THE AGRIENERGY CYCLE

Better soil. Better plants. *A living cycle.*



Understand the system. Strengthen every season.

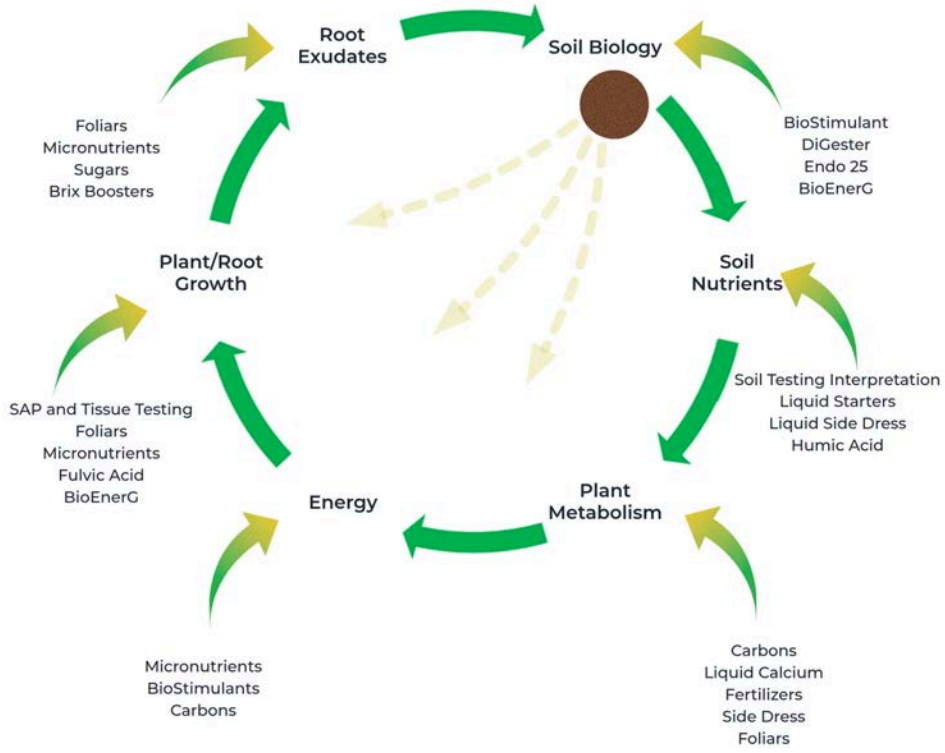
Soil biology, nutrition and plant growth.
Six connected stages. One whole-farm approach.

01 Soil Biology
02 Soil Nutrients
03 Plant Metabolism
04 Energy
05 Plant & Root Growth
06 Root Exudates

SIX STAGES. ONE CONNECTED SYSTEM.

HOW THE CYCLE WORKS

The AgriEnergy Cycle is simple but powerful: every stage of plant development feeds the next, and smart interventions at any point can strengthen the entire system rather than just fixing isolated problems. Instead of treating soil, plant, and nutrition as separate pieces, this approach views them as a continuously interacting cycle.



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01 SOIL BIOLOGY

THE LIVING ENGINE BENEATH YOUR FEET



Most of what happens in a crop is easy to see. We can watch it emerge, evaluate plant color and growth, dig roots, scout leaves, and eventually measure yield. Soil biology is different because much of its work happens out of sight, quietly breaking down residue, cycling nutrients, and helping create the kind of soil structure roots need. That is why Soil Biology is the first stage of the AgriEnergy Cycle.

Think of it as the living engine beneath the crop.

WHAT IS SOIL BIOLOGY ACTUALLY DOING?

Soil is more than sand, silt, clay, and nutrients. It is also home to bacteria, fungi, and other microscopic organisms that are constantly interacting with residue, roots, and organic matter. Their role is fairly simple to understand: they help break materials down, recycle nutrients, and create a better soil environment for the crop.

The goal is not simply to have more microorganisms in the soil. What matters is whether the environment allows those organisms to function well. Good biology depends on the conditions around it just as much as the organisms themselves.

START BY LOOKING AT RESIDUE

One of the easiest places to see the effects of soil biology is last year's crop residue. Stalks, leaves, husks, and roots all contain carbon and nutrients, but those materials have to be broken down before much of that fertility can be returned to the system. Soil microorganisms help do that work, gradually softening residue, breaking it apart, and moving those materials back into the soil.

> **That makes residue more than something left behind after harvest. It is a resource for the next crop.**

When residue is still tough and largely unchanged long after harvest, it may be worth asking why. Was it too dry? Too wet? Is the soil compacted? Is biological activity limited? Residue breakdown is not a perfect test of soil biology, but it is one practical clue that can help tell you what is happening below the surface.



A no-till field with corn residue, cover crop residue all aggressively decomposing from saprophytic fungi (see mushroom fruiting bodies), bacteria, and algae (see green algae on surface). A community of microorganisms working together to cycle nutrients to the growing crop's benefit. Sustainability at its best.

DIG THE SOIL

Another useful clue is soil structure. Take a shovel into the field and look at what comes out. Does the soil break apart easily into smaller, crumb-like pieces, or does it come out in hard slabs and dense chunks?

Biological activity helps soil particles form aggregates and pore spaces, and those spaces allow air and water to move through the soil. That matters for both roots and microorganisms. A soil with good structure gives roots more room to explore and creates a better environment for biological activity to continue.



Fungal hyphae so thick on decomposing cornstalk that it looks like paint. New corn root less than 24 hours old as it is just forming the active rhizosphere obvious at top as soil is aggregating on root from microorganism exudates. Nutrient cycling in action.

> **In other words, biology helps build better soil structure, and better soil structure helps support more biology.**

AIR AND WATER MATTER UNDERGROUND, TOO

We usually think about water in terms of what the crop needs, but soil organisms need the right balance of air and moisture as well. When soils are badly compacted, pore space is reduced. When soils stay saturated, those spaces fill with water instead of air. Either situation can make it harder for soil biology to function well.

That is why managing air and water has always been such an important part of AgriEnergy's approach. If we want biology to work for us, we have to give it the right environment to work in.

BIOLOGY NEEDS SOMETHING TO WORK ON

Every living system needs a source of energy, and in the soil much of that energy starts with plants. Crop residue provides food for microorganisms. Roots provide another source. Organic matter contributes as well. All of that material gives biology something to process and creates opportunities for nutrients to move back through the system.

This does not mean that simply leaving residue on the surface guarantees strong biological activity. It means carbon has to keep moving through the system in a form that biology can use. When that happens, the organisms responsible for decomposition and nutrient cycling have something to work with.

LOOK AT THE ROOTS

Roots can also tell you a lot about what is happening below ground. Are they growing deep and spreading through the soil, or are they turning sideways, following cracks, and struggling to move through dense layers?

Roots are not a direct measurement of soil biology, but roots and microorganisms live in the same environment. If the soil is compacted, poorly aerated, or holding too much water, both can struggle. A strong root system often tells you that the underground environment is working better.

WATCH WHAT HAPPENS TO WATER

The next time you get a good rain, pay attention to what the water does. Does it move into the soil, or does it sit on the surface and run off?

A lot of things affect water movement, including soil type, slope, compaction, and management. But aggregation and pore space matter too. When soil has good structure, water has pathways to move through the profile, and biology plays an important role in helping create that structure.

DON'T JUST ADD BIOLOGY. MANAGE FOR IT.

This may be one of the most important ideas in the entire discussion. Soil biology is not simply something you add. Even when beneficial microorganisms are introduced into a field, they still have to survive and function in the environment they enter.

That means asking some basic questions. Is there enough moisture? Is there enough air? Is the soil badly compacted? Is there residue or other carbon available? Are roots growing well? Those conditions have a major influence on whether biology can do the work we are asking it to do.

> **Adding biology and managing for biology are not the same thing. The best results come when the soil environment supports the organisms you are asking to work there.**

WHAT SHOULD YOU LOOK FOR?



You do not need a microscope to begin paying attention to soil biology. Start with what you can see. Look at residue decomposition. Dig the soil and check its structure. Look at the roots. Watch how water moves after a rain. Pay attention to whether the soil is hard and dense or loose and crumbly.

None of those observations tells the whole story by itself. Together, though, they can tell you a lot about whether the system beneath your feet is functioning well.

THE LIVING ENGINE BENEATH THE CROP

Soil biology is easy to overlook because we rarely see it directly, but we can see what it does. Residue breaks down. Nutrients are recycled. Soil structure improves. Roots encounter a better environment.

That is why Soil Biology sits at the beginning of the AgriEnergy Cycle. It is not the entire system. It is the living engine that helps the rest of the system work.

And once that engine is working well, the next stage of the Cycle has something to build on.

02 SOIL NUTRIENTS

IT'S WHAT THE CROP CAN USE



At first glance, fertility seems pretty straightforward. A crop needs nutrients, so we test the soil, determine what is lacking, and apply what the crop needs.

But there is an important difference between having nutrients in the soil and having nutrients the plant can actually use.

That difference is where nutrient management gets interesting.

WHAT'S THERE ISN'T ALWAYS WHAT'S AVAILABLE

A soil test can tell us a great deal about the fertility in a field. It can identify nutrients that are low, help us monitor trends, and give us a foundation for building a fertility program.

But a soil test is only part of the picture.

A nutrient may be present in the soil and still be difficult for the crop to access. Soil temperature, moisture, compaction, biological activity, root development, and other conditions can all influence whether a nutrient reaches the plant when it is needed.

Phosphorus is a good example. Corn can show phosphorus-related stress early in the season even when soil test levels appear adequate. Cool soil conditions can limit phosphorus availability at exactly the time a small plant needs it for early growth.

> **The nutrient may be there. The crop just can't get enough of it yet.**

That distinction between nutrient quantity and nutrient availability is central to the Soil Nutrients stage of the AgriEnergy Cycle.

BIOLOGY GETS NUTRIENTS MOVING

This is where Part 2 connects directly to Part 1.

The biological activity we discussed in Part 1 of the AgriEnergy Cycle helps break down residue and organic materials, releasing nutrients and moving them back through the soil system. Certain microorganisms also play a role in making nutrients more available around developing roots.

But biology doesn't eliminate the need for fertility.

A healthy biological system and a balanced fertility program work together.

Think of it this way: **biology helps keep nutrients cycling, but there still has to be enough of the right nutrients in the system to meet the needs of the crop.**

> **The goal isn't to choose between biology and fertility. It is to make the two work together more efficiently.**

THE CROP DOESN'T NEED EVERYTHING AT ONCE

One of the easiest traps in fertility management is to think of nutrient needs as a single event.

Apply fertilizer. Plant the crop. Done.

But the crop's needs change throughout the season. A young plant establishing roots has different demands than a crop moving through rapid vegetative growth. Those demands shift again as the plant enters reproduction and begins directing more resources toward grain or fruit development.

That means nutrient management needs to be timely.

The AgriEnergy approach is not built around the idea that one large fertilizer application has to carry the entire crop. Soil-applied fertility, starter programs, sidedress applications, foliar nutrition, and other tools give growers opportunities to respond as the crop develops.

> **The question becomes more practical: What does the crop need now — and can it get it?**

BALANCED FERTILITY MEANS MORE THAN N-P-K

Nitrogen, phosphorus, and potassium deserve the attention they receive. Crops use them in significant quantities, and shortages can quickly affect growth and yield. But plants don't operate on three nutrients alone.

Calcium, sulfur, magnesium, and micronutrients such as boron, zinc, manganese, iron, copper, and molybdenum all perform important jobs within the crop. The amount required may be smaller, but that doesn't make the nutrient unimportant.

A shortage of one nutrient can affect how well the plant performs even when other nutrients are plentiful. **This is why balanced fertility matters.**

Soil Nutrients / continued

Applying more of the nutrient we already have enough of doesn't necessarily solve a limitation somewhere else in the system. Sometimes the better question is not, "What do we need more of?" It is, **"What is holding the crop back?"**

Nutrient relationship reference

Nutrient		Support	Competition
N	Nitrogen	S, Mg, Mo	K, Cu, B
P	Phosphorus	Mg	K, Ca, Zn, Fe, Cu
K	Potassium	Fe, Mn	Ca, Mg, B, N, P
S	Sulfur	Mn, N	Ca, Cu, Mo
Ca	Calcium	—	Mg, Zn, Fe, Mn, B, P, K, S
Mg	Magnesium	N, P	K, Ca
Zn	Zinc	—	Fe, P, Ca
Fe	Iron	K	Cu, Mn, P, Ca, Zn
Cu	Copper	Mo	Mn, N, P, S, Fe
Mn	Manganese	K, S	Ca, Fe, Cu
B	Boron	—	N, K, Ca
Mo	Molybdenum	N, Cu	S

Support (synergism) at balanced levels.
Competition (antagonism) in excess.
— No relationship listed here; not "no interaction."

Qualitative guide, not a fertilizer prescription.

Source: Mulder's Chart

CONDITIONS CAN CHANGE THE FERTILITY PICTURE

Weather can change nutrient availability quickly.

Cool soils can slow early nutrient availability. Dry conditions reduce nutrient movement toward roots. Excess water can reduce soil oxygen and affect root function. Compaction can limit how much soil the roots are able to explore.

That last point is especially important.

You can apply the correct nutrients at the correct rates and still have a crop struggle if the root system cannot reach them.

A restricted root system explores less soil. Less soil explored means fewer opportunities to intercept water and nutrients. In that situation, what looks like a fertility problem above ground may actually begin with a physical problem below ground.

That is why the stages of the AgriEnergy Cycle cannot really be separated.

Biology, soil structure, water, roots, and nutrients are constantly affecting one another.

WATCH THE CROP, NOT JUST THE FERTILIZER PLAN

A fertility plan gives you a starting point. The crop tells you what is happening next.

> Walk the field. Dig plants. Compare areas that look good with areas that don't. Look at root development. Pay attention to color, growth, uniformity, and how plants respond as conditions change. And, use testing throughout the season when it makes sense.

Soil testing helps tell us what is available in the soil. Tissue and SAP analysis can provide another look at what the plant is actually taking up as the season progresses. Together, those tools can help answer two different questions:

- What does the soil have?
- What is the crop getting?

The gap between those answers can be valuable information.

MORE FERTILIZER ISN'T ALWAYS THE ANSWER

When a crop appears deficient, the natural response is often to add more fertility.

Sometimes that's exactly what needs to happen. **But not always**.

Before assuming there simply aren't enough nutrients in the field, consider the conditions around it. Is the soil cold? Is moisture limiting movement? Is the root zone compacted? Are roots healthy and actively exploring the soil? Is biological activity helping cycle nutrients? Is the nutrient present but tied up or unavailable?

Those questions can keep us from treating every symptom as an input shortage.

Good nutrient management is not about applying the least fertilizer possible or the most fertilizer possible.

It is about helping the crop use nutrients efficiently.

A FEW QUESTIONS WORTH ASKING IN THE FIELD

When you're evaluating fertility, don't stop at the application record. Ask what is actually happening in the soil and in the plant.

- Is the crop rooting well?
- Is there adequate moisture without prolonged saturation?
- Are there compacted areas where roots are restricted?
- Are nutrient problems appearing uniformly across the field, or only under certain soil conditions?
- Does the soil test show adequate fertility while the plant still appears deficient?
- Are changing crop demands being monitored as the season progresses?

Those observations can help separate a true lack of fertility from a problem with availability or uptake.

And that can lead to a much better management decision.

FROM SOIL NUTRIENTS TO PLANT ENERGY

The Soil Nutrients stage of the AgriEnergy Cycle is not simply about putting fertilizer into the field.

It is about getting balanced nutrition into the plant.

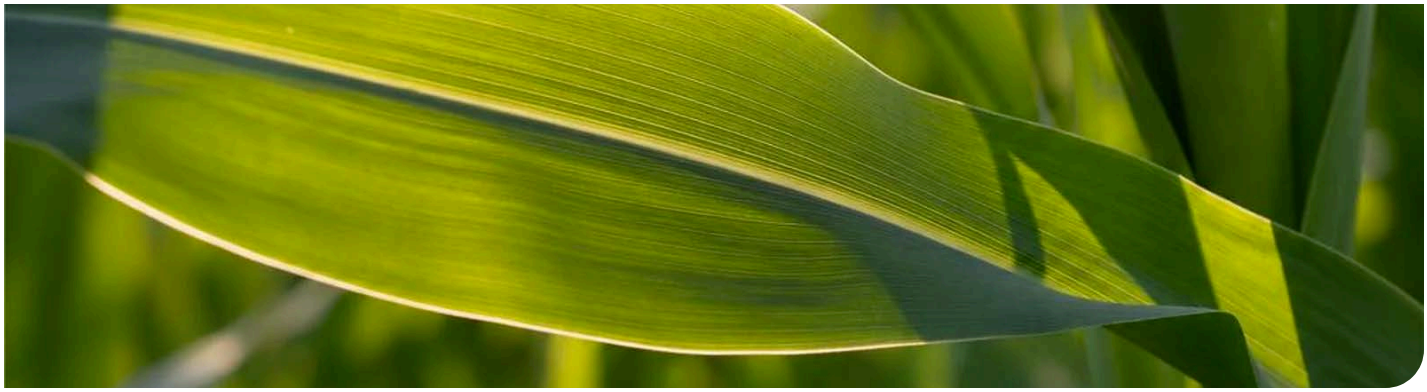
Healthy biology helps release and cycle nutrients. Good soil conditions help keep those nutrients accessible. Strong roots give the crop more opportunity to find them. Timely fertility helps fill the gaps as crop demand changes.

When those pieces come together, the plant has access to the nutrition it needs to do something important with it.

It can turn those nutrients into growth and energy.

03 PLANT METABOLISM

WHAT THE PLANT DOES WITH WHAT IT GETS



Previously, we looked at Soil Nutrients and an important distinction: having nutrients in the soil is not the same as having nutrients the crop can actually use.

But even nutrient uptake isn't the finish line.

Once those nutrients enter the plant, they have jobs to do. They become part of the processes that allow the crop to capture sunlight, build proteins, move sugars and nutrients, produce new tissue, respond to stress and eventually reproduce.

That brings us to the third stage of the AgriEnergy Cycle: **Plant Metabolism**. Put simply, plant metabolism is what the crop does with what it gets.

NUTRIENTS ARE TOOLS, NOT JUST NUMBERS

It is easy to think about fertility in pounds, percentages and application rates. Inside the plant, though, nutrients aren't numbers on a fertilizer analysis. They are tools the plant needs to perform specific jobs.

Nitrogen supports chlorophyll formation and plant growth. Sulfur is involved in protein production and photosynthesis. Potassium helps regulate water and move nutrients through the plant. Boron plays an important role in moving sugars and nutrients and becomes especially important during reproduction.

And those are only a few examples.

The important point isn't to memorize every function of every nutrient. It is to recognize that balanced nutrition allows many different plant processes to happen at the same time.

If one important piece is missing, simply having plenty of everything else may not fully solve the problem.

> **That's why balanced fertility matters beyond nutrient uptake. It affects what the plant is able to do after those nutrients arrive.**

THINK OF THE LEAF AS A WORKING FACTORY

A healthy green leaf is doing far more than simply making the field look good. It is capturing sunlight and using photosynthesis to turn light, water and carbon dioxide into carbohydrates the plant can use. That process supplies the basic building material and energy source for much of what happens next.

But photosynthesis depends on a plant that is functioning well.

The crop needs healthy leaf tissue. It needs adequate water. It needs nutrients involved in chlorophyll production and other plant processes. And it needs enough balance within the plant to keep all of that machinery operating.

AgriEnergy's 2026 soil and crop planning article makes this especially important as the crop approaches reproduction, when nutrient demands increase and photosynthetic activity needs to be working at a high level.

The plant isn't just collecting nutrients at that point. **It is putting them to work.**

A NUTRIENT DEFICIENCY CAN BE A METABOLISM PROBLEM

When we see a deficiency symptom, our first thought is often fertility. And sometimes the crop simply needs more of a particular nutrient.

But Part 2 showed us that availability matters. Part 3 adds another layer: once nutrients enter the plant, they need to be used effectively within a much larger system.

Consider sulfur. It isn't needed in the same quantity as nitrogen, but it plays a role in protein synthesis and chlorophyll formation. Boron is required in much smaller amounts, yet it helps move sugars and nutrients and supports reproductive development. Potassium is involved in water regulation and the movement and use of other nutrients.

A limitation in one area can therefore affect processes well beyond that nutrient itself.

This is one reason we don't want to look at plant nutrition as a collection of independent ingredients. The crop is trying to run an interconnected system.

TIMING MATTERS BECAUSE THE PLANT KEEPS CHANGING

The metabolism of a young seedling is supporting a very different job than the metabolism of a crop entering reproduction.

Early in the season, the plant is establishing roots and building leaf area. As vegetative growth accelerates, the crop is producing large amounts of new tissue. Later, resources begin shifting toward flowering, pollination, grain fill, fruit development or seed production.

Those transitions change what the plant is asking of its nutrient supply.

SOURCE A Happy and Healthy Soil Plan for 2026
https://agrienergysolutions.com/groundwork/happy-healthy-soil-plan-2026

This is why the AgriEnergy approach emphasizes timely nutrition rather than assuming one large application can perfectly match the crop from emergence through harvest. Sidedress and in-season fertility provide opportunities to support the crop as those demands change.

The practical question becomes: **What is the plant trying to accomplish right now, and does it have what it needs to do it well?**

STRESS CHANGES THE EQUATION

Plants don't grow in controlled environments.

Temperatures swing. Rainfall becomes excessive or disappears altogether. Roots encounter compacted areas. Cloudy stretches reduce available sunlight. Disease and insect pressure can damage productive leaf area.

All of those conditions can affect how well the plant functions.

A crop under stress may still have nutrients available, but its ability to take them up, move them or use them can change. Root activity can slow. Photosynthesis can decline. Growth can stall.

That means metabolism is not something we manage directly with a single application. Instead, we manage the conditions that support it.

Healthy roots help supply water and nutrients. Balanced fertility supplies the materials the plant needs. Good soil conditions reduce unnecessary limitations. And in-season observation gives us opportunities to respond when the crop begins telling us something has changed.

WATCH HOW THE CROP IS PERFORMING

Plant metabolism sounds like something that requires a laboratory to understand. But there are practical clues in the field.

Start with uniformity. Are plants developing at a similar pace, or are certain areas falling behind?

Look at leaf color and leaf condition. Is the crop maintaining healthy green leaf area, or are symptoms beginning to appear?

Look at new growth. Is the plant continuing to produce healthy tissue as demand increases?

Dig roots. A plant cannot maintain strong activity above ground for long if the system supplying it below ground is struggling.

And pay attention when conditions change. A crop that looked excellent before a wet period, dry stretch or heat event may tell a different story afterward.

None of those observations measures plant metabolism directly. But together they help answer a useful question: **Is this crop functioning the way it should be at this stage of growth?**

TESTING CAN HELP FILL IN THE PICTURE

This is also where in-season plant testing can become useful.

A soil test helps establish the fertility picture below ground. Tissue or SAP analysis can provide another perspective on what is happening inside the plant as the season progresses.

That information becomes more valuable when paired with field observation.

If the plant is struggling, testing may help identify a nutritional limitation before simply assuming that more of the same fertilizer is the answer. If the crop is moving into a period of rapidly increasing demand, testing can also help guide timely decisions.

Plant Metabolism / continued

The objective isn't testing for the sake of collecting more numbers. It is understanding what the crop needs while there is still time to do something about it.

DON'T FEED THE FIELD AND FORGET THE PLANT

A fertility program can look excellent on paper and still encounter problems in the field.

Weather changes. Root conditions vary. Nutrient demand shifts. Plants respond.

That is why fertility management doesn't end when the spreader or planter leaves the field.

Walk the crop. Look at what it is telling you. Compare strong areas with weak ones. Use testing when appropriate. And remember that the purpose of fertility is not simply to place nutrients in the soil or even to get them across the root.

The purpose is to help the plant function. **That is Plant Metabolism**.

FROM PLANT METABOLISM TO ENERGY

The first three stages of the AgriEnergy Cycle now begin to connect.

Soil Biology helps release and cycle nutrients.

Soil Nutrients provide the balanced nutrition the crop needs.

Plant Metabolism puts those nutrients to work through photosynthesis and the many processes taking place inside a growing plant.

Metabolism runs like a factory. There are two continuous shifts.

Day Shift: builds raw material through photosynthesis, glucose sugar.

Night Shift: moves the sugar and burns it through respiration and generates cellular energy (ATP). This powers plant maintenance, keeps the roots pumping, and keeps the plant alive and working through the night.

Plant food is the factory's machinery.

Nitrogen builds the green solar panels (leaves/chlorophyll) and the workers (proteins/enzymes).

Phosphorus is the electrical grid (moving energy via ATP).

Potassium manages the plumbing (keeps xylem and phloem water pressure working and runs the leaf pores/stomata).

Micronutrients are the specialized fuse boxes. Without zinc the enzyme that stretches cell walls cannot turn on and the whole assembly line backs up.

Peak efficiency on an assembly line or metabolism within the plant means all of the workers, electricity, and machinery must run. Any missing nutrient or missing fuse will prevent progress/growth.

When those processes are functioning well, the crop is able to capture and produce something every growing plant needs: Energy.

04 ENERGY

THE CROP'S ENERGY BUDGET



Energy can sound like an abstract part of crop production, but there is a practical way to think about it.

Every crop has an energy budget.

Photosynthesis puts energy into that budget. Growth, reproduction, root development, stress response and plant defense all draw from it. The more efficiently the crop can produce and use that energy, the more it has available to do the work required throughout the season.

WHERE DOES THE ENERGY COME FROM?

The primary source is sunlight.

Through photosynthesis, green leaf tissue captures light and uses it to produce carbohydrates. Those carbohydrates provide the energy and building material the plant needs for nearly everything that follows.

That means a healthy leaf is not simply a sign of a healthy crop. It is part of the crop's energy-producing system.

This becomes especially important as the season progresses. As AgriEnergy has discussed in A Happy and Healthy Soil Plan, nutrient demand increases as crops move toward reproduction, and photosynthetic activity needs to be functioning at a high level during that period.

By then, the plant is asking a lot of its energy budget.

SOURCE A Happy and Healthy Soil Plan
https://agrienergysolutions.com/groundwork/happy-healthy-soil-plan-2026

THE CROP HAS A LOT TO PAY FOR

Think about everything a plant has to accomplish during a growing season.

- It has to build roots.
- Produce leaves and stems.
- Move water and nutrients.
- Maintain existing tissue.
- Respond to heat, drought and other stresses.
- Defend itself against disease and insect pressure.
- Flower, pollinate and reproduce.
- And eventually fill grain, fruit or seed.

All of those activities require energy.

That is why energy is its own stage of the AgriEnergy Cycle. Good soil biology and balanced fertility are important, but ultimately those earlier stages are helping the plant build the capacity to do work. **Energy is what allows that work to happen.**

A BIGGER PLANT ISN'T ALWAYS THE WHOLE STORY

When we think about crop performance, visible growth naturally gets our attention.

A taller crop with more leaf area can look impressive. But the real question is whether the plant is producing enough energy to support everything it is trying to build — especially when reproductive demand begins to increase.

A crop can spend a tremendous amount of resources producing vegetative growth. Eventually, however, the plant has to shift more of its attention toward reproduction and yield. That transition puts additional pressure on the system.

The crop still has to maintain leaves, roots and basic plant functions while simultaneously supporting pollination, grain development, seed production or fruit fill.

The energy budget gets tighter.

That is when efficient photosynthesis and balanced nutrition become especially important.

STRESS IS EXPENSIVE

One of the easiest ways to understand plant energy is to think about what happens when the crop encounters stress.

- A hot, dry stretch can reduce photosynthetic activity and force the plant to manage limited water.
- Saturated soils can reduce root function.
- Compaction can restrict root exploration and make it harder for the plant to access water and nutrients.
- Nutrient deficiencies can interfere with the processes needed to maintain healthy leaf tissue and photosynthesis.
- Disease or insect damage can reduce productive leaf area.

In each situation, the plant may be producing less energy at the same time it is being asked to spend more of it dealing with the problem.

That is a difficult combination.

This is also why two crops with similar fertility programs can perform very differently by the end of the season. What matters isn't simply what was applied. It is how well the plant was able to keep functioning through the conditions it encountered.

PROTECT THE FACTORY

If leaves are producing much of the plant's energy, protecting healthy leaf area matters.

Walk the field and look beyond whether the plants are simply green.

- Is the canopy uniform?
- Are leaves maintaining good condition?
- Are plants showing early signs of nutrient stress?
- Are certain areas of the field beginning to lose color before others?
- Has disease or insect damage reduced productive leaf area?
- Is the crop recovering after a weather event, or does it continue to struggle?

Those observations can give you clues about how well the plant's energy-producing system is holding up.

This is particularly important during reproduction and grain fill, when maintaining photosynthetic activity can have a major impact on how much yield potential the crop is able to carry through to harvest.

NUTRITION STILL MATTERS - BUT SO DOES TIMING

This is another place where the stages of the Cycle connect.

Part 2 was about getting nutrients to the plant. Part 3 was about using those nutrients within plant metabolism. Now, in Part 4, we can see why maintaining that nutrition throughout the season matters.

A deficiency at a critical growth stage can affect more than appearance.

Potassium is involved in water regulation and nutrient movement. Sulfur supports chlorophyll formation, protein production and photosynthesis. Boron becomes especially important as the crop moves into reproduction.

The plant's needs change as its job changes.

That is one reason in-season fertility and sidedress management can be valuable. The objective isn't simply to apply more fertilizer. It is to support the crop when demand increases and conditions indicate that additional support may be useful.

The question remains the same: *What is the crop trying to accomplish right now, and does it have what it needs to keep doing it?*

YOU CAN'T STORE A WHOLE SEASON'S SUNLIGHT IN ADVANCE

Fertility can be planned months ahead. Sunlight can't. Additionally, neither can rainfall, heat, disease pressure or many of the other conditions a crop will encounter during the season.

The plant has to keep producing energy day after day.

That makes season-long crop health important. An excellent start matters, but the crop still has to function in June, July and August. It has to continue capturing sunlight and producing carbohydrates as its demands increase.

Energy / continued

There is no single application that can guarantee that.

Instead, the goal is to keep as many parts of the system working together as possible: healthy roots, adequate water, available nutrients, productive leaf area and timely management when conditions change.

LOOK FOR ENERGY PROBLEMS BEFORE THEY BECOME YIELD PROBLEMS

We cannot stand in a field and directly see a plant's energy reserves. But we can watch how the crop is performing.

Compare strong areas of the field with weaker ones. Look for differences in canopy development, leaf condition and root growth. Pay attention to how quickly plants recover following heat, drought or excess moisture.

As reproduction begins, watch whether the crop continues to maintain healthy leaf area and steady growth.

And when something doesn't look right, don't automatically assume the answer is simply more fertilizer.

Ask what might be interfering with the plant's ability to capture or use energy.

- Is the root system struggling?
- Is water limiting?
- Is the crop under nutritional stress?
- Has leaf area been damaged?
- Is compaction affecting part of the field?

Those questions can lead to a much better diagnosis than treating every problem as an input shortage.

ENERGY IS AN OUTCOME

This may be the most important point in Part 4.

You don't apply plant energy out of a jug. You create the conditions that allow the plant to produce it.

Healthy soil biology helps cycle nutrients. Available nutrients support plant metabolism. Strong metabolism helps the crop photosynthesize efficiently. Healthy leaf tissue keeps capturing sunlight. Good roots help supply the water and nutrition needed to keep that process moving.

Energy is the result of the system working well.

And the better that system works, the more energy the plant has available for everything that comes next.

WHERE DOES THE PLANT SPEND THAT ENERGY?

That question takes us directly to the next stage of the AgriEnergy Cycle.

The plant doesn't produce energy simply to store it.

It invests that energy.

Some goes above ground into new leaves, stems, flowers and reproductive development. Some goes below ground into an expanding root system. And as the plant gets larger, those growing roots gain access to more water, more nutrients and more soil.

Energy becomes growth.

05 PLANT & ROOT GROWTH

MORE ROOTS, MORE OPPORTUNITY



Plants don't produce energy just to have it. **They put it to work.**

Some of that energy goes into building leaves, stems and reproductive tissue above ground. A significant portion also goes below ground, building and maintaining the root system that supplies the plant with water and nutrients.

That brings us to the fifth stage of the AgriEnergy Cycle: Plant & Root Growth.

And when it comes to roots, one idea matters more than almost anything else:

> **More healthy roots mean more opportunity.**

ROOTS DO MUCH MORE THAN HOLD THE PLANT UP

We don't see roots when we drive past a field, so it is easy to focus most of our attention on what is happening above ground.

But the crop above the soil depends heavily on what is happening below it.

Roots explore the soil looking for water and nutrients. As the root system expands, the plant gains access to a larger volume of soil. More soil explored means more opportunities to encounter moisture and available fertility.

A small, restricted root system has fewer options.

A larger, healthier root system gives the plant more places to look.

That becomes especially important when growing conditions are less than ideal.

MORE ROOTS MEAN MORE SOIL TO EXPLORE

Imagine two plants growing side by side: one develops a deep, well-branched root system that spreads throughout the soil profile. The other encounters compaction and develops a smaller root system concentrated near the surface.

Even if both plants are growing in soil with similar fertility, they do not have equal access to it.

The plant with the larger root system is exploring more soil. It has access to a larger reservoir of water and more opportunities to intercept nutrients.

The restricted plant is trying to support itself from a much smaller area.

This is why we have emphasized throughout the AgriEnergy Cycle that nutrient availability and nutrient access are not the same thing.

The fertilizer can be there.

The roots still have to reach it.

ROOT GROWTH DEPENDS ON THE ENVIRONMENT

Roots will grow where the soil allows them to grow.

When soil has good structure and adequate pore space, roots have pathways to move through the profile. When soil becomes dense and compacted, those pathways become harder to find.

That can lead roots to turn sideways, follow cracks or remain concentrated in shallower portions of the soil.

AgriEnergy has seen this difference clearly in field work. In replicated corn plots at North Carolina State University, plants from treated areas showed roots moving more directly through compacted soil while untreated roots were much more irregular and restricted.

The lesson is bigger than any individual treatment.

Roots perform best when we give them an environment they can explore.

COMPACTION SHRINKS THE PLANT'S WORLD

Compaction doesn't simply make the soil harder. It effectively makes the plant's usable world smaller.

When roots cannot penetrate a dense layer, the crop loses access to some of the water and fertility below or beyond that restriction. Reduced pore space can also limit oxygen and slow water movement through the profile.

That is why soil compaction can create problems that look like fertility or water issues above ground.

A crop may be sitting above nutrients it cannot reach.

It may have moisture deeper in the profile that its roots cannot access.

SOURCE From the Field: Roots That Refuse to Struggle
https://agrienergysolutions.com/groundwork/roots-that-refuse-to-struggle

Plant & Root Growth / continued

And when dry conditions arrive, the difference between a shallow root system and a deeper one can become much more important.

The goal isn't simply to grow more roots.

It is to help the crop build roots where they can do useful work.

DON'T FORGET ABOUT NEW ROOTS

A root system is not something the plant builds early and then simply carries for the rest of the season.

Roots continue to grow and change as the crop develops.

That matters because nutrient and water demand can increase dramatically as the plant gets larger. AgriEnergy has long emphasized that maintaining new, healthy root tissue through the season is important as crop demand rises.

A crop entering reproduction has a much larger job than a young seedling.

It needs to support the plant above ground while continuing to supply water and nutrients during a period when reproductive demand may be increasing quickly.

That means root health matters well beyond emergence.

BIGGER ABOVE GROUND REQUIRES SUPPORT BELOW GROUND

We often celebrate rapid vegetative growth. And for good reason. Healthy leaf area gives the plant more capacity to capture sunlight and produce energy.

But as the crop gets larger above ground, the demand placed on the root system increases too.

More leaf area means more water moving through the plant. More plant tissue requires more nutrition. Reproductive growth adds another major demand; and that creates an important balance.

The plant above ground can only perform as well as the system below ground can support it.

This is why strong plant growth and strong root growth shouldn't be thought of as competing goals.

They have to develop together.

WHAT SHOULD YOU LOOK FOR?

This is one of the easiest stages of the AgriEnergy Cycle to investigate yourself.

Dig some plants. Don't just pull them from the ground. Use a shovel and take enough soil with the plant that you can see how the roots are actually growing.

- Look at depth. Are roots moving downward through the profile?
- Look at spread. Are they exploring soil in multiple directions?
- Look for restrictions. Do roots suddenly turn sideways at a particular depth?
- Compare good areas of the field with weaker ones.
- And pay attention to the soil around the roots. Is it loose and aggregated, or dense and difficult to break apart?

You do not need a laboratory to see when one plant has access to considerably more soil than another.

Sometimes the difference is sitting right there on the shovel.

DON'T JUDGE THE ROOT SYSTEM FROM THE TOP

A healthy-looking plant above ground can sometimes hide limitations below it.

Adequate rainfall may allow a shallow-rooted crop to look perfectly good early in the season. But if conditions turn dry later, that limited root system may suddenly become a much bigger problem.

The same can happen with fertility.

When nutrients are readily available near the surface, restricted rooting may not immediately show itself. As demand grows or surface conditions change, the plant may no longer have enough reach to keep up.

That is one reason digging plants throughout the season can be so useful.

Don't wait until a problem becomes visible from the road.

Look underneath.

BUILD THE OPPORTUNITY BEFORE THE CROP NEEDS IT

One of the challenges with roots is that you cannot suddenly build a deep, healthy root system the day drought arrives.

The opportunity has to be created earlier.

Good soil structure, active biology, available nutrition and proper moisture conditions all help create an environment where roots can continue exploring.

That takes us back through the earlier stages of the AgriEnergy Cycle.

- Soil Biology helps build the environment.
- Soil Nutrients provide the materials.
- Plant Metabolism puts those nutrients to work.
- Energy gives the plant the ability to grow.
- And Plant & Root Growth expands the crop's reach.

Each stage makes the next one possible.

THE BIGGER THE ROOT SYSTEM, THE BIGGER THE CONNECTION

There is one more reason root growth matters in the AgriEnergy Cycle.

Roots aren't simply taking from the soil.

They are also giving something back.

As roots grow and become more active, they release sugars and other compounds into the soil surrounding them. Those materials help support the microorganisms living around the root.

That means a larger, healthier root system creates something more than access to water and nutrients.

It creates a larger area where the plant and soil biology can interact. And that takes us to the final stage of the AgriEnergy Cycle: Root Exudates.

06 ROOT EXUDATES

WHAT THE PLANT GIVES BACK



Roots aren't only taking from the soil. They are giving something back.

As a healthy plant captures sunlight and produces carbohydrates, some of that energy moves below ground through the roots. The plant releases natural sugars and other compounds into the soil surrounding those roots.

These are root exudates, the sixth and final stage of the AgriEnergy Cycle.

And this is where the Cycle finally comes back to where we started.

WHAT ARE ROOT EXUDATES?

Root exudates are compounds released by living roots into the soil immediately around them. They include sugars, amino acids, organic acids and other materials produced by the plant.

For our purposes, the important part is simpler than the chemistry.

> **Root Exudates are food for biology.**

The plant captures energy above ground through photosynthesis, moves some of that energy below ground and releases carbon-rich compounds around its roots. Microorganisms living in that area can use those compounds as a food source.

That makes roots much more than pipes bringing water and nutrients into the plant.

They are also a connection between the plant and the biological community around it.

THE BUSY AREA AROUND THE ROOT

The soil immediately surrounding an active root is often referred to as the rhizosphere.

That sounds technical, but the concept is pretty straightforward: where you have actively growing roots, you have an area where the plant and soil biology are interacting very closely.

The plant releases compounds from its roots. Microorganisms use those compounds. Biological activity helps cycle nutrients in the root zone. Those nutrients can then become available to the plant.

AgriEnergy has talked about this root-zone exchange for years. In our Pore Space & Tilth work, active rhizospheres, good pore space, healthy roots and biologically created aggregates were all visible signs of a soil system functioning well.

The root isn't operating by itself. Neither is the biology. They are working in the same space.

HEALTHY PLANTS CAN FEED THE SOIL BETTER

This is where the earlier stages of the Cycle begin to matter again.

A plant needs available nutrients to support metabolism. It needs healthy leaf tissue to capture sunlight. It needs energy to build roots and above-ground growth. And it needs an active root system to create a strong connection with the soil around it.

When those pieces are working well, a healthier plant has more capacity to produce carbohydrates and send some of that energy below ground.

That gives us another way to think about crop health.

We're not only trying to grow a plant that can take more from the soil.

We're trying to grow a plant capable of putting more back into the system.

That is one of the central ideas behind the AgriEnergy Cycle.

MORE ROOTS CREATE MORE CONNECTION

Part 5 focused on why a larger, healthier root system gives the crop more opportunity to explore the soil. But, there is another side to that.

More healthy root growth also creates more contact between the plant and the soil biology surrounding those roots.

Every new section of active root expands the area where that exchange can happen. The plant has more opportunity to access water and nutrients, while the biological community has more opportunity to interact with compounds released by the root.

This is why root development and root exudates fit next to one another in the Cycle.

The plant invests energy into roots. Those roots expand through the soil.

And those active roots begin feeding energy back into the biological system.

SOURCE Pore Space & Tilth - Part 2
https://agrienergysolutions.com/groundwork/pore-space-and-tilth-part-2

BIOLOGY HAS TO BE THERE TO RECEIVE IT

Of course, releasing root exudates is only part of the story.

There needs to be an active biological community around the roots capable of using them.

We started this cycle by talking about the importance of creating an environment where biology can function: adequate air and moisture, good soil structure, available carbon and room for roots to grow.

Now we can see another reason those conditions matter.

A healthy plant may be supplying food below ground, but the soil environment still needs to support the organisms we're asking to use it.



Soil clings to the branching roots of this field-dug corn plant.

Once again, the answer isn't one isolated product or application.

> **It is the system.**

EXUDATES AND RESIDUE AREN'T THE SAME THING

There are several ways plants return carbon to the soil, and it is useful to separate them.

Crop residue is the material left behind — stalks, leaves, husks and roots that biology can begin processing and recycling. We've talked extensively about residue management and the nutrients contained in that material.

Root exudates are different because this exchange is happening while the plant is alive and actively growing. The living root is continually interacting with the soil around it. That gives us two important pathways:

During the growing season, active roots feed biology around the root zone.

Afterward, roots and above-ground residue become additional material for biology to process. The crop continues contributing to the soil system even as the form of that contribution changes.

YOU CAN'T SEE THE SUGAR — BUT YOU CAN LOOK AT THE SYSTEM



Root exudates aren't something you're going to walk into the field and see with your eyes. But there are plenty of things you can observe around them.

Dig some plants and look at the roots. Are they white and actively growing? Are they branching and exploring the soil, or are they restricted? Look at the soil around those roots. Is there good aggregation and pore space? Does the soil crumble apart, or does it come out in dense blocks?

Look at the crop above ground. Is it maintaining healthy leaf area and continuing to grow, or is stress limiting the system?

And compare different areas of the field. Some of the most useful information can come from putting a strong plant and a struggling plant side by side and asking what is different below ground.

You may not be able to see root exudates directly, but you can evaluate the plant and soil system responsible for producing and using them.

DON'T TRY TO MANAGE THE LAST STAGE BY ITSELF

This may be the most important lesson of this stage.

If you want more of the benefits associated with healthy root activity and root exudates, you don't simply jump to the last stage of the Cycle. **You work on the stages that lead to it.**

- Support soil biology.
- Make nutrients available.
- Build balanced plant nutrition.
- Keep the plant functioning.
- Protect its ability to produce energy.
- Encourage strong plant and root growth.

When those pieces are working together, the final stage becomes a natural result of everything that came before it.

That's what makes the AgriEnergy Cycle different from thinking about crop management as a series of unrelated inputs.

Each stage creates the opportunity for the next one.

AND WE'RE BACK TO SOIL BIOLOGY



Six stages ago, we started beneath our feet.

Soil Biology helps break down organic material and cycle nutrients.

Those Soil Nutrients become available to the plant.

Plant Metabolism puts those nutrients to work.

Healthy metabolism helps the plant produce Energy.

That energy drives Plant & Root Growth.

And those growing roots release Root Exudates that feed biology back in the soil. **Then it starts again.**

1. Soil Biology
2. Soil Nutrients
3. Plant Metabolism
4. Energy
5. Plant & Root Growth
6. Root Exudates

That is why we call it a Cycle. There really isn't a beginning or an end.

BUILD THE NEXT CROP WHILE GROWING THIS ONE

When we introduced the AgriEnergy Cycle, we used a simple idea:

> **Better soil builds better plants, and better plants build better soil.**

Root exudates show us exactly how literal that relationship can be.

The soil helps support the crop. The crop captures energy. The plant sends some of that energy back below ground. That helps support the biology responsible for cycling nutrients and building the soil environment that the crop — and the crop that follows it — will depend on.

The goal isn't just to take enough from a field to produce this year's crop. It is to manage the crop and soil in a way that keeps the system moving.

Because a healthy plant isn't only the result of healthier soil.

It can become part of building healthier soil, too.

And that closes the AgriEnergy Cycle.



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