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Tire & Track Pressures: Goal-setting

by Matt Hagny, consulting agronomist for no-till systems since '94.

Winter wheat failed to make a stand and survive the winter in tractor & air cart tracks *from seeding the previous soybean crop.* The transport wheels on the wings of the drill are also visible. And the track angling across is a sprayer track. Sprayer had correct inflation of 22 psi (lowest recommended by tire mfgr); tractor had 12—15 psi; air cart had ~30 psi in both front & rear; and drill toolbar had 45 psi in the transport wheels with JD turf-type flotation tires (only one rank of 1890 was used to drill the soybeans).

This view shows where the drill's transport wheels on the wings ran.

Thinking about upgrading tractors, combines, sprayers? The features and capacity are what everyone dreams of and drools over. The tires (or tracks) to carry that newer equipment are always an afterthought. Gee, the price to upgrade that piece of equipment is *soooo much* that we ran out of money in our budget and we'll just get by with whatever tires are standard—which are always too small (just enough to roll the machine out the OEM's door ☹). With upgrades, the machine weight always seems to creep up, up, up—and which now are truly of monstrous proportions.

You really ought to be thinking about how the extra machine weight should be carried *before* you seriously contemplate an upgrade. And don't think, "Well, it's almost as good as my current setup," because nearly everything I see in the field is causing major soil problems—especially in the low-OM and more highly weathered soils (more ancient geologically) that are found in the southern USA (let's use the rough guideline of Interstate 80 again to define 'southern'), or any other soils that are degraded.

But first: How serious is this compaction anyway? You probably get a lot of different views. Let me say this: Not only can I see it in the subsequent crop, I can *feel* it when I'm digging along a length of row while examining seed placement. In 20-year no-till on silty clay loam soils, I can tell you blindfolded when that seed row is in a track from a heavy wheel, regardless of whether the track is recent or from last year. And it's not subtle—it's a very striking difference once you become accustomed to feeling for it. The added density often causes the planter & drill openers to skate out (fail to penetrate), and makes it much more difficult to firm the seed into the more dense soil at the bottom of the furrow, and tougher to crumble the furrow shut with any type of closing wheels. The sidewalls of the furrow are harder. Early crop rooting is much reduced in these tracks. And a crop that gets off to a poor start never recovers.

I also see it in the thinner stands and slower growth in the tracks, regardless of whether they are from the combine, grain cart, sprayer, floater, tractor, or air cart tracks. And often even the transport wheels on the drill toolbar! (See photo.) In some cases, it's a fairly severe retardation of growth, and substantial yield reduction. You see, the roots are suffocating in that denser soil. Roots need oxygen to grow—they respire, i.e., burn sugars, just like animals do (the green photosynthesizing plant parts are where the net emitting of oxygen occurs). In the analogy of soil as a house, the air circulates from room to room. But if the house collapses in a pile of rubble, everyone inside will soon suffocate. It became uninhabitable. Roots in compacted soil suffer the same fate—they need room to breathe, to grow. Oxygen diffusion rates through the soil are closely related to root growth and yield, particularly at seedling stage if soils are saturated and compacted.[1] Although varying by crop species, below certain oxygen diffusion rates: A) germination will not occur; and, B) for established plants, root growth will cease.

And as to root growth, the density of the soil also plays a major role. The division of cells at the root tip has limits as to what it can push through, and this varies by crop species (and even by variety). Roots will follow the path of least resistance, which is to say they will often follow old root channels and earthworm burrows in no-tillage systems. But this is still subject to having enough oxygen. (And what if the previous rooting activity was very limited due to compaction? Now there aren't many root channels for the new roots to follow—it's a downward spiral.) The rate of oxygen exchange is slow enough anyway, even when the soil has marvelous structure and no compaction (experiments show tremendous plant growth stimulation from piping & emitting oxygen into the root zone). If the soil is compacted, it's well-nigh impossible to get enough oxygen to the roots. Anything that impairs rooting cuts yield potential—quickly, severely.

Think you can repair the compaction with tillage? Think again. The shattering and resulting pore space (and disconnected pores at that) is a very short-term effect. As soon as it rains, it all runs back together again—and you have a net worsening of compaction. (Also, the second pass with a tractor tire negates all the benefit of subsoiling.)[2] Compaction remediation requires natural phenomena: Chemical reactions, perhaps the shrink/swell of clays (but not freeze/thaw),[3] and the all-important biological activity to reacquire pore structure and bind it into stability. See '<u>The Biology of Soil Compaction</u>.'

You spend x $ each year on seed, fertilizer, herbicides, and field operations, yet you are willing to give up 10, 20, or 50% of the yield in all these tracks across the field?[4] That is a lot of surface area. And the yield loss isn't just in this year's crop—it persists for years (although the soil does recover faster in the 2d thru 20th years in no-till than with tillage).[5] You don't need a very sharp pencil to realize that running tires that are too small (or old[6]) is "penny wise, and pound foolish."

[1] M.D. Flowers & R. Lal, 1998, Axle load and tillage effects on soil physical properties and soybean grain yield on a mollic ochraqualf in northwest Ohio*, Soil & Tillage Research* 48:21-35.

[2] R.L. Raper & J. Mac Kirby, 2006, 'Soil Compaction: How to Do It, Undo It, or Avoid Doing It' (a review), presented at 2006 Ag. Equip. Tech. Conf., Louisville, KY (12—14 Feb 2006), ASABE publ #913C0106 (not peer-reviewed).

[3] Freeze/thaw, even repeatedly to depths of 40 to 70 cm, appears to do nothing to alleviate compaction. See Raper & Mac Kirby, 2006.

[4] I'm extrapolating from plots (later in this footnote) that were completely trafficked, whereas a single track across the field from a tire or track may still allow the plants on either side to do *some* compensating, depending on crop type—although this compensation becomes trivial very quickly if the compaction is deep or severe, or if the track is several feet (or more) in width. Anyway, here's an introduction to the research as pertains to no-till: Flowers & Lal, 1998 (9—19% yield reduction in grain yield of soybean from previous year's grain cart traffic across entire subplots at 30—35% soil moisture). See also Lloyd Murdock's 5-year study at http://www2.ca.uky.edu/agc/pubs/agr/agr197/agr197.pdf (yield loss in no-till was 98% [severe sidewall compaction & tomahawk rooting*] the first year, 20% the 2d yr, and about 10% for the remaining 3 years; the tillage plots lost 25% the first year, 20% in the 2d & 3d yrs, and didn't get to 'only' 10% yield loss until the 5th year)(*Lloyd Murdock, personal email Nov & Dec 2014). I've also been involved with a study for one of my clients that showed a mere 2% yield loss in long-term NT, but with the combine traffic occurring when soil was very dry (and yet the traffic still presented other problems, however, such as increased runoff potential, and greater down-pressure requirements on the seeding implement). There's a wide range of yield-loss findings in various published studies, most of which were done in tillage regimes, and many of which continued to show 5—10% yield loss persisting in Yrs 5—10 after the compaction event, and occasionally 15—20 yrs later (although sometimes the effect disappears for a year or two, then reappears—presumably in a tougher season). You can do your own literature search, but beware of the oft-mentioned conclusion of controlled traffic to solve these problems—in continuous no-till, that only works on very flat fields that never have any runoff.

[5] See Murdock's study, previous fn.

[6] Tires are expendable. As with belts & hoses, they aren't meant to last forever. If you aren't covering enough acres to wear out your tires within 5 –6 yrs, you'll just have to come to grips with replacing them before they get too stiff. It's a false economy to over-inflate tires and run them until the lugs are nearly gone, and the sidewalls too stiff to handle the proper (low) inflation pressures. On drive tires in particular, you will have burned a lot of extra diesel from the increased wheel slippage from over-inflation, as well as the yield loss from soil damage.

Since these degraded soils in the southern USA often have worsening problems with water infiltration (despite continually altering our rotations to boost mulch cover ever higher), this is also a sign that we're doing too much damage to the soils and they're not recovering nearly fast enough with shrink/swell, fungal hyphae, earthworms, etc. Sometimes we're on the treadmill of needing ever-greater down-pressure on planter & drill openers to penetrate hard tracks from previous field operations—despite decades of continuous no-till with aggressive cropping, cover crops, tap-rooted crops, and lots of high-carbon crops being grown.

For a given soil and moisture content, **most of the problems with compaction & other changes in soil physical properties are directly related to the pressure applied to the soil** (as well as how large of an area it is applied to, and for how long—yes, driving faster apparently does reduce compaction[7]). The *size* of the area the pressure is applied to dictates *how deeply* the compacting force is transmitted, *so putting ever-larger tires on ever-heavier equipment isn't the complete answer*. Deep compaction is the worst type, since it's slower to be rectified by natural forces, and some may be considered permanent (although alfalfa may remove it). However, no-till soils are far less susceptible to deep compaction (they have far more load-bearing strength). Also, deep compaction doesn't present the problems with poor infiltration and issues with seeding that are the main focus of this article, so we will mostly discuss ground pressures here which are the most important for 'shallow' compaction (up to 12 inches deep).

Let's put some numerical goals in front of us, based on my experience in watching this for 20+ years as a consulting agronomist for no-till systems in Kansas & nearby states. Since the *proper* minimum inflation pressure of a tire (*for both radials and bias-ply*) is a very good estimate of the pressure exerted on the soil (when loaded),[8] my guidelines are:

7 psi = good (minimal damage)
15 psi = problematic
20 psi = seriously damaging to your soils
25+ psi = do not use![9]

We'll discuss these more in a moment, since there are obviously differences in how frequently an implement goes across a field, and whether it's likely to be wet when it does go across, and how wide of a swath the implement takes (giving you some idea of priorities in tire upgrades). But first, a word on tracks. Okay, quite a few words ☺

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[7] Sjoerd Duiker, *Avoiding Soil Compaction*, 2004 (Penn. State Univ.).

[8] This estimate fails at the extremes. If you have a flat tire, you're carrying everything on the scrunched up sidewall or rim—the inflation pressure is zero, but the ground pressure is very high since you've got a smaller surface area carrying the same weight. At the opposite end, if you vastly over-inflate a tire, the ground pressure doesn't keep up because the surface area can only shrink so much—50 psi in the tires on your 500-lb ATV doesn't create 51 psi ground pressure, since you never get down to just 10 square inches of total tire contact area in the real world of field soil. *This estimate also fails if sidewalls are overly stiff.* But for all other 'normal' scenarios of tires carrying their max load in the field, this is a very good estimate of what the soil experiences. As for axle loads, those are used in determining tire pressure requirements, and researchers focus on those for deep compaction because as tire sizes are increased to cover more area, it can drive compaction deeper because "what happens at depth depends on how the forces are transmitted through the soil (a more complex distribution than just considering ground contact pressure alone). The complicated physics of force distribution within the soil profile is what makes axle load so important in subsoil compaction and ground contact pressure less of a factor at depth." (Tom Schumacher, SDSU soil scientist, personal email Nov & Dec 2014) (see also Raper & Mac Kirby 2006; Daniel Hillel, 1998, *Environ. Soil Physics*, Academic Press, Chapter 13; M. Lamande & P. Schjonning, 2011, Transmission of vertical stress in a real soil profile, Part II: Effect of tyre size, inflation pressure and wheel load, *Soil & Tillage Res.* 114: 71-77).

[9] An adult human walking applies about 35 psi (or more if you're really hefty). This can be a factor in small-scale plots that are hand-weeded; the foot traffic really messes up the infiltration, and yields. It's also a factor for small vegetable farmers who offer 'pick your own' produce. Still don't believe that human footprints are damaging?—Think about all the trails where people walk across lawns, or out in the wild grasslands—nothing grows there, and those persist for many years even after walking across them is discontinued. The reason we don't worry about it much in the field is that people tend not to be ambitious enough to walk across much % of the field (and also the compaction doesn't extend very deep). Cattle are another matter—while foraging, they often will traffic 100% of the area, creating major problems for infiltration and seedling establishment on some no-till soils.

Although tracks are great for flotation, they're not as good as large, low-pressure radial tires for minimizing compaction of the upper soil profile in firm no-till conditions. The full-length, two-track systems, such as shown here, have even more problems in this regard than pivotally mounted half-tracks such as Case's Quad-Trac.

Tracks are much more complicated. Track vendors would like to have you believe that the ground pressure (what the soil experiences) is the weight carried divided by the "contact area" of the rubber track.[10] There are multiple problems with this gross over-simplification, the greatest being the assumption that the belt (rubber loop of track) is stretched tight enough to perfectly spread the load *between* the idlers—which is never true. Measurements always show big spikes occurring in ground pressure as the idlers roll across, with far less pressure exerted between the idlers. Remember, the soil 'feels' or remembers the peak load, not the average. This problem can be partly overcome by stretching the belt (track) tighter, but then you lose some of the flex that you'd like to retain if a spot between the idlers is a bump in the soil terrain. (Tires casings flex enough to minimize the issue with small-scale variations in terrain—i.e., low-inflation tires will always conform to match the terrain, thus providing cushioning.)

Which brings us to the next problem: In mud (especially in a tilled field), everything squishes around so that tracks aren't terrible in dealing with small bumps. In firm no-till fields that have a high degree of structure, there are always some slightly higher spots, and these aren't going to squish out—they're going to get hammered by the idlers (the belt provides almost zero cushioning when it goes under an idler).

Another example of full-length tracks.

But how much hammering from idlers depends on the engineering of the undercarriage. Some of the older rubber-track systems were lousy—everything was rigid. Most of those designs have been abandoned, although some are still in service—especially as grain-cart tracks. Newer track designs allow far more movement of the idlers (although at greater cost, both initially and in maintenance). Even so, these do not entirely overcome the hammering effect.

Another engineering issue: Half-tracks usually are built to oscillate / pivot (see videos of Case-IH's QuadTrac) to ensure the load is carried equally along the track length. In contrast, full-length tracks on tractors are inferior to the quad-tracks. The problem is the tractor has inconsistent draft load most of the time. Under big load, the tractor rocks back onto its haunches (due to torque), and most of the weight is on the rear driver and very little on the rest of the track. Compaction can be quite high in this case. If you put enough weight on the front of these tractors for max draft, then when draft is light you have most of the weight on the front idler. How much of a problem this is depends on the variability of the load & draft, and how the tractor with full-length tracks is ballasted for that implement.[11]

With pivotally mounted half-tracks, at least the ballasting and rocking problems are no longer present. But many other reasons exist as to why they're not the silver bullet for compaction prevention in no-till.

Another problem is that the front & rear idlers often are a smidge higher than the middle idlers (see photo), depending on the track design. In a soft field, the grousers (lugs) sink in, mitigating this, but *it's yet another reason that simply dividing the weight carried by the alleged contact area is highly misleading*. And if the belt has much width beyond the idlers, that part of the belt again carries far less weight than what is under the idlers.

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[10] All discussions of tracks herein are rubber belts, not the steel tracks of 60 yrs ago.

[11] This type of tracked tractor has further problems in that the drawbar height changes continuously across the field (ever hear of these tractors "rocking the operator to sleep"?)—this drawbar height fluctuation can be a big problem for some implements.

Notice how the belt under the front & rear idlers isn't setting on the soil. This is an engineering trick to reduce berming during a turn, but it also greatly reduces the effective footprint—especially on firm no-till soils.

The center of the belt is worn a lot more than the edges, an effect of the inability of the track to spread weight much wider than the idlers. The extra width of the belt does reduce berming during turns, however.

Note the curling or cupping of the outside edge of belt—water has collected near the idlers. Also note that there's less water between the idlers, demonstrating the reason for the ground pressure spikes occurring under each idler.

In summary, tracks aren't nearly as good at preventing compaction as portrayed by the vendors (although for flotation across mud, they are unsurpassed—unless you have a hovercraft ☺). And yet even the worst track setups aren't as bad as tires that are much too small and/or over-inflated.

A plus for tracks is the width of the area damaged is generally less—especially if the comparison is to "super-single" tires or wide duals. Even at 6 or 7 psi (large tires), there's still damage to the soil for infiltration ability (unless you have nightcrawlers re-establishing their burrow openings to the surface within 24 hrs after the wheel passes). There's also the issue of trampling more stubble from the tires taking a wider swath. For these reasons, there are circumstances when sophisticated, modern track systems may make more sense than tires (or when other engineering constraints prevent putting sufficiently large tires on a machine), and this is especially true as machine weights continue to grow—although in most cases, the machines are designed for taller tires, and this helps spread the weight out with a longer footprint. However, there is some evidence that under extremely heavy loads, well-designed tracks may not cause as much deep compaction as large, low-inflation tires (even though the surface compaction is often worse with rubber tracks).[12]

Good tracks are extremely expensive to purchase, and long-term maintenance costs may be higher than tires. All things considered, I'd rather have low-inflation tires on farm equipment for compaction avoidance in no-till (at least until we get some sort of track design that more fully cushions them, perhaps via a soft internal matrix in a multi-layered belt). If I farmed in a bog and was always getting stuck, however, I'd likely opt for tracks. And for large grain carts, tracks may be the most feasible way of getting the ground contact psi to a reasonable level.

Getting back to my tire inflation pressure guidelines (& whatever you can figure out for actual ground contact pressure for tracks). *Not all implements need to be the same.* But it depends on where you farm—long-term rainfall patterns, which crops are grown, and what % of the farm is in each crop.

Planters and drills go over fields that are typically moist to wet because we usually try to seed into moisture, so those field operations are big concerns (especially if there has been a long fallow time—not every climate is conducive to cover crops). There is also an optimum window for planting date, and in some cases that is a fairly short time, so if it does rain, you are needing to get back to seeding soon afterwards—too soon from a soil compaction standpoint.

For the tractor pulling the seeding tool, I think it's entirely reasonable (looking at economics) to try to get all the tires below 10 psi, and preferably down to 7 psi. This is very do-able with today's technology. The front tires on 2WD and MFWA are not exempt from this need to be very low, whether by dualing them up or simply much larger singles.

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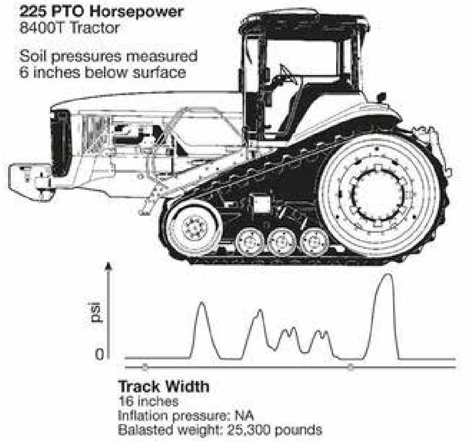
[12] An excellent literature review, including all the conflicting results, is found in D. Ansorge & R.J. Godwin, 2007, The effect of tyres and a rubber track at high axle loads on soil compaction, Part 1: Single axle studies, *Biosystems Engineering* 98: 115-126 (however, the study itself is largely irrelevant to no-till systems on clayey soils, since it was conducted on a perfectly smooth indoor soil bin without any soil structure).



Pressure spikes measured under the idlers of a track. From R. G. Hoeft, E. D. Nafziger, R. R. Johnson & S. R. Aldrich, 2000, Modern Corn and Soybean Production (MCSP Publications, Champaign, IL).

Remember the cart tires on air drills, and transport tires on the toolbar itself (esp on central-fill planters, and/or if sizeable fertilizer tanks are carried).[13] Use radials with bar lugs as much as possible on these (yes, farm implement tires are available as radials in those sizes).[14] The seeding toolbar's transport tires aren't quite as critical as the tractor pulling it, since a lot of the weight is moved onto the openers when going across the field, except on central-fill (seed tanks mounted on the center section of planter or drill frame). In some cases, the transport tires carry zero weight when going across the field, in which case we don't care about their inflation pressure. At other times, they do carry significant weight, and then you do want wider, flat-faced tires.

For drills with **air carts**, usually no weight goes onto the openers. And, if you're on your toes, some of you might be thinking, "Well, the air cart is half-empty on average. Or maybe 3/4-empty on average, if one or more tanks isn't carrying much seed or product. How does that affect our goal?" Excellent question, and the correct answer isn't clear-cut. There is evidence that removing half (or all) the load weight from a grain cart eliminates half (or all) the negative effects on the soil, despite no change in tire pressure (there's also some evidence to the contrary).[15] So our +1 psi estimate may fail if much of the load is removed—i.e., the compaction isn't nearly as bad as predicted by the tire inflation pressure, which remains high (unchanged). Since there's a lot of uncertainty here, let's just aim to get the air carts below 12—15 psi on all tires, which is easy enough on the rear tires, but a sticky wicket on the front dolly / caster wheels (tow-between carts usually don't have front dolly or caster wheels—which makes one headache go away!). And if you haven't gotten the front very low, I'm not sure there's a lot of value in going super-low on the rear of the cart, such as by dualing up—although this does depend on whether you carry much load in the front tank.

A 430-bu air cart with 21.5L-16.1R38 tires on the front (12 psi), and 900 metrics on the rear (15 psi). The tractor pulling the rig has tires at 7 psi, so the worst offender here is the rear tires on the cart—so, the next bit of progress would be to go to 710 duals on the back of the cart.

For instance, on the *tow-behind* 430-bu JD 1910 carts, maybe you go to 21.5L-16.1/R38 tires on the front (these are standard on the 550-bu carts) with bar-lug tread. However, you can't back up very well (if both casters swing around at the same time, they hit), and you likely will need to slow down during roading due to chatter (make sure the flex points of the walking axles are up-to-spec, and you still might want to add a "friction brake" such as what the 550-bu carts use). This allows 12 psi on the dollies on the 430-bu cart, which is heaps better(!) than the 25—35 psi with the standard front tires (but still not keeping pace with our exemplary 7 psi on the tractor, although we're unsure if we need to, except when the cart is loaded to the hilt). Using 900mm singles on the rear (special rims required, otherwise you can't get the meter rolls out) allows 15 psi—probably not good enough. You might want to go to 1000 singles, or dual 710s or 800s (keep in mind clearance for the auger to swing out, although dual 710s on this Deere air cart model have been done without problems).

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[13] Non-driven (free-rolling, a.k.a. 'trailer') tires aren't quite as big of a concern as drive or traction tires anyway—they're not compressing soil rearwardly in an effort to move the equipment forward.

[14] If you want the tires to keep turning in mud, you need bar lugs. From an erosion standpoint, you definitely want bar lugs—the intermittent depressions of the lugs reduce runoff as compared to turf or ribbed tires. The crops usually grow / survive better behind bar lugs, too.

[15] Flowers & Lal, 1998. See also Raper & Mac Kirby (citing Taylor et al., 1980; Bailey et al., 1996). *Contra* Raper & Mac Kirby (citing Bedard et al., 1997; Taylor et al., 1986, 1989).

For equipment where the loads change vastly during field operation (air carts, grain carts), this is a great place to deploy on-board central inflation systems where you can change pressure from the tractor cab—more on these in a moment.

If you're doing the traditional single-setting inflation pressure, **remember temperature effects**. You get a 1 psi decrease for every 10 F drop in temperature. So re-check them when the weather changes and it's cold in the morning. *This is especially critical when running the very low inflation pressures we've been talking about.* And forget about using pencil gauges—you need a good dial gauge. Or a digital gauge that has been calibrated against a valid benchmark (perhaps the expensive benchmark unit stays in a safe place somewhere, while the everyday units are being used—with markings on them as to +/- departure from the benchmark).

Tires large enough to allow 18 psi (Case Patriots aren't quite as overweight as some other brands, which helps). A great improvement over skinny tires, although I'd like to see even lower pressures since the sprayer often ends up going across wet fields.

Sprayers often go over very moist soils because if it's too wet to plant, we go spray for a couple days if there's any needing to be done. On the plus side, at least a very wide swath is taken, so the number of tracks is minimized. But if you're operating on slopes in "never-till" (permanent no-till), the tracks can easily give rise to rills down-slope (and rills soon become gullies). Try very hard to get your sprayer tires below 15 psi, and kudos to you if you've outfitted your sprayer with something even larger. Do whatever it takes. If there are fenders in the way, remove them (some brands of sprayers require a torch to do this—get 'er done). Ideally, you would get down to 6 or 7 psi on the sprayer too, although I don't know of anyone who has done this—for most of the modern self-propelled sprayers, you'd need to go to 1000s to accomplish this—but why not? (Okay, you might void the warranty on wheel motors, etc. Still, do what needs to be done to protect soil productivity. Surely some of the brands of sprayers have wheel motors that can handle this.[16]) You might want to go back to 750s in-crop late-season, but by then you've got a good root mass and green stalks to drive over to help support the tire. (Forget about running the skinny 450 "pizza cutter" tires—those are only good for going down the road!) And forget about trying to run only between the 30-inch rows on corn and similar crops—if you're going to run large, modern sprayers, you'll just have to get used to spraying cross-wise (perpendicular) to the rows. (Everyone on 20-inch rows already does this.) If you spray sufficiently early in the crop's life, the plants on either side will partly compensate for the gap.

If you are faced with width constraints, or simply want to use existing rims, you can help yourself considerably with newer radial tire technology such as **IF & VF, which are more flexible sidewalls**. IF (Increased Flex) tires can carry the same load at significantly lower pressures than standard tires. VF (Very high Flex) tires allow even greater flexing and still lower pressures. But remember that these more-flexible sidewalls bulge a lot more, and for some duals (especially the front of combines), the wheels sometimes must be spaced farther apart to prevent the sidewalls from touching under max load. *If you're not yet using VF, you're really missing out.*

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[16] Or maybe we'll end up going back to floaters with large radial VF tires, and central inflation systems. This would have some advantages for high-gallonage paraquat work. More likely, we will end up with triangle tracks on modern high-clearance sprayers, which a number of aftermarket track companies are developing.

As road speeds of all this machinery increase, these often become the limiting factor: Tires need higher inflation pressures for going down the road at high speed than they do in the field at high torque. The key technology here is adjusting the tire pressure from the cab, lowering them once you get to the field, i.e., the use of **on-board central tire-inflation systems**. For instance, see http://www.precisioninflation.com.

Jack Wiley, retired Principal Engineer, Deere & Co., considers the central inflation systems to be crucial technology for minimizing compaction (as well as IF and VF). Wiley reminds us that these inflation systems are proven in Europe, but are just now seeing some early adoption in the USA. Wiley summarizes, "I know this technology seems 'expensive' to farmers when they first hear the cost [~$10,000 to 20,000 USD], but it is a false impression. The cost is readily recouped in the increased yields resulting from reduced soil compaction. Of course, this has its greatest impact on planters 24 rows and larger pulled by large tractors. But the yield benefit is really there for other equipment such as grain carts, sprayers, and combines as well."

I agree completely. When you start talking about large tires & rims (or, egad, tracks), or the yield losses from compaction, $20,000 isn't that much money, and it truly lets you maximize the benefits of large tires, particularly when either the load varies greatly, or if road speeds start requiring extra inflation. (Of course, you can always manually adjust pressures if you have a service truck with an air compressor—but good luck finding the patience and self-discipline to do this every time you need to road the machine a fair distance [for short distances, you can always drive slower].)

Harvest machinery is often operated on drier soils because you just got done growing a crop that should've extracted most if not all the moisture in the soil profile. But if you get big rains at crop maturity or dry-down, nobody wants to hold up harvest due to wet soils (nor is this good risk mgmt, especially for shatter-prone crops such as wheat or soybeans). But at least you have the option of waiting (in some climates more than others), whereas that's rare with planting, and rarer yet for spraying. I try to get my clients to outfit their combines to be under 20 psi on all tires—including the steering tires! This is very feasible, even on the overweight JD combines: On a Deere S670 (ordered without tires & rims), using Michelin IF 650/85R38 straddle duals on the front allows 20 psi, and Mega X Bib 750/65R26 on the rear lets you go down to 18 psi on those. (You still need to exercise patience when soils are quite wet.) "Super-singles" (a.k.a logger, or flotation tires) on the front of an S670, such as Firestone & Titan/Goodyear's VF 1250s, allow you to get down to 16—18 psi. Although some farmers don't care for the extra roll (side-to-side rocking) of the combine with super-singles, especially when going over terraces (contour bunds) with the corn head, etc. If you don't have terraces, this isn't much of an issue.

Michelin Mega X Bib 750/65R26 on the back of an S680 combine. It's possible to go to 850s (which are Deere-approved), although I hear of tie-rods breaking occasionally.

Another new technology is **Michelin's Xeo-Bibs**, which have been available in Europe but are just now (Nov 2014) being introduced in the USA. These are sized for a machine's weight, and never inflated to more than 14 psi. Improved sidewall construction allows this—although my skeptic hat makes me wonder if the sidewall is now carrying more of the load, which would cause the compaction to be a lot worse under those sidewalls than what the 14 psi inflation pressure would suggest (i.e., the rule of ground pressure being 1—2 psi greater than inflation pressure is violated when sidewalls become

This farmer has done a great job with running big IF & VF tires on his combines at the correct inflation pressures. And he tries to exercise patience in going back into the field after a rain, even though he never spins a tire nor leaves a track in his 20-year no-till fields.

Of course, these should never be in the field. Unless they're frozen.

very stiff, such as with some low-sidewall designs, or if standard tires are under-inflated—although I almost never see farmers under-inflating tires, the point is that you can't cheat your way to lower compaction by under-inflating, since it simply causes the sidewalls to carry more of the load and creates pressure spikes under the sidewalls). However, since Michelin has been the leader in high-flex sidewalls, it's quite possible the Xeo-Bib has an adequately supple yet strong sidewall—i.e., that it truly does deliver 15 psi ground pressure all the way across the tire, from centerline to sidewall. If so, what a wonderful thing!

Grain carts are another huge problem—pun intended. At least they usually don't traffic quite as much area as the combine does (depending on yield), but still they should be below 20 psi as well, and preferably under 15 psi. That takes some really big radial tires, or tracks. I'd also suggest instructing your cart drivers to run in the same tracks that the combine did, rather than just taking off across the field at whatever angle.

Depending on how you farm, there are usually other implements that go across your fields—don't forget about how those are carried. Especially fertilizer rigs.

For those who farm out in dry country, count yourself lucky. For the rest of you, there are real consequences (both economic and sustainability) in failing to adequately manage this problem. Set your goals and priorities. The dull black of bigger tires (at the correct inflation pressures) will often make you more money than the bright, shiny colors of new paint on bigger, fancier equipment.

*Special thanks to my panel of experts for reviewing this document for factual & technical accuracy.