was colonized by nightcrawlers over the course of no-tilling it since the mid-1990s. These nightcrawlers came out of the nearby creek, downstream from the town of Palmer. The nightcrawlers in Burger's field seem to be doing quite well despite some drought years. While the crops are quite prosperous in that field, Burger didn't begin gathering yield data early enough to answer what effect the nightcrawlers are having (they spread across the field rather quickly in this case).

As a youngster, Joe Swanson often went fishing with his dad, and they tossed out their leftover nightcrawler bait near their farm house about 15 miles north of Hutchinson, KS. The nightcrawlers took up residence in the lawn and a small nearby bottomland field, and slowly started to 'invade' a larger bottomland field behind the house. Eventually (and this took decades), they had colonized part of a shelterbelt on upland and were moving into the corner of an upland field in annual crops. Both Swanson and I wondered if that upland population would survive a prolonged drought (apparently they did), and how well they would do as they got farther from the hedgerow (if the population in the field died out during a drought, they might have repopulated via fresh migration from the shelterbelt). We also didn't know the overall effect on infiltration due to residue consumption, although Joe now reports, "Water sometimes ponded in that corner of the field previously, but not anymore. The nightcrawlers are having a huge impact on infiltration." Even if infiltration turned out to be improved, I was also concerned about crop yield effects, since loss of mulch cover greatly affects evaporation rates and soil temperature. However, Swanson's harvesters' yield monitors and mapping indicate a benefit to the summer crops (as well as the wheat) in areas colonized by the nightcrawlers.

So with those answers in place, I think we are now ready to embark on efforts to 'plant' nightcrawlers (either in live/active stages, or dormant). This has been done on cropland in higher-rainfall areas, so the know-how is available, but that is beyond the scope of this article.

If you are in extremely dry regions (the western 1/3 of Kansas, for instance), nightcrawlers probably aren't going to survive except under irrigation. You will have to make do with the transient-burrowers. So what can be done to enhance the build up of the grey worms? Feed them more, and don't do any tillage. You will feed them more by growing better crops, eliminating non-crop periods, adding cover crops, and keeping the residue on the soil. Applying manure also appears to be a good way to feed earthworms,[10] although heavy applications of manure with high chloride levels can inhibit earthworms.[11]

Photo by Matt Hagny.

Soybean comparison with and without cover-crop rye (the left side didn't have a cover crop, and has a light scattering of lambsquarters in the beans). The rye was killed at early boot stage, just after the soybeans were seeded. Despite a very dry summer, soybean yields were the same following the cover crop versus without: 19.8 bu/a for both (average of 3 replications for the cover, 2 replications without). This result is typical, especially for soybeans and cotton: everyone worries about the cover crop using too much moisture, but the cash crop is almost never impacted negatively.

[10] Kladivko, 1993.

[11] Clapperton, personal communication Aug. 2008 (research by Chi Chang at Edmonton indicated that application of beef feedlot manure probably shouldn't exceed 12 tons/acre annually due to suppression of earthworms by chloride compounds. High levels of parasiticides [avermectins, etc.] can also pose problems if manures are applied at heavy rates).

Calcium & Clay Flocculation

Gypsum and lime are often touted for 'softening' soils, improving the clay flocculation, aeration, and water infiltration. The view is supported by some empirical research and many anecdotal accounts (its value for reclaiming soils with excess sodium is indisputable; the question is whether it is useful to a significant extent on soils with normal or low sodium). The mechanism is calcium ions displacing magnesium and sodium ions on the exchange complex of soil particles, mostly clays. However, for most soils of the U.S. Great Plains, the effect of calcium appears to be quite small in relation to mulch cover, soil structure (no tillage), and earthworm plenitude.[12]

Terra-Forming

Preventing erosion really comes down to a few simple things, but with a multitude of ways of tweaking them. Mulch cover is the #1 factor, so find ways of growing more, and making it last longer (keep it standing!), while the second-biggest factor is extracting sufficient moisture with vegetation. Furthermore, soil aggregation is improved by abundant roots and mycorrhizal hyphae. Both mulch cover and root mass increase when we do a better job of 'harvesting sunlight' with appropriate species and management (nature does all the hard work of biochemical assembly; we are just the facilitators☺). Finally, try to avoid anything that screws up the earthworms, mycorrhizae, or soil ecology in general, and perhaps the next step will be to introduce nightcrawlers on cropland where they can be expected to survive.

Priorities: Many of you will react to this article, "These are valid concerns, but I can't fix everything at once." True enough—just don't wait too long to take action. Repairing ditches and gullies is expensive and time-consuming, and much of the soil is essentially gone forever (somewhere downstream). Ag land is valuable primarily because of its ability to grow crops, which is strongly correlated with topsoil depth. You'd certainly object to continual deletions from your other investments, and it should be the same with cropland.

[12] See, e.g., the discussion in P.M. Bierman & C.J. Rosen, 2005, *Nutrient Cycling & Maintaining Soil Fertility in Fruit and Vegetable Crop Systems*, publ. M1193, U. Minn. Extension (adapted from an Ohio State Univ. 1999 publication). (Some soil management philosophies dating from the 1920s emphasize an 'adequate' Ca:Mg ratio in the soil as the key to maximum infiltration, and that gypsum or calcitic limestone be applied to raise this ratio by adding calcium. But universities and independent scientists have found *no* significant effect in soils down to 1:1, as Bierman & Rosen note: "However, within the ranges of these the two ions commonly found in soil, there is no clear evidence for a Ca:Mg ratio effect on soil structure." *Note that this is only for clay flocculation and water infiltration, not crop nutrition of Ca, Mg, or any other nutrient.* Many Kansas soils are 4:1 to 8:1, and up to 30:1 on some bottomlands, but occasionally as low as 2:1 or 1:1. In a laboratory, elevating Ca:Mg above 1:1 improves clay flocculation and water percolation, but this is with *pulverized* soil—more finely crushed than in any tillage system. For no-till with adequate mulch cover, the effect of Ca:Mg on infiltration becomes utterly trivial.)

Current Actions for Controlling Erosion

by Kevin Wiltse

TECHNIQUE

Wiltse is a longtime no-tiller, farming 20 miles west of Great Bend, KS.

The past couple of years I've seen a disturbing trend of increasing erosion in our fields. This is partly due to the extremely intense rainfall events we've had the previous two springs. However, it's an indication to me that something within our system needs adjusting. Even with 10 to 20+ years of no-tillage, our soils' infiltration rates haven't improved like I had hoped (although part of the problem lies with the soil profile being full during these spring rains).

Case in point: In May of 2008, I had a quarter-section of carryover wheat stubble (no cover crop or double crop) that had a 7-inch rainfall event in a very short time. I drilled milo one week later, and received another 3.5-inch rain with tennis ball hail the night I finished seeding. A majority of the wheat residue (50-bu/a wheat in 2007) was washed off the field. Many terraces broke over and numerous new gullies formed. This was a field of converted CRP, plus 10 years of no-till cropping, for a 20-year history of not being tilled. It had never been grazed, and I largely adhered to a wht >>wht >>milo >>milo >>soybean rotation.

Granted, this is an extreme case. We will probably never be able to get our soils to infiltrate these rains. But, for me, any erosion is simply not acceptable. I've made several management decisions to help prevent this from happening again.

First, residue is crucial. We have to become more focused on growing it and keeping it. That is one of the main reasons I rented a 32-ft Shelbourne stripper head for wheat harvest in 2008. I also wanted the benefits of the standing stubble for seeding cover crops and double-crops. It's much easier to get good seed placement behind a stripper head than behind a sickle head where the straw isn't evenly distributed behind the combine. The disc openers have a difficult time cutting through the residue lying on the soil surface. Speaking of seeding, I have always been a proponent of minimal disturbance. We run a 10-inch JD 1890 CCS drill with narrow gauge wheels. We seed wheat on 10-inch spacing, but most other crops (soybeans, milo, cover crops) go in on 20-inch spacing with the front rank locked up. Again, minimal soil and residue disturbance. Other equipment upgrades include going to flotation 650/65 R38 tires on our CIH Patriot sprayer. This has reduced gully erosion in the wheel tracks compared to the narrow row-crop tires we used to run.

All of my wheat stubble going to milo gets a cover crop, this year and in the future.

While equipment certainly plays a role in the system, I think adjusting our rotation and ultimately improving our soil quality will provide the biggest gains. There are a couple of areas that I am addressing here. I have been getting away from stacking milo for several reasons, one of which is the tendency for increased erosion during the summer-crop phase as compared to wheat. Going to soybeans after just one year of milo tends to help since there usually is still some wheat residue present on the soil surface. This isn't a long-term solution since a wht >>wht >>milo >>soybean rotation probably won't be sustainable for very long due to 'cheatgrass' pressure. For this reason, I am going to revisit field peas on some of my acres to replace the soybeans, and with only a single year of wheat following the peas. With proper management, including an aggressive fertility program, wheat following field peas has tremendous yield potential. Along with high yield comes lots of residue.

That leads me to my greatest area of concern for erosion—carryover wheat stubble prior to milo planting in the spring. These soil profiles are completely full when the big spring rains come, greatly increasing the risk of erosion. This wheat stubble simply must be double-cropped or cover-cropped—so I seeded 130 acres to cover-crop sunn hemp in late July, and in late August I planted 470 acres to a mix of vetch, canola, radish, and turnip. So *all* of my wheat stubble going to milo gets a cover crop, this year and in the future. (*Editors' Note: Kevin's cropland is separate from his dad's, part of which was cover-cropped, although the previous figures include his dad's covers*.) I believe that we *must* intensify our rotation and add cover crops, or we may never see the true benefits of long-term no-tillage.

Erosion shouldn't be tolerated. Growing and keeping more residue, and improving the physical properties and biological activity in the soil through cover crops, should get us started down the right path.

Photos by Kevin Wiltse

Wiltse's field suffering severe erosion in 2008.

Fine-Tuning

by Matt Hagny

The original story on Palen appeared in the Sept. '03 issue.

Having had 10 years of continuous no-till under his belt already in 2003, you might think Doug Palen would be merely coasting by now. Yet he has found many aspects that needed some tuning to keep 'er running smoothly.

The most fundamental changes occurred in crop rotations as Palen came to understand the need for much greater intensity. While he dabbled in double-cropping during the drought of 2000 to '05, he dramatically ramped up from '06 onward as rainfall became more plentiful again: Almost every acre of wheat stubble going to corn or milo the next year was double-cropped or cover-cropped during '06 – '08.

Sunflowers are Palen's double-crop of choice, but he has also used milo, soybeans, proso millet (on fields going to corn), and pearl millet ('08 was the first attempt, and it's very unhappy due to excess moisture). Palen enjoyed some highly profitable double-crops in '07, but the true goal is simply to break-even while preparing the field for corn or milo the following year by using excess moisture from the subsoil, which sunflowers are adept at doing. Palen explains: "I was seeing too much water coming off of fields, especially in carry-over wheat stubble. [After watching for several years] I'm more comfortable with ramping up the intensity with double-cropping and covers. We need to utilize the moisture whenever it falls. I feel strongly that this is the direction we need to go."

Otherwise, Palen has tended to adhere to his rotation of 2 wheat crops (plus a double-crop after the 2d wheat), followed by 2 – 3 milo crops, and a single year of soybeans (stacked soybeans were quickly dropped from his system due to reductions in mulch cover). Some fields only get a single year of milo due to shattercane. And sometimes 1 – 2 years of corn are used instead of milo. Palen has grown field peas instead of soybeans on some acres in '07 (good results) and '08 (poor results): "The jury's still out." The following wheat does benefit from peas instead of soybeans, although the non-crop period after pea harvest is a bit of an issue due to rapid residue decomposition.

"We need to do everything possible to get covers and double-crops planted in all the wheat stubble."

Palen says that all this additional cropping and diversity creates some real management challenges. Hiring his harvesting helps, but other logistical and timeliness issues haven't entirely been overcome by moving up to an air drill (a 30-ft Deere 1890), a 16-row planter, a JD 4920 sprayer, and semis to tend the seeders and the sprayer.

One of Palen's nagging concerns has been rill erosion: "My residue just doesn't last as long as it once did." Along with the greatly increased cropping intensity, he has initiated several other strategies, including planting a cover-crop cocktail (bin-run sunflowers, mung beans, and sudan) between stacked wheat crops on 200 acres. Those fields will get beef feedlot manure applied onto the living covers, which will then be terminated 3 – 4 weeks before wheat seeding. Palen says, "We need something growing to keep the soil active and put more roots in the soil. We can improve infiltration by using the water from the soil."

Another tactic has been to revisit using stripper heads—Palen had 2 of the 3 combines used in the '08 wheat harvest running stripper heads. Palen reports, "My reason for going that route is erosion control. In the past, if we didn't do covers or double-crops, the stripper head created issues with the straw detaching and drifting into piles. I'm now of the opinion that we need to do everything possible to get covers and double-crops planted in all the wheat stubble [to be carried over]." Palen notes that stripper heads do require more management in terms of adjustments and being timely with harvest (shattering from the rotor is greatly reduced if the wheat isn't tinder dry). However, he likes what he sees in planter and drill performance in the stripper-harvested stubble, and weed pressure is reduced due to shading (although the double-crops don't particularly like the shading either).

While a bit taxing at times, Palen clearly enjoys these adventures: "We need to continue to learn and try." Then he adds, "But only experiment at a level where you can handle a loss, and at a level where you can reasonably evaluate the effects."

Forever a Student

by Charles Long

All of us were forced to be students in our early years, although some willingly embrace learning and remain eager students throughout life. While no-tillers in general often enjoy the learning process, Chad and Jennifer Simmelink of Jewell County, KS, are at the top of their class. They're no slouches in turning scholarship into profitable activities, either.

Chad, now 28 years old, his wife, Jennifer, and their two very young daughters live and work about 45 miles west of Belleville in north-central KS, and just a few miles from the Nebraska border. Chad began farming on his own in 1995 to earn money to attend college, and his first financial interest in farming was on rented land using his father's equipment in a tillage system.

Chad graduated from KSU in 2002 with a Bachelor's degree in biological and agricultural engineering with the machinery option. Jennifer also graduated from KSU with the same degree except she had the environmental option. Jennifer, from York, NE, worked for Mycogen Seeds while in high school, then for Exxon Mobil in Texas after graduating from college. She later married Chad and moved to the farm. Chad says, "She helped with some research on erosion in college, and she keeps me aware of the need to be smart in our use of chemicals—making sure they stay on the fields with better infiltration and less runoff."

Photo by Charles Long.

Milo does best for the Simmelinks if something was grown following wheat harvest the previous year.

While in college, Chad continued to be involved in farming and first tried no-till in '99. One of the first experiments with no-till wasn't too successful: Chad and his father, Danny, thought that with spraying it wasn't necessary to kill the weeds early on, and the weeds were so large by the time they were sprayed that they didn't get a good kill. Thus, the crop lagged behind the weeds all season and this adversely affected the crop. Yet when Chad returned to the farm full time, he convinced Danny that no-till was the way to farm their land. In 2003, they converted to all no-till and began raising crops on all acres every year (previously, they had some summerfallow every year).

Asked why he thought no-till was the way to farm, Chad replies that they needed to improve soil quality. He believed they had too much erosion on their land and weren't using rainfall efficiently. Chad also thought no-till would reduce labor costs and allow machinery to be used more efficiently.

"I've decided to really try and spread out the cover-crop planting times next year for moisture, time, and maximum residue-accumulation reasons."

Chad reports they didn't meet with much resistance from landlords at the idea of converting to no-till farming practices, after explaining the expected benefits, and also because of good long-term relationships with the landlords. At that time, some of the relationships had been as long as thirty years. To continue these relationships, good communications are maintained with the landlords. One example is a letter Chad is composing to explain the additional cost of the fertilizer program needed due to the recent run-up in fertilizer prices.

New Curricula

Although each is financially independent, Chad and Danny share machinery and labor on cropland totaling about 2,400 acres as well as on a cattle enterprise utilizing 2,200 acres of permanent pasture. Since going no-till, the Simmelinks have been using mainly a wheat >>wheat >>milo

>>milo >>soybean rotation. Chad says that while this rotation has worked well, they need to make some changes. They are seeing too much shattercane due to the stacked milo, so corn is being considered as an option to replace the first milo. Other rotations being considered include wheat >>wheat >>milo >>soybeans, or wheat >>milo >>soybeans. While these changes would help control shattercane, Chad is afraid if the rotation is shortened, 'cheatgrass' may become a problem in the wheat, especially for the rotation that is 50% wheat (2 years in 4).

Overall, the Simmelinks think that weed pressure has decreased since going to no-till. Bindweed and devil's claw are two that have ceased causing problems. In some fields, Chad can see a shift towards other weeds becoming more prevalent. Marestail is one of these weeds; another is pigweeds in some milo fields.

While erosion was a major concern when they shifted to no-till, Chad reports that it still isn't completely under control. He says the residue doesn't seem to last as long as it did when they first started no-tilling. To gain additional residue and to decrease runoff, he is endeavoring to have something growing on all the fields throughout the growing season. Chad tells a story about Jennifer when she first moved to the farm: "It was during wheat harvest after she first moved back. She asked what I would plant in that field next, and I told her it would be milo next year. She said, 'It won't grow anything until next year?' with a questioning voice. That got me thinking about cover crops after wheat harvest and I am finally pushing harder to get something growing on those acres. That kinda shows how someone without a strong background to a farm can give a different perspective."

Following wheat harvest on fields slated for milo (or corn) the next year, the Simmelinks are doing their version of 'cover crops'—to be harvested as seed in the fall, harvested as hay early enough to allow ample regrowth for residue cover, or used for limited grazing. Occasionally, these crops or mixtures are purely for cover. On fields that had something planted after the '07 wheat harvest, Chad says they planted beautifully to milo in '08 with no problem areas. On the fields that didn't get 'cover crops' after '07 wheat harvest, there were areas too wet to plant, and other areas where the milo was mudded in during the spring of 2008.


Photo by Chad Simmelink.

Simmelinks' air cart and dry boom.

Simmelinks are trying various 'cover crops' including pearl millet, sudan, turnips, and cowpeas for hay. Later in the summer, Simmelinks plant oats, field peas (or vetch), and various brassicas (radishes, turnips, canola). They also use German foxtail millet, planted late enough to not set seed. Due to abundant rainfall since the '08 wheat harvest, Simmelinks' fields have been wet enough to present major problems in getting cover crops planted. Some of the pearl millet that was planted and emerged well is showing a dislike for the excessively wet conditions: On terrace tops it looks good, but in any low areas the growth is now very poor and the stand is decreasing. Chad says, "I have decided to really try and spread out the cover-crop planting times next year for moisture, time, and maximum residue-accumulation reasons."

Chad now has the additional goal of having all wheat stubble that is going to second-year wheat to have a short-term cover crop planted after harvest and killed before wheat planting. So far he hasn't tried this, but intends to in the future. He says, "In a wet year like this, I think I could almost plant sudan, graze it for a short period, and then plant wheat again."

Doing His Homework

In discussing his fertility program, Chad still isn't satisfied with the results. He has done some soil testing and has sent in many plant tissue samples. Chad thinks their P levels are too low for optimum wheat yields even though they have for years applied about 35 pounds of P_2O_5 at planting. For the '08 wheat crop, Chad applied 9 gallons/acre of 10-34-0 (35 pounds of P_2O_5 per acre). After the wheat had emerged, he went back in November and broadcast 100 lbs/a of 11-52-0. Where he did this, he had his best wheat yields. In addition to N and P, Chad also uses zinc, sulfur, copper, chloride, and has tried molybdenum. Chad mixes ammoniated zinc chloride, copper EDTA chelate, and sodium molybdate with the 10-34-0, while the sulfur is either sprayed on or broadcast as dry product. Additional copper and moly are sometimes applied foliarly.

In spite of Chad and Danny providing virtually the only labor for both the cattle and the crop-

Photo by Charles Long.

Simmelink's soybean crop 2008.

ping operations, equipment is kept to a lean minimum. Two tractors, one a four-wheel-drive and the other a MFWD, provide the power. The 4WD pulls an 1890 CCS drill, and the MFWD is dedicated to the sprayer in the summer and to feeding cattle in the winter. Simmelinks do their own harvesting which includes a yield monitor and mapping. With many fields of widely varying sizes, this helps to keep track of experiments and to identify problem areas.

Simmelinks do all their seeding with the 30-foot 1890 CCS with 10-inch row spacing. (If corn is added to the rotation, a planter will be added to the machinery lineup.) The drill has been modified to include Thompson closing wheels to replace the JD cast closing wheels, and Fins to replace the JD in-furrow firming wheels. The Fin provides seed firming as well as a method to apply liquid fertilizer in the seed row for crops that need and can tolerate fertilizer in the row.

Chad does all their spraying with an 80-foot-boom Hardi. When spraying, he uses auto-steer and automatic boom controls. For spreading urea, Chad has an air cart on which he has added a boom. So far, he has not tried to use the air cart in tandem with his drill.

For Simmelinks, wheat seeding rates vary with the calendar, from 1.1 million seeds/acre in early October, to 1.7 million by late October. Milo is seeded at a rate of about 55,000 seeds per acre in 20-inch rows, with 3.5 to 4 gallons of 10-34-0 applied in the row. Soybeans are also planted in 20-inch rows, with a seed drop of 110,000 – 130,000 seeds/a. For soybeans, no in-row fertilizer is applied, although all soybeans receive a triple rate of inoculant since not all their land has had soybeans in the past. Soybeans are the first crop to go into fields coming out of CRP, which also receive broadcast P to give them a boost.

Advanced Degrees

While the cropping operation takes up a large part of Simmelinks' time and labor, Chad says their cattle enterprise provides them with "something to do after the cropping season is completed." From November to January, they usually purchase about 450 head of open heifers. These heifers are bred in the spring and then sold the following December before calving.

Just as Simmelinks have worked to make the cropping enterprise more efficient, they strive to improve the grazing operation. They noticed that continual grazing of pastures throughout the summer appeared to lessen the vigor and productivity of the rangeland plants. To address this, Simmelinks have begun a program of rotational grazing of their pastures. This permits the pastures to have a resting period during the summer growing season and allows for winter grazing. So far, they have primarily focused on changing up the times during which any given pasture is grazed, but this past year they also have begun cross-fencing for smaller grazing areas.

Chad says that they have stopped grazing harvested crop residue, such as milo stalks, since the grazing leaves too little residue on the fields, increases erosion, and can adversely affect the yields of the following crop. Instead, living 'cover crops' such as millet, turnips, and sudan are grazed. Care is taken that adequate residue is left on any fields grazed, and that the cover crops have ample time to regrow after grazing.

Chad has a questioning mind and continually looks for ever-better ways of doing things. Chad thinks there is something new to learn all the time: he attends informational meetings and seminars on both no-till and pasture management. Chad tries to learn from veteran no-tillers so he doesn't have to make the same mistakes someone else has already made, and he easily networks with other no-tillers of all ages to share information and ideas. He says no-till is an entirely different ball game from tillage

Photo by Charles Long.

Cover-crop millet and turnips emerging on the Simmelink farm; these plantings are often grazed.

farming and requires learning some new things rather quickly. Continuing challenges Chad sees include being able to adapt to changing weather patterns and market prices, keeping enough residue, finding the right mix of cover crops for each field and season, attaining proper crop nutrition, and staying ahead of weed tolerance and resistance to herbicides.

Chad has an impressive knowledge of each field's cropping history, including its particular problems or peculiarities caused by happenings from years ago, such as a line through the field demarcating where alfalfa had been many years prior, or where a feeding area for livestock in the past shows much better crop vigor due to improved fertility. Simmelinks have many fields of small and irregular shapes due to the rolling terrain of western Jewell County, and yet, from memory, Chad can tell what variety of milo or soybeans is planted in each, what herbicides were applied and when, and what weed problems they were to control.

Chad reports that no-till farming is doing the things he had expected when he started the process. He says progress has been made in soil quality, erosion control, more efficient water usage, reduced labor, controlling costs, and improved machinery-usage efficiency. He thinks his crops are showing improved yields. However, Chad gives the impression that he thinks he is just beginning, and he's looking for substantial progress as he develops and improves his practices with cover crops, fertility, and all the other facets of no-till. Chad says, "In farming there are always surprises. This is especially true for no-till farming. I have to be ready to adapt and meet all new challenges."

Photo by Joe Morris.

2008 wheat harvest on the Simmelink farm.

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