

Note from the author, Pete Vegas a PAPSAC member. Rick Clark (a farmer spokesperson, who is in attendance) says he has never seen any group agree on the definition of regenerative agriculture. I do not attempt to define the term. Practices are so different for each type of crop that I don't see how it can be defined. I have personally focused my attention on large scale row crop farming where I believe regenerative ag can create the biggest impact. About 70% of farmland worldwide is grazing land, and I do not have the expertise to give that section of this primer the attention it deserves. PAPSAC operates under Chatham House Rules. This document is not part of that, nor is it owned by Harvard. If you believe it to be useful to others, feel free to pass it around.

Contents:

Introduction & Photos	2
Photosynthesis and the Development of our Environment.	9
Regenerative Agriculture on Grazing land.	11
Regenerative Agriculture with Row Crop Farming.	13
Mitigation of Climate Change, Soil Health, Water Loss and Damage caused by chemicals and Fertilizers.	16
Organic versus Regenerative.	21
History and Status of the Regenerative Movement.	23

Introduction to Regenerative Agriculture.

It took the earth's resources of nature and photosynthesis over 4 billion years to develop the balance of nature and fertile soils we had only a few hundred years ago. Regenerative Agriculture is about restoring those soils to their natural state. Regenerative Agriculture has become of interest to the public because of its ability to sequester carbon in the ground, and in doing so, fight climate change. It is becoming of interest to farmers because of its potential to restore the health of depleted soils and improve profitability by reducing inputs.

In simple terms, regenerative agriculture is about improving soil health by increasing the carbon content and restoring a healthy microbiome. In the case of row crops, cover crops are grown in the off season so that something green is always growing on the land. The roots and residues from the year-round growth are sequestering carbon in the ground in the form of organic matter. The land is farmed without tillage, so the carbon remains in the ground. Less fertilizers and chemicals are used so that along with the feed from the roots and residue of the cover crops, the microbiome in the soil is allowed to flourish.

Below are photos of various cover crops and regenerative farming practices, so the narrative can be better understood:



Spring results of various grasses (rye, oats, & barley) grown in the fall in California as a cover crop. Imagine an equal amount of organic matter under the ground in the form of roots.



Spring results of a winter cover crop in Northern California. Some grasses, but also legumes, brassicas, and forbs all planted in the fall.

Note the herd of sheep in the background that terminated this in hours leaving their manure so this field could be ready for the next crop to be planted.



A winter grown crop of 8 different species on a farm financed by Pete Vegas in Louisiana and managed by his nephew Braxton. Various grass varieties, legumes, and brassicas. This was taken in April, and the field was almost ready to be planted.



Adam Chappell in his field of winter grown cover crop of Florida rye, barley, and radish in Arkansas on June 3 of this year. This field was to be planted that same day (a late planting) with soybeans directly into this standing rye. He was not planning to roller crimp or terminate the cover crop, the cover crop had matured, and he just let it fall to the ground on its own.



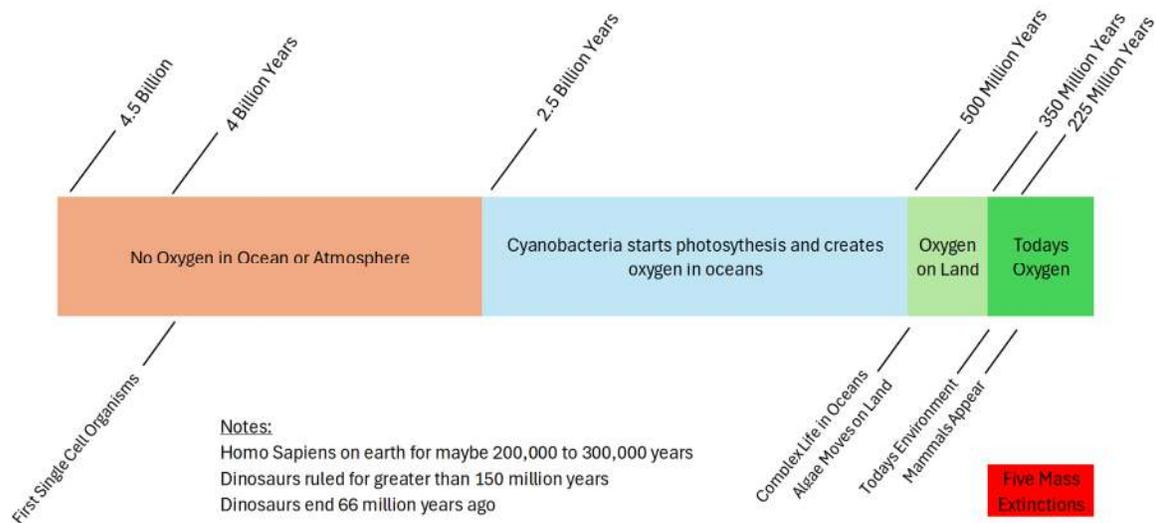
Same Adam Chappel field in Cotton Plant Arkansas on Aug 13. Note the straw on the ground. At this point the beans have overlapped and are shading out weeds.



Large scale regenerative farming. Soybeans were planted into a standing cover crop of primarily rye grass. Two weeks later when this photo was taken and the soybeans were about 6 inches tall the rye grass is being terminated (knocked down and the stem broken after flowering, but before seeds are fully formed, with a roller crimper. The cover crop will not grow back and will provide a straw mat on the ground. The soybeans are supple enough to survive the roller crimper and will grow back through the straw mat.

Photosynthesis and the Development of our Environment.

Four and a half billion years ago the young earth was covered in water with volcanoes spewing out caustic gases. There was no available oxygen in the water or air for life. The first life to develop was anaerobic. After 2.5 billion years, cyanobacteria (blue green algae) started using photosynthesis to release some oxygen in the oceans. Eventually cyanobacteria and other forms of plankton created enough oxygen for primitive life forms to develop in the oceans. After 4 million years (500 million years from today), lichens then moss and ferns moved on land. Their roots and the microbiome that developed to feed on them broke up rocks to form soils that eventually allowed grasses, plants, and trees to grow. Photosynthesis removed carbon from the atmosphere and sequestered it in plants and soils. Oxygen levels increased and finally about 350 million years from today enough oxygen existed in the atmosphere to sustain the type of life that we have today.



Organic Carbon Cycle

Photosynthesis

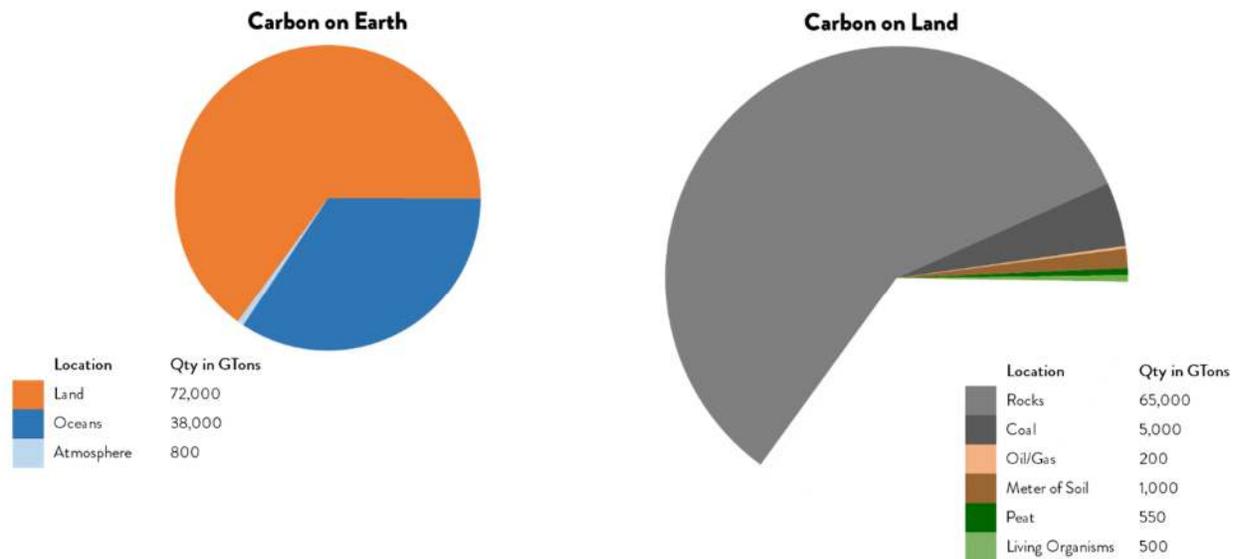
$6\text{CO}_2 + 6\text{H}_2\text{O} > \text{energy absorbed} > \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
 carbon dioxide and water > yields > glucose and Oxygen

Respiration

$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 > \text{energy released} > 6\text{CO}_2 + 6\text{H}_2\text{O}$
 glucose and oxygen > yields > Carbon dioxide and water

All organic matter: trees, scrubs, plants, grasses, their roots, animals, insects, other microorganisms, along with bacteria and fungi are about 50 percent carbon on a dry basis. Forests and grasslands left undisturbed were retaining carbon in their structures above ground and constantly increasing the amount of organic matter in the soil with their roots. There are several complex carbon cycles on earth. But what is often called the biological carbon cycle, or organic carbon cycle (utilizing photosynthesis), if left alone, stores carbon on and under the earth's surface and generates oxygen for the atmosphere.

Pie Chart of carbon in the earth²



Source: The Global Carbon Cycle by David Archer, Princeton Primers in Climate.

Source: The Global Carbon Cycle by David Archer, Princeton Primers in Climate.

Note: Regenerative Agriculture can move carbon from the atmosphere into Living Organisms & First Meter of Soil.

Regenerative Agriculture on Grazing land.

Globally about 70% of farmland is grazing land, with the remaining portion being crop land. Overgrazing and current livestock practices are causing desertification at an alarming rate. Most grazing land has been degraded to some extent and, as per the United Nations Convention to Combat Desertification, as much as 20 to 25 percent have been degraded to some degree of desertification.

The spread of man and agriculture has removed 30 to 40 percent of the earth forests and modern farming practices have reduced organic matter and damaged the microbiome in crop land. The tall grasslands of the Midwest and the great plains of the United States once held United States once held 6 to 12 percent organic matter in their topsoil. Most estimates show the US losing at least 50 percent of its organic matter due to modern farming practices.

In 2013 Alan Savory, a native of Zimbabwe, in what is now a famous Ted Talk, “*How to fight desertification and reverse climate change*”, introduced the world to his version of holistic planned grazing. His basic concept was that modern practices of leaving animals permanently located on grazing land, or not grazing at all, were causing desertification and loss of carbon in the soil. Nature’s way of moving large herds of migrating animals bunched in large groups across the grasslands of Africa, or large migrating Bison herds in the US were much better for the land. Intense grazing for short periods of time, stomping grass into the ground, leaving manure and urine, and then quickly moving on and allowing the grass to recover was a much better system and is what allowed those African lands and our Great Plains lands to become so fertile.

These systems are being improved and readily adopted in the US. There is very little initial investment and the payback is quick. The basic concept is that in a typical large ranch with, as an example, one cow per every five acres. That cow will overgraze and cut the grass right down to the ground, stunting the growth of the grass. That cow will also first eat the best and most nutritious plants leaving the poor grasses and plants to take over the competition for expansion.

The new alternative method is to move a dense herd of livestock very quickly from one confined pasture or paddock to another before the grass is completely chewed down to the ground. Leaving 4 to 6 inches of grass is like pruning and causes the grass to respond and grow back fast. The cattle are competing for feed and don’t have time to “cherry pick” the

best types of grass so future populations of various varieties of grass stay intact. The livestock leave manure, saliva, and urine as fertilizer and do not return to that paddock until it has fully recovered. The financial impact is more grass produced per acre and so more beef per acre. The environmental and soil health impact is more carbon per acre buried in the soil.

These practices often called Adaptive Multi-Paddock Grazing, Holistic Planned Grazing, Mob Grazing have recently become modernized. Ranchers put out temporary fencing in the form of single electric wires that the cattle have learned to stay away from. They quickly put out these fences riding around the area in ATVs with a roll of electric wire. More recently cattle are fitted with shock collars and the rancher changes paddocks on his computer. Cattle become accustomed to the systems and quickly move to the next paddock knowing the grass will be greener.

Regenerative Agriculture with Row Crop Farming.

Gabe Brown was probably the first farmer to bring regenerative agriculture to the public's attention. In 1991, He took over his in laws 1760 acres farm in Bismark, North Dakota and started farming conventionally. Weather calamities and financial problems caused him to try something different. His farming techniques and success drew attention to what is now called regenerative farming. 20 years later, he was farming 5000 profitable acres, increased organic matter from 2% to 6%, cutback almost all inputs, and claims to exceed average crop yields in the area by 20 to 25%. He has written books, and put out many YouTube videos, and formed companies to teach and consult with farmers.

No till is not a new concept. Neither are cover crops as they were more widely used in the past. But the concept of growing a cover crop and then not tilling the cover crop into the soil and managing the growth of the microbiome below the soil is new with modern regenerative agriculture.

There is no perfect alignment on exactly what regenerative agriculture is, but below are the basic tenants of regenerative agriculture, with an emphasis on row crop farming:

- Always going something green. Grow cover crops during off season.
- No tillage disturbing the soil. Do not plow under the cover crop.
- Keeping “armor” on the soil. (a mat of straw and plant residue.)
- Multi-Species cover crops and crop rotation to get variety of roots in the soil and break cycles of insects and weeds.
- Creating and managing a diverse microbiome in the soil. A good mix of bacteria, fungi (mycorrhizal fungi), insects, worms and other microorganisms. Actually, farming the soil to feed and maintain a good microbiome.
- Reducing fertilizers and chemicals.
- In many cases, incorporating livestock. (Less likely in large scale row crop farming.)
- Improved profits because of reduced input costs, and often greater yields.

Below is a photo of a first year regen farmer in Nevada. It is a single cover crop of triticale, not ideal for corn long term, but perfect for establishing “armor” or a straw mat on the ground the first year. And perfect for demonstrating the advantages of regenerative farming.



The triticale grass type cover crop was planted after corn was harvested in the fall. It was then knocked down with a roller crimper in the spring and the corn was planted into that straw mat with a planter with coulters and spreaders designed to cut into and plant into thick mats.

Note the following from the above photo:

- The cover crop provided root growth (essentially organic matter) during the off season to provide organic matter and natural fertilizer to the soil and subsequent crops and keep the microbiome fed year-round.
- The triticale absorbed much of the nitrogen fertilizer applied to the previous corn crop that would have leached off after harvest into nearby streams and rivers. As it decomposes, the cover crop will feed the scavenged nitrogen to the next corn crop. (Less than 50% of the nitrogen applied to crops gets absorbed by the crops.)
- That thick straw mat prevents weed growth and reduces the need for herbicides.
- The cover crop and resulting mat prevents water runoff and loss of topsoil with heavy rains. More of the rain percolates into the soil.
- The straw mat shades the ground by as much as 30 degrees in hot days, allowing moisture retention and the microbiome to flourish.
- Eventually with improvement in the organic content and microbiome of the soil, this soil will percolate water much faster in heavy rains and the mat will prevent moisture evaporation. This causes better yields in wet and dry years and more consistent yields over several years.

Mitigation of Climate Change, Soil Health, Water Loss, and Damage caused by Chemicals and Fertilizers.

Climate Change²

There is enough historical data that few people dispute the very tight correlation between CO₂ levels in the atmosphere with temperatures on earth. For the last 500 million years the earth has been in a greenhouse/hot house for about 85% of the time, with temperatures often 20 degrees hotter than today. Things started cooling down about 34 million years ago. Today we are in an interglacial period. It was only about 18,000 years ago that Seattle was 3000 feet under ice.

It has been 3 million years since the CO₂ levels spiked for a short period of time to reach **today's level of over 400ppm**. It has been 14 million years ago since CO₂ levels were consistently over 400 ppm. If CO₂ levels hit 1000 ppm as is often predicted by the turn of the century, we will be going back 35 million years in time.

The earth with its many carbon cycles does have a way of somewhat regulating itself, and it does change temperature over time without man's influence, but in the last 800,000 years, CO₂ levels exceeded 300 PPM only once. For the last 12,000 years CO₂ levels were very stable at 280 PPM, varying only about 20 PPM. That changed with the industrial revolution, when CO₂ started climbing steadily around the year 1750 and accelerated around 1960.

We all know that man has disrupted the balance by releasing plant stored carbon in the way of released fossil fuels and burnt forests. But you may not know that farming practices in our recent history have released a tremendous amount of CO₂. About 25% to 40% of the increase in carbon in the air today came from our soils. Plowing or tilling the soil turns over organic matter and causes it to be released into the air. Applying chemicals and fertilizers kill the natural microbiome below the soil that help store carbon. We have depleted well over ½ of the carbon that was once stored in the soil.

Will there ever be a better way to pull carbon out of the atmosphere and sequester it than increasing organic matter in our soils with regenerative agriculture? Take Gabe Brown's example (which I grant is exceptional) of adding 4% organic matter (about 2% carbon) to

the soil. If we could do that on the top 18 inches of soil in the 350,000,000 acres of US cropland, that would amount to 24 gigatons (Gtons) removed from the atmosphere.

Note:

- Annual emissions from fossil fuels are about 10 Gton per year.
- Total carbon in the atmosphere is around 800 Gtons.
- There are 3.7 billion acres of cropland worldwide.
- There are 8.6 billion acres of grazing land worldwide.

So imagine if regenerative practices went worldwide even on a lesser scale of organic matter buildup.

(The math if interested.)

Assume 100 lbs per square ft of soil and Carbon for organic matter at 58%

350,000,000 acres x 43,560 cubic feet per acres x 1.5 feet x 100lb per ft x .04 organic matter x .58 carbon x .453592 lb to kilos converted to gigatons of carbon.)

Soil Health

Modern farm practices have severely damaged soil health, reduced organic matter and damaged the microbiome, essentially life in the soil. About 95 percent of cropland in the United States is bare in the winter. Most farmland is monocropped or rarely rotated. Tillage exposes organic matter to oxygen and respiration releases its carbon to the atmosphere. Chemicals (pesticides, herbicides, fungicides, etc.) kill the microbiome in the soil that convert organic matter and minerals into usable nutrients. Our soils today provide less nutritious food and require increasing amounts of fertilizer as organic matter is depleted. History is full of civilizations that disappeared after depleting their soils and food sources.

A healthy soil is not compact. The combination of organic matter and a healthy microbiome, including a healthy percentage of mycorrhizal fungi, creates an agglomerated structure. This structure is often described as cottage cheese like. It is easy to push a shovel into, and most importantly water penetrates and percolates through the soil quickly. When you pull roots out of healthy globs of soil cling to the roots.

Degraded or compacted soil will cause a one-half inch of rain received in an hour to pool on the surface and then run off carrying topsoil with it. Healthy soil can percolate as much as 3-to-6-inches of rain in an hour without runoff. Besides runoff removing topsoil, addition water absorbed into the soil provides needed moisture when the rains stop.

Besides a high percentage of organic matter, healthy soil has a healthy microbiome. A healthy mix of bacteria that can break down minerals into nutrients and provide sources of key nutrients like nitrogen. Beneficial bacteria, insects, and microorganisms that can fight off diseases and insect pests. Healthy soil has a high percentage of fungi, (mycorrhizal fungi in particular) that form a large web in the ground delivering moisture and nutrients to the plants. High worm populations are a good sign of a healthy soil. The microbiome lives off the extrudates of the plants, decomposing organic matter and minerals, still in the form of rocks, to provide nutrients to the plants.

Water Loss²

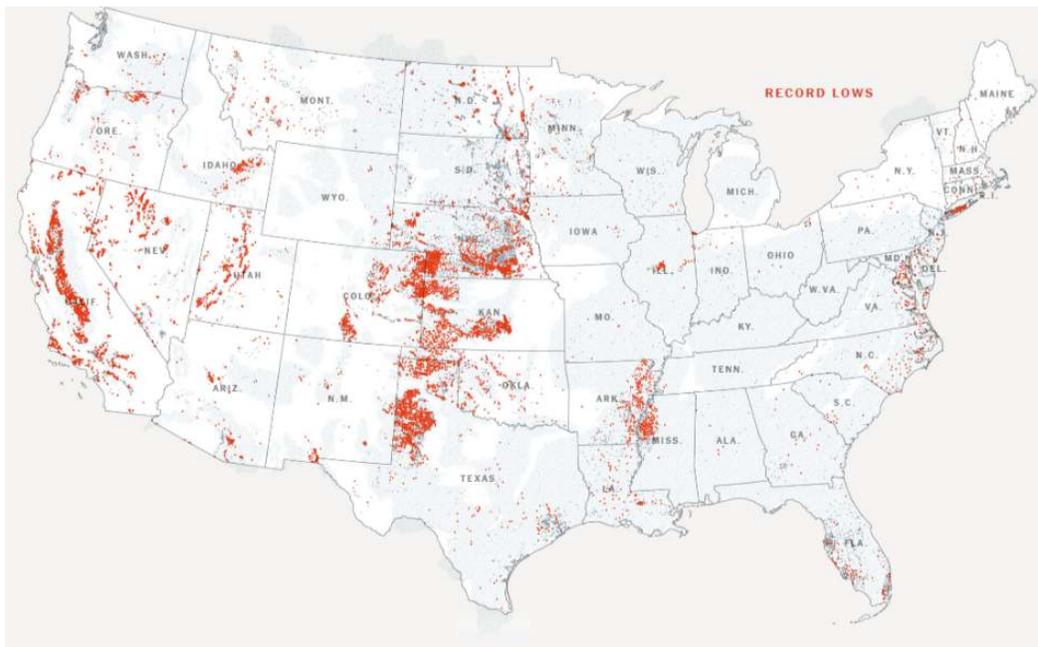
The following chart published by the New York times a year or so tells the story. And it is a simple one.

In our quest for higher yields, we are draining our water aquifers with irrigation systems, and it would take thousands of years to replenish these water levels, if we could.

Modern farm practices are causing this. Depleted and compacted soils lose too much natural rainfall to consistently produce good crops. And so, we irrigate. And just as with rainfall, much of that water does not percolate into the soil and is lost to runoff. Carrying farm chemicals and fertilizers into our streams and rivers, eventually the ocean. We have created a nasty cycle. Irrigate more and more as we lose more and more to runoff and evaporation.

There is a similar nasty cycle occurring with lands heading towards desertification. Plant respiration can cause rainfall. The less the vegetation, the less the rainfall.

Aquifers with Record Low Levels



Source: New York Times Article: "America is Using Up It's Groundwater Like There's No Tomorrow", August 28, 2023

Chemical and Fertilizer Overuse?

This is a subject matter that is just far too big and complex for me to cover in this document, and I am far from an expert. We all know that populations of bees and insects have been drastically reduced in the last 40 years. Chemicals and nitrogen fertilizer runoff have contaminated lakes, rivers and streams and have caused dead zones in the oceans. Reefs are dying and along with them the fish populations that live off the reefs. I believe human health is being affected.

Actual chemical use has declined somewhat since the peak in the 1980's and the chemical companies take credit for that with their genetically modified crops designed to survive chemical applications (like roundup ready soybeans and dicamba resistant soybeans). Crop varieties that allow a solid dose of chemical to kill everything except their resistant varieties. My personal comment is that in my 50 years of involvement in farming, I have never seen so much destruction to nearby trees and plants as in the last 5 years. Plants have become resistant to the old chemicals like roundup, and so the new chemicals, like dicamba, are much more lethal and because some volatilize and drift, they can cause plant damage as far as a mile away from the application zone.

Regenerative has the potential to cut chemical and fertilizer use by at least 50%

Organic versus Regenerative.

Organic is often thought of better for the environment than regenerative. But that is not often the case. Large scale organic farms use tillage to control weeds. Cover crops are rarely grown. Soil health and all the benefits (like carbon sequestration) that come with regenerative do not necessarily come with organic.

Purpose:

Organic. Provide safe and pesticide free food for human consumption. Eliminate chemicals in the environment.

Regenerative. Improve soil health. Sequester carbon.

Chemical and Fertilizer requirements:

Organic. No chemicals or fertilizers that are not natural. Chicken manure is about the best source of nitrogen but delivers far less than urea or anhydrous ammonia. No GMO crops are allowed.

Regenerative. No restrictions on chemicals or fertilizers, but best practices should reduce usage by over 50%. No restrictions on GMO.s

Yields:

Organic. Very dependent on type of crop, agronomic conditions, labor input, and scale. But for nitrogen needy large-scale crops like rice, corn, cotton my experience is a yield of about 60%.

Regenerative Highly dependent on agronomic conditions, yields can be higher on non-irrigated lands. Legumes like soybeans that provide their own nitrogen can have higher yields. With nitrogen needy crops like corn and cotton, yields will be dependent on how much nitrogen is applied. But in general, regenerative farmers may find the financial return sweet spot is with a slightly reduced yield, but a significant reduction in inputs.

Startup Costs:

Organic. Three years of no chemicals or unapproved fertilizers being applied before an organic crop can be grown. That means at least 2 crops sold at conventional prices, but with lower yields due to issues affecting organic production. On expensive land this is often prohibitive.

Regenerative.

Potentially reduced yields and revenue if the input/yield balance is not managed correctly for the first couple of years. A cover crop should be the biggest new expense, and that might cost \$45 per acre. Versus soybean revenue of roughly \$600 per acre, or corn at \$800 per acre to put that into perspective. Overall equipment needs are less, but regenerative

farming might require some specialized equipment like a roller crimper or modifications to the plant to plant through thick mats.

Environmental Issues?

Organic. No chemicals applied to the environment. Possible improved health and water infiltration.

Regenerative. Carbon Sequestration. Water infiltration. Improved soil health, and reduction in chemicals.

Pricing?

Organic. Usually in the range (to the farmer) of 50% to 100% more than conventional.

Regenerative. Currently, conventional pricing.

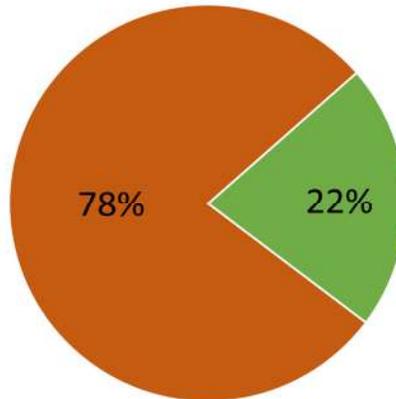
Scalability? (please see chart below)

Organic. Market is usually limited to a percentage of the direct human market. (Exceptions being feed grown for organic meat producers or eggs as an example.) Reduced yields make it impossible to supply growing population demands.

Regenerative. Unlimited scalability.

Not for Human Consumption

Type	Million Acres
Corn	92
Soy	86
Hay	50
Cotton	12
Sorghum/Rye/Barley	9
Canola/Peanuts	5
TOTAL	254



Type	Million Acres
Wheat	47
Specialty Grains	15.5
Pulses	4
Rice	3
Potatoes	1
TOTAL	70.5

History and Status of the Regenerative Movement.

No till farming, which is a precursor to regenerative farming, goes back to the 60's and became more common in the 80's. Gabe Brown and Ray Archuleta (a former USDA agronomist) started bringing the concept of soil health and regenerative farming to farmer attention in the mid 1990's. Since then, other successful large-scale farmers like Rick Clark and Adam Chappel (who are both in attendance in our PAPSAC meeting) have helped educate other farmers and provided content for YouTube. Numerous meetings have sprung up around the country to educate farmers and discuss farming methods. YouTube is now full of short films and instructional information. (just search YouTube for “planting soybeans into standing rye” and see how many videos come up)² **It is important to understand that this is a farmer-led revolution**² As there are little potential profits to be made by the large ag chemical companies (Syngenta, Bayer, BASF, etc) selling inputs into regenerative ag.

Gabe Brown's book, dirt to soil came out in 2018. The movie “The Biggest Little Farm” also came out in 2018. The movie/documentary “Kiss the ground” came out in 2020. And so a small portion of the mainstream population started getting some exposure to regenerative agriculture. Many other movie/documentaries have since come out.

The USDA implemented several programs to provide some assistance with farmers growing cover crops and implementing environmental programs. Some of these programs were recently cut back. Efforts have been made to provide farmers with some revenue from carbon credits. There has been a movement to provide a market at higher prices for regeneratively farmed products. There have been attempts to create regenerative labels, similar to how the organic labeling developed, but a description of what constitutes regenerative is difficult, maybe impossible. Many of the large food companies have programs to incentivize regenerative farmers. But in reality, so far, few of these efforts have brought any financial benefits to farmers.

There are several nonprofits assisting the regen ag movement. The Rodale Institute, Ecdysis Foundation with its 1000 farm initiative, The Carbon Underground, Mad Ag, Farmer Footprint, and Soil Health Institute are examples.

Along with VC firms focusing on regenerative agriculture, there are several for profit companies that have funded and entered space. Probably the best known is Indigo Ag having raised well over one billion dollars. Indigo Ag seems to focus on inoculants

(feeding the soil with beneficial bacteria and fungi) and trading carbon credits. Many others are focusing on inoculants. Some of the larger ones are Pivot Bio, Living Water Agriculture, Agricen, Groundwork BioAg, Loam Bio. Some are providing soil and microbiome analytical services. Other companies are attempting to provide consulting and startup financing services. Some attempting to market products under a regenerative label. Examples of other for-profit companies are Mad Ag., Vayda (recently went broke.) and Understanding Ag. The Soil Health Academy charges for 3 to 4 days on farm teaching programs. And of course, the big ag chemical companies (Bayer, BASF, & Syngenta) are doing some work in the area.

There will be some big shakeouts in the for-profit companies before the market opportunities in regenerative agriculture will be fully understood. There will be opportunities with precision ag to reduce inputs. The Regenerative Agricultural movement is gaining momentum, but I note, when you closely follow the movement, and hear the noise from farms illegitimately claiming to be regenerative, it can seem the movement is quite big but, in reality, only about 5 percent of the US farmland grows cover crops and most of those are plowed under.