Episode Title: The Tipping Point: Understanding Tractor Stability

Topic: Tractor Stability

Summary: As farmers return to the fields, this FarmSafe episode brings attention to tractor rollover risks. We bring in Aaron Yoder to explain the basics about a vehicle's center of gravity, which is important to understand both with and without loads. When the weight is balanced, a tractor's center of gravity is between the front and back axels and between left and right tires. As long as this center of gravity is within this "stability baseline", the tractor remains upright. Once it shifts outside that boundary, a rollover becomes unavoidable. Our discussion emphasizes how sloping terrain affects rollover risks. Understanding risks, maintaining equipment, and practicing safe operation—especially on slopes—are key to preventing serious injuries.

Expert: Aaron Yoder

Episode Quote:

"If you've ever balanced a ball or a frisbee or something on your finger, there's a point where all the weight is equal around that point… where there's as much weight before and behind, above and below. It's a theoretical spot, but it's where all that balance is."

– Aaron Yoder, CS-CASH, Associate Professor at the University of Nebraska

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Transcript

00:10 E Ritchie

Welcome to the *FarmSafe* Podcast brought to you by the Great Plains Center for Agricultural Health. In the blink of an eye, an injury can change your life and your farm forever. During each episode, we share first-hand stories and real-life tips for making safer and healthier decisions while on the farm.

00:32 E Ritchie

As we head into planting season, more equipment is hitting the fields—and with that comes increased risk, especially when working on uneven ground. Today, we're tackling a question that sounds simple but can have serious consequences: what happens when a tractor starts to tip on a slope—and what should you do about it?

To help us break it down, we're joined by Aaron Yoder, an agricultural safety expert from the University of Nebraska. We start with one of the most important—but often misunderstood—concepts in tractor safety: the **center of gravity**. Think of it like balancing a ball on your finger—there's a single point where everything stays in equilibrium. For tractors, that invisible balance point determines whether the machine stays upright…or rolls over. And once that balance shifts beyond the tractor's base, there's no stopping it. So today, we'll explore what affects that balance, why slopes are so dangerous, and what every operator needs to know before heading out into the field.

01:36 A Yoder

I'm Aaron Yoder. I'm an Associate Professor at the University of Nebraska. I work with both the University of Nebraska Medical Center and our Central States Center for Ag Safety and Health. And then through UNL, University of Nebraska-Lincoln, I work with the Cooperative Extension Service throughout the state.

01:53 E Ritchie

Today, I wanted to ask you a little bit about the center of gravity for tractors. First, I want you to talk just a little bit about what the center of gravity for tractors means, what is it, and why is it important?

02:09 A Yoder

Yeah, so when we talk about tractor stability, one of the key concepts there is center of gravity. And then the other thing that goes along with that is the stability baseline. So, the center of gravity itself. The way I like to explain it, if you've ever balanced a ball or a frisbee or something on your finger, there's a point where all the weight is equal around that point and that's both left to right. But it's also up and down, so figuring out where the center of mass is another word they use for that – so, where that balance point is, where there's as much weight before and behind, above and below. It's a theoretical spot, but it's where all that balance is.

And you can do different tests to figure that out. We did that when I did some tractor stability research at Penn State. Figuring out where that center of gravity is at and why that's important is then we draw lines where the tires touch the ground, and we call that the stability baseline. And if that center of gravity gets outside of that stability baseline, so the center of balance of that machine gets outside where the tires touch the ground, basically, it's going to tip over, and there's nothing you can do to stop it.

03:16 E Ritchie

Generally, when we talk about tractor rollovers, we tend to caution people from driving at all on a slope, sideways on a slope. We tend to say drive up or down the hill, but sometimes you can't always get around that. What type of slope conditions increases the risk of a side rollover?

03:37 A Yoder

Right, so the steeper the slope, we know is going to get that center of gravity closer to where the tires touch the ground or the stability baseline. Slopes, they used to give you a general rule of thumb of like 15-degree slopes or something like that, but there's so many variables that play into that. How the tractor's weighted, the type of tires it has, how wide the wheels are set, that changes that stability. So, there's so many variables that tell you how stable a tractor is going to be or any piece of machinery, that they don't really make those recommendations anymore. That used to be the general rule of thumb. And if you think of a 15-degree slope, that's not very steep. 45 degrees, halfway between straight up, we think about, and then if we cut that into three pieces, that's 15 degrees, right? So that's not a very steep slope, and we know people operate on that.

04:26 A Yoder

So, we've got the variables of the machine itself, but then there's all the variables of the slope. Is it a slippery surface? Is there grass? Is it wet? Is it loose dirt? Is it hard packed? Concrete flat surface would be the best traction, the easiest to predict. But we're not working on concrete out there in the fields. We could have gopher holes, we could have washouts on the low side. If that tire drops down into a hole, it changes the dynamics of that tractor very quickly. And then the loads we have on the tractor, whether it's something that could move if it had a spray tank on it and that fluid can move back and forth.

05:02 A Yoder

That shifts that center of gravity. On smaller machines, it even applies to ATVs, right? So, we talk about if you have an extra rider on there, that totally raises it. With tractors, it could be a front-end loader that we have a load on. Skid steers, the same thing. Loads are pretty dynamic most of the time, or if we have a load that shifts its weight. So, there's lots of those variables. But 15 degrees is what they used to say. Now it depends on the situation. And then the terrain, you know, if the uphill side hits a bump, the low hillside drops in a hole that changes that whole dynamic pretty quickly.

05:39 E Ritchie

A couple of weeks ago, we received a question asking about what to do if you're driving on a slope and you start to feel your tractor tip. Do you generally turn uphill or downhill to avoid rolling over?

05:52 A Yoder

Yeah, like I said, I used to do research with this, and we had a remote-control tractor, big full-size remote-control tractor. And the way I would get it to roll over most of the times would be to turn uphill. So, *we don't want to turn uphill* because I know from experience that that makes it tip over. What happens is when that front tire turns uphill, the bottom tire catches into the ground.

And what that does, again, is take our momentum from the center of gravity and pushes it out over the tire. Or that momentum, things that go on a straight path, want to keep going in a straight path, we turn the tractor uphill, and then that momentum from the tractor in the center of gravity tip it over. We turn it downhill. What that does is it moves that stability baseline with the front tire down lower on the hill. And then we can get to that position, like you said earlier, driving up and down the hill, rather than going across the side of it. Centrifugal force is another thing that acts on that. So, if we turn, we've all been in a car that's turned a little too fast and leaned against the door, that's centrifugal force. I like to explain it to my ag kids by you take that bucket of water and swing it around and the water stays in it above your head. That's centrifugal force. That centrifugal force also pushes the center of gravity out towards the tires and that stability baseline.

07:10 A Yoder

Even if we're not going that fast, still the faster we're going the more that force is. In general, turning downhill is going to be your safest bet. Except if there's an obstacle there. We don't want to turn into a ditch. We don't want to turn into a body of water. We don't want to turn into a wall or, you know, drop offs, that sort of thing. So, in general, turning downhill is going to stabilize the tractor quicker. Going straight and slowing down, even stopping sometimes can be a good strategy to keep it from tipping over.

07:41 E Ritchie

If you must transport a load on a slope, what steps should you take to maintain stability?

07:50 A Yoder

I mentioned a few things kind of sprinkled in there, but speed is a huge factor. The more speed we have, the more impact it has on the center of gravity through that, continuing in a straight line, centrifugal force, all that kind of stuff, is going to be impacted a lot by speed. If we know we're working on slopes with machinery, putting more weight down low, so that's either ballasting the tires or putting weights down low. If we are transporting something, making sure we have a good, stable trailer attachment, whatever we're doing, front end loaders, keeping them as low to the ground as possible. So, we want to keep that center of gravity down low, so it stays inside of that. So those type of things make a huge difference. Some machinery we can adjust the width of the tires. So, setting those tires out wide, putting dual wheels on it so that it makes it a little bit wider even yet and add some weight down low. So, there's some different things we can do to the machines themselves. How we operate the machine, like I said, speed, no sudden turns and jerks. And then understanding the terrain. If it is something that has a lot of ditches or washouts or bumps in it. Maybe we can level out the terrain somehow so when we are going across it, we don't have to deal with that uneven terrain.

09:06 E Ritchie

We haven't talked yet about rollover protective structures. So, how does a rollover protective structure protect operators during a rollover? And why is it important to wear a seatbelt if you have that protective structure?

09:21 A. Yoder

Yeah, so, rollover protective structures, are certified by an organization called ASABE, the American Society of Ag and Biological Engineers. They provide standards of how they're supposed to be built and how strong they need to be. In that standard, it explains that it creates a protective zone and prevents the tractor from rolling more than 90 degrees is the goal of them, whether it's backwards or sideways. So, it stops it there and creates a zone to protect the operator.

So, through not bending too much, absorbing some energy from the roll, keeps you in that area. If you don't have your seatbelt on, you could fly out of that area. And I know I've seen a lot of stories, especially with side-by-sides and other machines, where people get thrown out and then the roll bar lands on top of them. It's not only not protecting them, but it's also injuring them. But without a roll bar on it, that tractor would completely roll over and land on top. And we know in most rollover incidents, it's the crushing injuries that get people, especially with slower speed collisions like that. If it's faster speed and people get ejected, the seatbelt helps prevent people from being ejected and hitting other things. But on tractors, that seatbelt keeps you in that zone of protection that the roll bar

creates. So, they've been tested heavily. We know there's a lot of good information. We know it helps just to have the roll bar on there. It helps even more if we wear our seatbelt and stay in that safe zone when it does tip over.

10:46 E Ritchie

What training practices best help new operators understand slope hazards? And maybe that also includes what type of resources are there to help refresh operators who have been farming for a long time? Reminders of what to do, reminders of slope hazards, things like that.

11:05 A Yoder

When we do operator training, again, we have the opportunity to do that here in a month or two. We'll be out on the road for about a month teaching 14- and 15-year-olds and anybody else that would like to show up to our trainings. But we emphasize understanding the risks, you know, and what could go wrong. And then once we understand what those risks are, a lot of the things that I explained, then we can figure out ways to minimize those risks. So, we do that a lot in all of our safety programmings. Those risks that I mentioned, uneven terrain, operating at higher speeds, with the operators themselves understanding the machine. When you get on a new machine for the first time, understanding what all the controls to, how to speed it up, how to slow it down, how to operate the lifts that are on the front and the back of it. Because if we don't understand that an emergency situation arises, it takes us longer to react. And in most emergency situations, reaction time is a key factor. Understanding the machine, being comfortable with it, knowing what all the controls do. If somebody asks you, do you understand how to control this and you don't, make sure you tell them that. Practice on safe terrain and in safe areas. All of those type of things makes a good and a safer operator.

12:18 A Yoder

Another thing is just to keep the machines in good operating condition, that the tires are in good condition because if a tire blows out or slips off the rim, that could lead to a rollover, whether it's on the highway, you know, at highway speeds or in a field in field operations. So, making sure the equipment's in good running condition, everything's lubricated and inflated to how it should be, just all of those maintenance issues can help prevent bad things from happening as well.

12:48 E Ritchie

As we've heard today, tractor stability isn't determined by just one factor—it's a combination of machine setup, terrain, speed, and operator decisions. The key takeaway is simple: keep the center of gravity low, stay aware of your surroundings, and avoid sudden movements—especially on slopes. And if a tractor does start to tip, your safest move in most cases is to steer downhill, reduce speed, and regain stability if possible.

13:26 E Ritchie

Before operating machinery during this year's planting season and beyond, make sure your equipment is properly maintained, your tires are in good condition, and your rollover protective structure—and seatbelt—are always in use. That protective zone only works if you stay inside it. You can use the Tractor Pre-Operational Checklist provided in the resources for this episode. If you would like more information on tractor maintenance, you can listen to episode 3, "Safe Operation and Maintenance of Tractors," from Season 3 of the FarmSafe Podcast. For more information on roll-over protective structures, check out episode 2, "Safe Tractor Operation", also from Season 3.

14:09 E Ritchie

The National Safe Tractor and Machinery Operation Program (NSTMOP) was developed through a collaborative effort involving Penn State University, Ohio State University, and the agricultural division of the National Safety Council. The project was funded by the U.S. Department of Agriculture, National Institute of Food and Agriculture. The program was originally developed and designed for 14- and 15-year-olds seeking employment in production agriculture. If you would like to learn more about this program, you can visit the NSTMOP website provided in the resources for this episode.

If you would like to watch the videos on testing tractor stability that Aaron discussed, we have provided the link to Penn State's website where those videos can be found under the resources for this episode.

15:00 E Ritchie

Listen in on the *FarmSafe* podcast to join in on the conversation about keeping safe on the farm.

We want to hear from you. Share your stories about health and safety issues on the farm, about injuries that made you change the way you work, or about the ways you keep yourself and others safe on your farm. Also let us know if there's questions you have or topics that you want to hear about on the air. You can visit our website, gpcah.org, or email us.

Original music for the *FarmSafe* podcast was written and performed by Ben Schmidt. This work was funded by the Centers for Disease Control and Prevention as part of the National Institute for Occupational Safety and Health's Great Plains Center for Agricultural Health.

Episode Resources

- Pre-Operational Checklist, GPCAH
- **Information on the NSTMOP Program:** Ag Safety Extension Page and Penn State University Page
- Tractor Stability Overview, NSTMOP Program Manual
- Tractor Stability Presentation, NSTMOP
- Testing Tractor Stability Videos, Penn State University
- *Used Farm Equipment: Assessing Quality, Safety, and Economics*, **Small Farm Series,** Natural Resource, Agriculture, and Engineering Service

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