

FREE REPORT

Designing an Integrated Agri-Hub: Energy, Food, Water, Soil and Waste Working Together

A practical planning guide for turning separate farm activities into one connected, place-based system.

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Funding Regeneration | fundingregeneration.earth | Educational resource, November 2026

Who this report is for

This report is for people in the United States and Canada who manage land or plan for rural places. That includes farmers and ranchers, landowners, tribal and First Nations natural resource and planning staff, county and municipal planners, conservation district and conservation authority staff, and community leaders who want local food, energy and water systems that support each other.

You do not need an engineering background. This report assumes you know the basics of what an agri-hub is and focuses on design: mapping resource flows, choosing what to connect first, measuring results and finding support. Examples are grouped by bioregion, such as Cascadia (British Columbia, Washington, Oregon) and the Great Lakes basin (Ontario, Quebec and the eight Great Lakes states). Cases from other countries appear as lessons you can adapt, not as templates.

WHAT IS NEW IN THIS EDITION

- **Section 5 (new): microbial tools.** On-site brewing of fermented microbial cultures, Effective Microorganisms (EM) and Johnson-Su compost bioreactors, with the evidence for and against.
- **Section 7 (new): grey water and reuse.** Produce wash water, livestock and yard runoff, household greywater, and what a Colombian beneficial-microbe water project can and cannot teach North American farms.
- **Section 8 (new): "Do I need a permit for a new pond, well or diversion?"** A US and Canada guide to water rights, wetland rules and who to call first.
- **Permaculture methods** woven through Sections 1, 3, 4 and 6, including food forests and leading examples from North America and abroad.
- **Endnotes with links** for every source, plus a "Watch and read" library of well-viewed videos and free PDFs.

Key findings at a glance

- **An agri-hub is designed around flows, not projects.** The useful question is not "Should we add solar?" but "Where do energy, water, nutrients and materials already move here, and where are they being lost?"

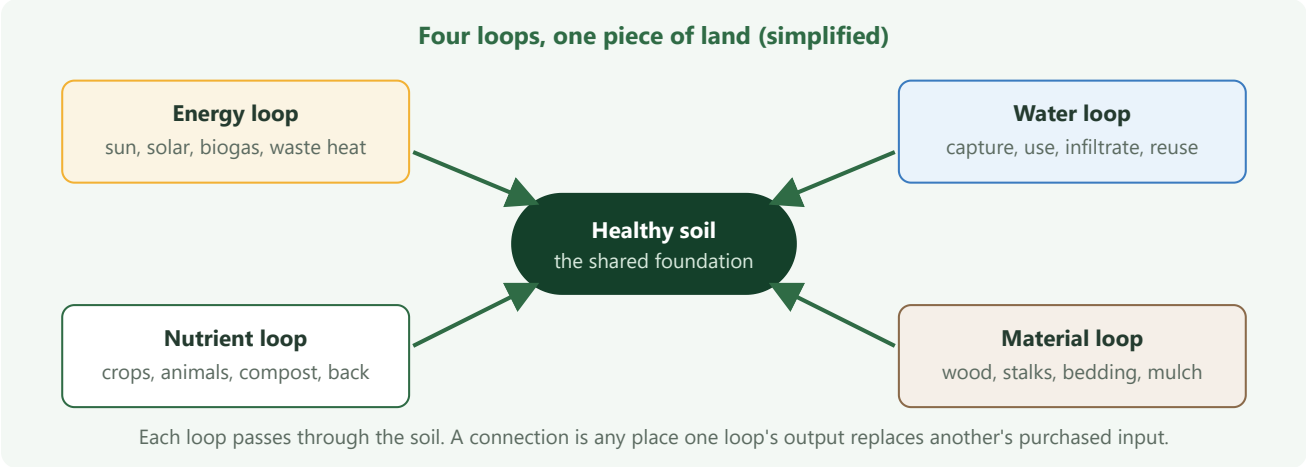
- **Soil is the shared foundation.** USDA NRCS describes four soil health principles: minimize disturbance, maximize soil cover, maximize biodiversity and maximize the presence of living roots.[1] Every other part of the hub works better when these are in place.
- **Gains in soil carbon are real but modest and slow.** A widely cited meta-analysis estimated that cover crops add about 0.32 tonnes of carbon per hectare per year on average.[14] Plan for years, not seasons.
- **Microbes are a tool, not a miracle.** Fermented cultures and fungal-rich compost can cut odor and ammonia and may improve soil biology, but independent field results are mixed.[22, 23, 24] Run your own side-by-side trial before scaling.
- **Wash water is a resource.** Ontario vegetable washers that measured and recycled water cut fresh water use by 50 percent or more, and the most efficient systems ran on about 20 percent of the water of systems that used fresh water at every stage.[35]
- **Perennial food systems take a decade but pay for longer.** Food forests and savanna-style farms in Seattle, Wisconsin and Quebec show what permaculture design can look like at North American scale.[50, 52, 53]
- **Water permits are a common and costly surprise.** A new pond, well or stream diversion can need a state or provincial water right, a federal wetland review and local approvals. Ask before you dig.[42, 43, 46, 47]
- **Funding is available but changes often.** USDA programs such as EQIP and CSP (and REAP, which has no open application window as of November 2026), and Canadian cost-share under the Sustainable Canadian Agricultural Partnership, can support pieces of a hub.[3, 4, 6, 18] Check with local offices every year.



1. The building blocks and how they connect

An integrated agri-hub has five building blocks: food production, renewable energy, water management, soil health and waste recycling. What makes it a hub is not the blocks themselves. It is the connections between them.

A simple way to picture it is four loops running through the same piece of land.



The energy loop. Sunlight grows crops and pasture. Solar panels, wind or biogas from manure can turn part of that energy into electricity or heat. That power runs pumps, cold storage, dryers, greenhouse fans or electric fencing. Waste heat from equipment or digesters can warm greenhouses or process water.

The water loop. Rain lands on roofs, fields and panels. It is captured in tanks, ponds or the soil itself. It is used for irrigation, livestock and produce washing, then returns to the ground through infiltration or to a treatment step such as a constructed wetland before reuse.

The nutrient loop. Crops and forage take up nutrients. Animals and people eat them. Manure, crop residues, food scraps and processing waste are composted, digested, fermented or fed to insects. The finished products return nutrients, organic matter and soil life to the ground, which grows the next crop.

The material loop. Wood from windbreaks and orchards, crop stalks, packaging and spent bedding all have second uses as mulch, bedding, biochar feedstock, compost carbon or building material.

When you map these loops on your own land, look for outputs that are currently wasted, such as manure piled without a plan, roof runoff going to a ditch or wash water going down a drain. Then look for inputs you buy from far away, such as fertilizer, feed, diesel or water. Each place where an output could replace an input is a potential connection.

> **A 30-MINUTE FLOW AUDIT**

- Walk the property with a notebook and list everything that leaves: manure, runoff, wash water, residue, culls, heat, packaging.
- Then list everything you buy from off the farm: fertilizer, feed, fuel, power, water, bedding.
- Draw a line wherever something on the first list could stand in for something on the second.
- The shortest line, with both ends already on your land, is usually your best first connection.

A permaculture lens: zones and sectors. Permaculture is a design approach developed in Australia in the 1970s by Bill Mollison and David Holmgren. Its name comes from "permanent agriculture," and its core idea is to copy the relationships found in natural ecosystems.[57] Two of its tools fit hub planning especially well.

- **Zones** place each activity by how often you visit it. Zone 0 is the house or main building. Zone 1 holds daily tasks such as the kitchen garden, seedlings and the brewing station for microbial cultures. Zone 2 holds frequent tasks such as poultry, compost and the orchard. Zone 3 is main crops and pasture, Zone 4 is managed woodland, and Zone 5 is left wild. Putting the compost pad next to the barn, not across the farm, saves hours every week.
- **Sectors** map the outside energies that cross the site: winter wind, summer sun angle, fire risk, flood paths, frost pockets, noise and views. Windbreaks go across the wind sector, solar arrays face the sun sector, and ponds sit where water already gathers.

The FAO describes "recycling" and "synergies" as two of its ten elements of agroecology.[11] Permaculture adds a matching rule of thumb: every element should serve several functions, and every important function should be backed up by more than one element. A pond that stores irrigation water, raises ducks and acts as a fire reserve is a good hub element. So is a hedgerow that breaks the wind, feeds pollinators and supplies chip mulch.

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2. Soil health as the foundation

Every loop in the hub passes through the soil. Water infiltrates or runs off depending on soil structure. Nutrients are held or leached depending on organic matter and biology. Crops thrive or struggle depending on all of it.

USDA NRCS frames soil health around four principles: minimize disturbance, maximize soil cover, maximize biodiversity and maximize living roots.[1] SARE's free book *Building Soils for Better Crops* explains the science behind these principles in practical terms and is one of the best single references for hub planners.[7]

What the evidence says. Long-term trials give some of the clearest signals. The Rodale Institute's Farming Systems Trial in Pennsylvania has compared organic and conventional grain systems side by side since 1981. Rodale reports that after a transition period, its organic systems produced yields

comparable to conventional systems and performed better in drought years, which it links to improved soil structure and water holding.[9]

Soil carbon gains are real but should be framed carefully. Poeplau and Don's 2015 meta-analysis estimated an average gain of about 0.32 tonnes of carbon per hectare per year from cover crops.[14] Other researchers have since argued that some estimates of cover crop carbon gains are too high, especially at depth. The safe takeaway is that practices such as cover crops, reduced tillage and compost additions can build soil carbon over time, but results vary by climate, soil type and management. Measure on your own ground.

SOIL NUMBERS TO KEEP IN PERSPECTIVE

4
NRCS soil health principles: less disturbance, more cover, more diversity, living roots

0.32 t C/ha/yr
average soil carbon gain from cover crops (Poeplau and Don, 2015)

Since 1981
Rodale side-by-side trial of organic and conventional grain

2 to 3 yrs
sensible gap between repeat soil organic matter samples

Underground networks. Mycorrhizal fungi help move phosphorus and water to crops. Heavy tillage, bare fallows and high soluble phosphorus rates can weaken them, while year-round living roots, mulch and mature compost support them. Section 5 looks at composting methods designed specifically to build fungal-rich soil life.



Mycorrhizal fungi extend the reach of plant roots. Living roots year-round and less tillage help keep these networks intact.

What to do in practice. Start every hub plan with a soil map and baseline tests. The free NRCS Web Soil Survey shows soil types, drainage classes and limitations for any parcel in the US.[2] In Canada, provincial soil surveys and the Canadian Soil Information Service play the same role. Pair that with lab tests for organic matter, pH, nutrients and, if possible, a biological indicator such as respiration. Take samples at the same depth, at the same time of year, from the same marked locations so you can compare year to year.

BASELINE SOIL SAMPLING, DONE RIGHT

Mark sampling points with GPS or permanent stakes, and record them on your site map

Sample each field or management zone separately, not the whole farm as one sample

Use the same depth every time (your lab or extension office can suggest one)

Sample in the same month each time, ideally before fertilizer, manure or compost goes on

Use the same lab and the same test package so results are comparable

File the lab reports with your water log and purchase records

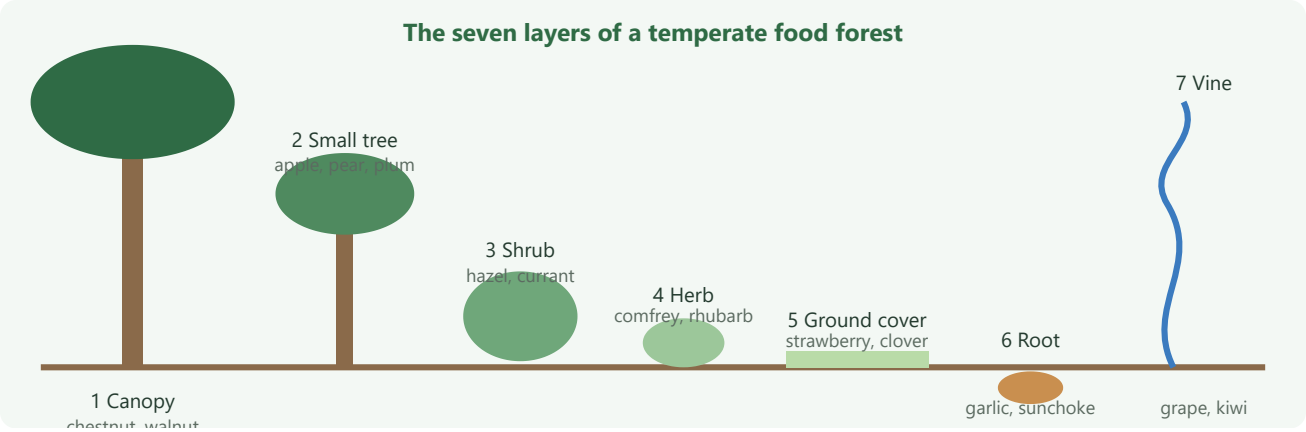
3. Agroforestry, food forests and perennial systems

Trees and perennials are the long-term backbone of a hub. They take years to establish, so they belong early in the plan even if the payoff comes later.

The USDA National Agroforestry Center recognizes five main practices in the US: alley cropping, silvopasture, windbreaks, riparian forest buffers and forest farming.[10] Each one connects to other parts of the hub.

- **Windbreaks** reduce wind erosion, protect livestock and buildings, and can lower heating loads on barns and homes. They also give you a future source of wood chips for compost and mulch.
- **Riparian buffers** filter nutrients and sediment from field runoff before it reaches streams. In a hub, they act as the last safety net for the nutrient loop.
- **Silvopasture** combines trees, forage and livestock. Shade can reduce heat stress on animals, and grazing manages the understory.
- **Alley cropping** places rows of trees with annual crops between them, spreading income across short and long time frames.

Food forests: permaculture's perennial core. A food forest, also called a forest garden, is a planting designed to work like a young woodland in which most plants are useful to people. Designers usually describe seven layers: tall canopy trees, smaller fruit and nut trees, shrubs, herbaceous perennials, ground covers, root crops and climbing vines. Plants are grouped into "guilds" around a central tree, with nitrogen-fixing shrubs, deep-rooted plants such as comfrey that are cut for mulch, and flowers that bring in pollinators and pest predators. Once established, a food forest usually needs less tillage, fertilizer and irrigation than annual beds, and its prunings feed the compost and mulch loops.



North American examples worth visiting or watching

Example	Bioregion	What it shows	Why it matters for a hub
Beacon Food Forest, Seattle, Washington[50, 51]	Cascadia	A 7-acre public food forest on city land at Jefferson Park, planted from 2012 by volunteers with the city's P-Patch community gardening program	Community governance, public harvest and education can sit on municipal land
New Forest Farm, Viola, Wisconsin (farmer and author Mark Shepard)[52]	Upper Midwest, Great Lakes states	A 106-acre former conventional farm redesigned to mimic oak savanna with chestnuts, hazelnuts, apples and grazing	Perennial staple crops can be run as a commercial farm with machinery, not only by hand
Miracle Farms, southern Quebec (orchardist and teacher Stefan Sobkowiak)[53]	St. Lawrence and Great Lakes basin	A roughly 5-acre commercial orchard converted to a permaculture design with mixed fruit rows, nitrogen fixers and poultry	Diverse rows cut pest pressure and spread harvest and income across the season

International lessons

- **Martin Crawford's forest garden, Devon, England.** Started on a flat field in 1994 and now a mature woodland of about 500 edible species run by the Agroforestry Research Trust.[54] *Lesson:* a cool, wet temperate climate much like coastal Cascadia can support a highly productive food forest. Its 30-year record makes it one of the longest-running examples of how a food forest matures.
- **Ernst Götsch's syntropic agriculture, Bahia, Brazil.** Götsch restored degraded farmland with dense, heavily pruned plantings where the prunings become mulch. Springs are reported to have returned as the land recovered.[55] *Lesson:* frequent pruning and chop-and-drop (cutting plants and leaving them as mulch in place) can build soil fast. The method is being tested in North American market gardens and orchards.
- **Greening the Desert, Jordan (Geoff Lawton, an Australian permaculture teacher).** Started in 2009 on a barren, rocky site. Water-harvesting earthworks, heavy mulch and pioneer trees turned it

into a productive garden within a decade.[56] *Lesson:* water-harvesting earthworks and organic matter come first. That lesson applies directly to the arid US Southwest and the dry interior of British Columbia.

Design tip. Plan tree rows around your water and energy layout. Place buffers below compost pads and livestock areas, and map mature canopy heights so trees will not shade future solar arrays.

BEFORE YOU PLANT A SINGLE TREE

What job is this row doing: wind, shade, filtering, food, income or wood supply? Aim for several.

How tall and wide will it be at maturity, and what will it shade at noon in winter?

Does it block a lane, gate, drain tile or future building site?

Is it downslope of manure, compost or livestock areas where it can catch runoff?

Who will water, mow around and replace losses for the first three years?

Are the species suited to your soil and hardiness zone, and do your state or provincial nursery or conservation district offer stock or cost share?

FREE DESIGN HELP FOR TREES ON FARMS

The USDA National Agroforestry Center publishes free planning guides, and many conservation districts will help lay out windbreaks and buffers. Windbreaks, riparian buffers and silvopasture are also listed NRCS conservation practices, which means they can qualify for EQIP cost share where they meet the practice standard.[3, 5]

4. Nutrient cycling: compost, manure, frass and digestate

Nutrients are often the most valuable thing a hub can recycle, and the easiest to lose. Nitrogen escapes to the air as ammonia or to water as nitrate. Phosphorus washes off with eroded soil.

There are four common recycling pathways, and they work best in combination. Section 5 adds microbial tools that make each of them work better.

Compost. Aerobic composting of manure, bedding, crop residues and food scraps stabilizes nutrients and builds organic matter. Good compost needs the right balance of carbon-rich and nitrogen-rich materials, moisture and air. NRCS has a conservation practice standard for composting facilities (Code 317), which is worth reading even if you do not seek cost share, because it sets out siting and runoff controls.[5]

Manure management. Fresh manure can be applied directly, but timing and rate matter. A nutrient management plan, often built around NRCS standard Code 590, matches applications to crop needs

and soil tests.[5] This is where your baseline soil data pays off.

> **CANADIAN READERS: NUTRIENT RULES**
>
> Provinces set their own manure and nutrient rules. Ontario's Nutrient Management Act, for example, requires larger and expanding livestock operations to prepare a nutrient management strategy or plan, and provincial Environmental Farm Plan workshops help any farm review how it stores and spreads manure.

Insect frass. Black soldier fly larvae can process food waste and some manures, producing larvae used as animal feed and frass used as a soil amendment. This pathway is newer, and the rules for feeding larvae and selling frass vary by state and province. Treat it as an add-on once your core compost system is working.

Digestate. Anaerobic digesters turn manure and food waste into biogas, which can make heat or electricity, and digestate, which keeps most of the nutrients. The EPA's AgSTAR program provides free guidance on whether a digester fits a farm.[12] Digesters are complex and usually make most sense for larger livestock operations or when several farms and food processors pool feedstock.

Permaculture nutrient methods. Permaculture adds several low-cost ways to keep nutrients where they fall:

- **Chop and drop.** Cut comfrey, nitrogen-fixing shrubs and cover crops and leave them as mulch under the trees they feed.
- **Animal rotations.** Move chickens behind grazing cattle or through the orchard after harvest so the animals spread manure, scratch in residues and eat pest larvae and fallen fruit.
- **Deep-litter bedding.** Let carbon-rich bedding build up in winter housing so it composts in place, then move it to the fields in spring.
- **Sheet mulching.** Layer cardboard, compost and wood chips to start new beds without tilling.

Close the loop on paper first. Before building anything, estimate how many tons of manure, residue and food waste you produce or could receive, and how many acres need them. If you will have more nutrients than your land can use, you need a partner who can take the surplus.

BEFORE YOU ACCEPT OUTSIDE FOOD SCRAPS OR MANURE

Do you know the nitrogen and phosphorus content, from a lab test or published values?

Will total nutrients from all sources stay within your nutrient management plan?

Does your state or province require a compost or solid waste permit at this volume or for this material?

Who removes packaging, glass and plastic, and what happens to a contaminated load?

Is there a written agreement covering volume, schedule, fees and how either side can end it?



Manure, residues and food scraps become soil inputs again when composting, fermenting or digesting is built into the farm layout.

5. Microbial tools: on-site brewing, EM and Johnson-Su bioreactors

Compost, manure and digestate carry nutrients. They also carry microbes, and a growing number of farms manage those microbes on purpose. This section covers three approaches that suit an agri-hub: brewing fermented microbial cultures on site, using Effective Microorganisms (EM) in the nutrient loop, and making fungal-rich compost in a Johnson-Su bioreactor.

5.1 Effective Microorganisms: what they are

The idea of a mixed community of beneficial microbes, rather than a single strain, came from Dr. Teruo Higa, a horticulture professor at the University of the Ryukyus in Okinawa, Japan. In the early 1980s he found that a combination of compatible species did far better than any single organism, and named the culture "Effective Microorganisms." With J.F. Parr of the USDA he published a technical review in 1994,[20] and the EM Research Organization (EMRO) carries the work forward.[21] Since then the method has spread to farms, composting, sanitation and wastewater treatment in many countries.

BOKASHI: THE MOST FAMILIAR USE IN NORTH AMERICA

Many North American gardeners first meet these cultures as bokashi, a Japanese word for fermented organic matter. Food scraps are packed into a sealed bin with bran that has been soaked in a fermented culture and dried. After about two weeks the scraps are pickled rather than rotten, with little smell, and they break down quickly once buried or added to a compost pile. Farms, schools and restaurants use the same method to handle food waste before it reaches the compost pad.

A culture brewed in this tradition is a co-cultured community of five functional groups, grown together in molasses and water. Together they hold a low pH of about 3.5, which keeps the culture stable and keeps spoilage organisms out.

Group	Typical organisms	What it does	What it means on the farm
Lactic acid bacteria	*Lactiplantibacillus plantarum*, *Lacticaseibacillus casei*	Ferment sugars into lactic acid and lower pH; crowd out *Salmonella*, *E. coli* and *Clostridium*	Acidifies manure and bedding; suppresses spoilage and putrefying microbes
Yeasts	*Saccharomyces cerevisiae*	Use oxygen and sugars; make vitamins, amino acids and growth factors for the bacteria	Supports the other groups and starts breakdown of feed and residues
Phototrophic bacteria	*Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*	Use hydrogen sulfide, organic acids and ammonium; make amino acids and carotenoids	The "cleanup crew": less odor and ammonia in manure and wastewater
Actinomycetes	*Streptomyces* species	Make natural antimicrobial and antifungal compounds; break down chitin and cellulose	Suppress molds in litter and compost
Fermenting fungi	*Aspergillus oryzae*	Release enzymes that break down complex organic matter	Start the chain that feeds the other groups

The groups feed one another. Fungi and yeasts release sugars. Lactic acid bacteria ferment those sugars and lower the pH. Phototrophic bacteria use the acids and hydrogen sulfide the others make, and actinomycetes protect the community. Dr. Higa described a "principle of dominance": in any microbial setting a small share of organisms builds up, a small share breaks down, and the large majority follow whichever group leads. He illustrated it as roughly 10/10/80. It is a teaching model, not a measured constant, but it explains the farm goal: shift manure, bedding and compost from rotting (putrefaction, ammonia, flies) to preserving (fermentation, mild smell, nutrients held).

PUTREFYING VERSUS FERMENTING MANURE

Rotting
ammonia, hydrogen sulfide and amines; sharp smell; rising pH; flies favored; nitrogen lost to air

Fermenting
lactic and other organic acids; mild sweet-sour smell; falling pH; flies suppressed; nitrogen kept for soil

3.5
approximate pH of a finished fermented culture

5.2 What the evidence says

The evidence is strongest for odor and ammonia control, and weakest for crop yield.

- **Manure, litter and housing.** In poultry manure tests, an EM culture, with or without zeolite, cut malodor and ammonia.[23] A 2026 study found that weekly spraying of litter with a microbial culture and zeolite (a porous mineral that holds ammonia) lowered litter moisture, pH, ammonia and carbon dioxide in the poultry house without hurting production.[24] Keeping nitrogen in the manure instead of the air makes it a better fertilizer for the next loop.

- **Crops and soil.** A careful multi-year Swiss field trial found that EM products did not improve soil microbial biomass or soil quality, and that yield gains came mainly from the nutrients in the EM-fermented bran (bokashi), not from the microbes themselves.[22] Other trials, mostly in warm climates, report benefits. Results depend on culture quality, dose, delivery and climate.
- **Animal performance.** Peer-reviewed poultry trials report better laying rate, feed conversion and gut health when cultures are given in feed and water,[58] but one commercial broiler farm trial found no statistically significant performance gain.[59]

THE HONEST BOTTOM LINE

Use fermented cultures where the evidence is best: odor, ammonia, compost speed and bedding. Treat crop and soil claims as something to test on your own ground with an untreated control strip, before and after soil tests and yield records.

RUNNING A FAIR ON-FARM TRIAL OF ANY MICROBIAL PRODUCT

Pick one question, such as "Does weekly spraying cut ammonia in barn A?"

Keep a matched untreated control: a strip, a pen or a barn managed the same way

Measure before you start, then on a fixed schedule, with the same tools each time

Run it for a full season or a full flock cycle, not two weeks

Write down costs, labor and anything that went wrong

Judge it on the numbers, and share results with your extension office or a SARE farmer grant team

RELATED VIEWING: "HOW MICROBES CAN HELP FEED THE WORLD"

In a 2015 talk at Rutgers University for Solve for X, a series of talks on ambitious technology ideas, Louis Elwell III, CEO of a company that sells a microbial soil inoculant, made the case for "fertilizer 2.0": rebuilding soil biology so farms can use less synthetic fertilizer.[32] He describes falling farmland area, flat yields and polluted runoff, and he shows root, crop and soil photos from customers. His central reference is a 2013 American Academy of Microbiology report of the same name. That report came out of a USDA-funded colloquium of leading agricultural microbiologists, and it set a goal of 20 percent higher yields with 20 percent less fertilizer within 20 years.[33]

How to use it: the talk is a company presentation, and several figures in it are the speaker's own and are not cited. Read the full Academy report (link in endnote 33) for the independent science, and treat product results as claims to test with a control strip.

5.3 Brewing on site

Ready-to-use cultures are expensive to ship, because they are mostly water. Many farms buy a small amount of "mother culture" and extend it about twenty-fold on site with molasses and clean water.

Phil Nauta's Smiling Gardener video shows the basic home method.[30] At farm scale, the same idea becomes a small brewing station in Zone 1 or 2.

Start with a pilot. Good practice, and the approach taken in the research trials cited above, is to begin with a controlled pilot, with matched treated and untreated barns and accredited lab testing, before any scale-up. That holds whichever culture you use. EM and EM·1 are trademarks of EM Research Organization.

The table below shows where brewed cultures fit in a hub and what to measure in each place.

Hub loop	Typical use	What to measure
Compost and manure pads	Spray layers as you build the pile, or the pad surface weekly	Odor, fly counts, pile temperature, time to finished compost
Livestock housing	Spray bedding, litter and manure hotspots weekly	Ammonia (ppm), litter moisture and pH
Food scraps	Ferment in sealed bins with inoculated bran (bokashi) before composting	Smell, pests, contamination
Lagoons and settling basins	Dose inlets to reduce odor	Odor complaints, sludge depth

A FARM-SCALE BREWING STATION

Ingredients. About 5 percent mother culture and 5 percent molasses in warm water that contains no chlorine. Follow the culture supplier's instructions, since recipes vary.

Vessel. A food-grade, sealable tank with a one-way airlock or blow-off tube, so gas can escape without drawing in room air.

Heat. An insulated chamber or wrap with a thermostat to hold the brew warm and steady.

Ready check. The batch is done when the pH has dropped to about 3.7 or below (finished cultures often settle near 3.5) and it smells sweet and sour. A cheap pH meter takes out the guesswork.

Records. Log batch date, culture lot, temperature, final pH and where each batch went.

Never mix with chlorine or peroxide. Oxidizers kill live cultures on contact. Keep dosing lines and sprayers separate.

5.4 Johnson-Su bioreactors: fungal-rich compost without turning

The Johnson-Su bioreactor was developed by Dr. David Johnson and Hui-Chun Su Johnson at New Mexico State University. It is a static compost pile that is never turned. Instead, air reaches the middle through vertical channels.[25]

How it is built. A cylinder of concrete reinforcing mesh, about 12 feet 6 inches around and 5 feet tall, is lined with woven landscape fabric and set on a shipping pallet. Six 4-inch perforated drain pipes

stand upright through holes in the pallet while the cylinder is filled with wet feedstock. They are pulled out once the material settles, leaving air channels so that no compost is more than about 12 inches from air. A drip line on a timer keeps the pile moist. The developers' manual, written for a USDA Farm Service Agency outreach grant, says one person can build it in four to five hours with about $40 of materials.[25]

How it runs. The pile heats to 145 to 165°F for about four days to a week, then cools. Worms are added for a long vermicomposting (worm composting) phase, and the pile is usually left for about a year. Because it is never turned, fungal networks stay intact.

How it compares with other composting methods:

Method	Labor	Time to finished product	Main strength	Main limit
Turned windrow	High (turning)	2 to 4 months	Handles large volumes	Can lose nitrogen; fungi disrupted by turning
Static aerated pile	Medium	2 to 4 months	Less turning; good pathogen kill	Needs blowers or careful pile design
Bokashi (fermented)	Low	2 to 4 weeks plus soil time	Handles food scraps with little odor	Small batches; needs inoculated bran
Johnson-Su bioreactor	Low after build	About 12 months	Fungal-rich inoculant at very low rates	Slow; small volume per unit
Anaerobic digester	High (engineering)	Continuous	Energy plus digestate	High capital cost and permits

> *The compost introduces beneficial microbes to the soil like a baker introduces yeast to bread dough.*
>
> David Johnson and Patrick DeSimio, Best Management Practices: Johnson-Su Composting Bioreactors, New Mexico State University (2017)

Why farmers use it. The finished compost is microbially diverse and fungal-dominant. Because it is meant to be an inoculant rather than a bulk amendment, it can be applied at very low rates. The manual cites rates as low as 1 kilogram per hectare, usually as a seed coating or a liquid extract.[25] That makes a few bioreactors enough for a whole farm, which suits hubs with little manure.

What to watch. The most quoted results come from a 2015 paper by Johnson and colleagues that reported large gains in plant growth and soil carbon in field trials.[26] It was released as a preprint and has not been through formal peer review, and the carbon figures are far above typical rates.[14] Treat it

as promising and test it yourself. The developers' original build video,[27] a widely watched homestead build,[28] and an interview with Dr. Johnson on why the compost works[29] are listed in "Watch and read."

6. Water: capture, efficiency and permaculture earthworks

Water ties the hub together, and in much of North America it is the tightest constraint. Design for water in three steps: capture, use it efficiently, and reuse it (Section 7).

Capture. Roofs on barns, packing sheds and greenhouses are clean, concentrated catchment areas. Ponds and swales slow runoff and let it soak in. Healthy soils with good structure act as the biggest storage tank of all. Check your water law before capturing runoff. Some western states restrict rainwater harvesting under prior appropriation rules. Colorado, for example, limits most homes to two rain barrels.

Permaculture earthworks. Permaculture's water strategy is often summed up as "slow it, spread it, sink it."

- **Swales** are level ditches dug on contour with a mound on the downhill side. They catch runoff and let it soak in, and trees planted on the mound draw on that stored water.
- **Keyline design**, developed by Australian farmer P.A. Yeomans, uses subsoil ripping patterns that move water from wet valleys out toward drier ridges.
- **Ponds and dams** placed high in the landscape let gravity deliver water later. Several small ponds often beat one large one.
- **Rain gardens and infiltration basins** below roofs and lanes turn a drainage problem into planting space.

Before you dig, read Section 8. Earthworks that intercept a stream, sit in a wetland or store water can need permits.

SITING A FARM POND

Put it where water already gathers, but outside wetlands and stream channels

Check soils for clay content, since sandy and gravelly soils leak

Place it above the gardens or troughs it will serve, so gravity does the work

Plan a safe overflow spillway and a fence or gentle edge for livestock and people

RAINWATER MATH FOR A BARN ROOF

One inch of rain falling on 1,000 square feet of roof yields about 623 gallons. A 40 by 60 foot barn roof (2,400 square feet) in a place that gets 35 inches of rain a year could collect roughly 52,000 gallons before losses to splash, evaporation and first-flush diversion.

Roof area	20 in. rain per year	35 in. rain per year	50 in. rain per year
1,000 sq ft	about 12,500 gal	about 21,800 gal	about 31,200 gal
2,400 sq ft	about 29,900 gal	about 52,300 gal	about 74,800 gal
5,000 sq ft	about 62,300 gal	about 109,000 gal	about 155,800 gal

Plan on capturing 75 to 90 percent of these figures, and size the tank to bridge your longest dry spell, not the whole year. Divert the first flush of each storm, which carries dust and bird droppings off the roof, and use food-safe tanks if the water will reach livestock or wash stations.

Efficiency. Drip irrigation, soil moisture sensors and scheduling reduce waste. Solar pumps match pumping to daylight, when crop demand is often highest.

The solar and water connection. Sharing land between panels and crops can raise total land productivity,[15] and agrivoltaic research has found that panels can change the microclimate beneath them. Barron-Gafford and colleagues (2019), working in Arizona, reported that some crops grown under panels used water more efficiently and that the vegetation helped keep panels cooler.[16] Results depend heavily on crop, climate and panel design, so treat this as a promising option to test, not a guaranteed gain.

FOUR WATER QUESTIONS FOR YOUR EXTENSION OFFICE OR STATE OR PROVINCIAL WATER AGENCY

- Am I allowed to capture roof or field runoff here, and is there a size limit?
- Do I need a permit for a new pond, well or diversion? (See Section 8.)
- If I grow fresh produce, which water uses fall under the Produce Safety Rule, and what testing applies?
- Is cost share available for drip irrigation, meters or a solar pump in my county this year?

7. Grey water and reuse: wash water, runoff and household greywater

A hub produces several kinds of used water. Each can be reused, but not in the same way. The rule is simple: match the water to the use, and never let lower-quality water touch the edible part of a crop unless food safety rules allow it.

Water stream	Typical contents	Good reuse options	Main cautions
Produce wash water	Soil, plant debris, sanitizer residue, possible pathogens	Recycle for early soaks and flumes; settle and screen; irrigate non-edible areas, pasture or orchard floors	Final rinse must meet produce safety standards; check for phosphorus and sanitizer loads
Barnyard and feedlot runoff	Manure, nutrients, pathogens	Settling basin, then a vegetated treatment area or constructed wetland; land-apply under a nutrient plan	Keep clean roof water separate; protect wells and streams
Roof runoff	Mostly clean rainwater	Livestock water, washdown, irrigation	Check water rights; divert the dirty first flush of each storm
Household greywater (laundry, showers)	Soap, lint, low pathogens	Subsurface irrigation of trees and shrubs	State and provincial plumbing rules; keep it underground
Kitchen and toilet water (blackwater)	High pathogens and organics	Licensed septic or treatment systems only	Never reuse without approved treatment

7.1 Produce wash water: the Holland Marsh lesson

The Holland Marsh in Ontario is one of Canada's densest vegetable-growing areas, draining to Lake Simcoe in the Great Lakes basin. Farm & Food Care Ontario, a farm-sector organization, ran "water smart" assessments with vegetable processors there, and its short video *Vegetable Wash: water recycling* walks through what they learned.[35]

- **Measure first.** Clamp-on meters, and a rotameter (a simple flow gauge) or sight gauge on each machine, show operators how much water each machine uses so they can turn it down to the minimum.
- **Leave dirt in the field.** De-dirting conveyors on harvesters and at the plant shake off soil before any water is used. This saves water and keeps phosphorus in the field where it belongs.
- **Cascade the water.** Use recycled water for the first soak and for flumes (water channels that carry produce), and save fresh potable water for the final rinse.
- **Use recycling trays.** Trays under barrel washers (rotating drum washers) cut water use by about half compared with fresh water at every stage.

RESULTS FROM THE HOLLAND MARSH ASSESSMENTS

50%+
fresh water savings from most assessments

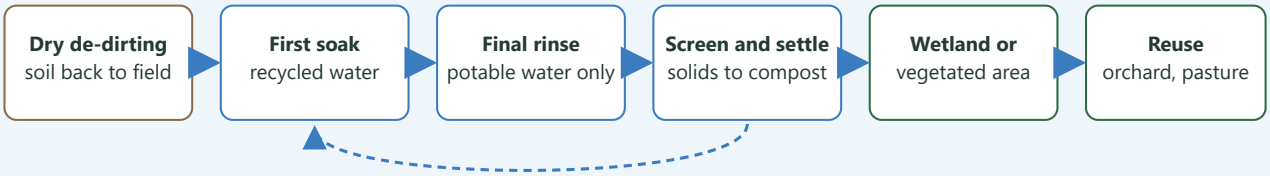
50%
less water when recycling trays sit under the barrel washer

70%
less water with recycling trays plus a final fresh-water spray bar

20%
water needed by the most efficient systems, compared with all-fresh systems

Smaller flows also mean a smaller, cheaper treatment system outside the plant, and fewer issues with permits to take water. Farm & Food Care's self-assessment guide[36] and Ontario's free *Vegetable and Fruit Washwater Treatment Manual*[37] explain the treatment options in detail: screens, settling tanks and ponds, filters, constructed wetlands and land application. In the US, University of Vermont Extension's guide on wash water discharge from vegetable pack sheds covers the same choices for smaller farms.[38]

A wash water cascade for a small packing shed



Settled water can feed the first soak again. Edible crops get only water that meets produce safety rules.

Food safety comes first. In the US, farms covered by the FDA Produce Safety Rule[13] must use water for washing and other harvest and post-harvest uses that has no detectable generic *E. coli* in a 100-milliliter sample. Untreated surface water cannot be used for these purposes, and recirculated water must be monitored and changed on a schedule.[39] In 2024 the FDA replaced the old numeric testing rules for pre-harvest water with an annual, systems-based assessment of each water source.[40] Canadian growers typically follow the CanadaGAP food safety program, and the federal Safe Food for Canadians Regulations apply to produce sold across provincial or national borders. Talk to your extension produce safety team before any reuse touches edible crops.

7.2 Barnyard runoff and constructed wetlands

Keep clean water clean first. Gutters and diversions that send roof water away from manure areas shrink the amount of dirty water you have to manage. What remains can flow to a settling basin, then to a vegetated treatment area (NRCS Code 635) or a constructed wetland (NRCS Code 656), where plants, soil and microbes take up nutrients and break down organic matter.[5]

Permaculture instructor Andrew Millison of Oregon State University explains the principle in *How to Recycle Waste Water Using Plants*, one of the most watched videos on the subject. Wetland plant roots host dense communities of bacteria and fungi that break down most minor pollutants. A lined, gravel-

filled basin keeps the water below the surface, and baffles force it to move past as many roots as possible.[41]

> *Plants and biologically active soil can clean dirty water. It's as simple as that.*
>
> Andrew Millison, permaculture instructor, Oregon State University, in *How to Recycle Waste Water Using Plants* (2021)

7.3 Household greywater

For the farmhouse, bunkhouse or farm store, laundry and shower water can irrigate trees and shrubs. Millison's video shows the "branched drain" design of greywater designer and author Art Ludwig. Pipes drop greywater into buried, mulch-filled chambers around fruit trees, with an air gap so roots cannot clog the pipe and no water reaches the surface.[41] Use biocompatible soaps low in sodium and boron, keep kitchen-sink water out, and do not install a greywater system where the water table is shallow.

Rules vary widely. Arizona and California allow simple laundry-to-landscape systems without a permit when owners follow set conditions, while Oregon issues tiered greywater permits. Most Canadian provinces regulate greywater through plumbing and onsite sewage codes. Check with your local building or health department first.

7.4 A lesson from Colombia: beneficial microbes in community water systems

A Colombian television news report, *Margarita Correa News Report* (2011), tells how Margarita Correa, a Colombian promoter of beneficial-microbe technology, used a mixed culture of lactic acid bacteria, yeasts and phototrophic bacteria to treat drinking water for small towns.[34] In Barichara, a town of about 10,000 people, the recipe was 7 kilograms of wood charcoal and two mud bricks in a plastic net sack, soaked for eight days in the microbial solution and then placed in the water system. One sack served an aqueduct flowing at 10 liters per second and was replaced every 20 days. The mayor reported total coliforms falling from 100 to zero at a cost of about $7 per 20 days. The report says the method spread to other towns, including one of about 40,000 people, and that the national government hired Correa as a consultant.

THE BARICHARA NUMBERS, AS REPORTED

10,000
People in Barichara served by the treated water system

7 kg + 2 bricks
Wood charcoal and mud bricks per sack, soaked 8 days in the culture

10 L/second
Aqueduct flow served by one sack, replaced every 20 days

100 to 0
Total coliforms before and after, as reported by the mayor, at about $7 per 20 days

What North American readers should take from it. The report is journalism, not a published study. It shows no lab data, and in the US and Canada public drinking water must meet Safe Drinking Water Act or provincial standards with approved treatment and disinfection. Microbial dosing is not a substitute for those. The useful lesson for a hub is the delivery method. Porous carriers such as charcoal, brick or ceramic, charged with a fermented culture, can release microbes slowly into non-potable water such as settling ponds, lagoons and constructed wetland inlets, where the goal is less odor and faster breakdown. If you try it, take before and after samples through an accredited lab.

8. Do I need a permit for a new pond, well or diversion?

Often, yes: many new ponds, wells and diversions need at least one permit. Getting this wrong is a common and costly mistake, and fixing a violation after the fact costs far more than asking first. The answer depends on three layers of rules: water rights (who may use the water), environmental rules (what you may do to wetlands, streams and fish habitat) and local rules (grading, building, floodplain and dam safety).

This section is general guidance for planning, not legal advice. Rules change and vary by state, province and county. Confirm your plans with the agencies named here, and with a water rights attorney or engineer for larger projects.

8.1 United States

Water rights: it depends where you are.

- **Western states (prior appropriation, "first in time, first in right").** Most surface water and groundwater use needs a permit from the state water agency, and senior rights come first in a shortage. Storing water in a new pond usually needs a water right too. Exemptions are narrow. In Oregon, exempt uses include stock watering at certain small ponds constructed and registered before January 31, 1997, household groundwater use up to 15,000 gallons per day, and groundwater for stock watering. New wells must still be registered even when the use is exempt.[45] Washington's groundwater permit exemption covers domestic use up to 5,000 gallons per day, non-commercial lawn or garden irrigation up to half an acre, and stock water. Exempt wells are still subject to senior rights and local streamflow rules.[44]

- **Eastern and Great Lakes states (riparian "reasonable use").** Landowners next to water can make reasonable use of it, but many states require registration or a permit above a volume threshold. Under the Great Lakes–St. Lawrence River Basin Water Resources Compact, the eight Great Lakes states manage large withdrawals and diversions, and water may not be diverted out of the basin except in narrow cases.[49]

> **EXEMPT DOES NOT MEAN UNREGISTERED**
>
> In Oregon, household groundwater use up to 15,000 gallons per day needs no water right, but the new well must still be registered with the state.[45] In Washington, exempt domestic wells are still subject to senior water rights and local streamflow rules.[44] An exemption removes the permit, not the paperwork or the limits.

Wells. Nearly every state requires a licensed well driller, a well log filed with the state, and setbacks from septic systems, manure storage and property lines. Some counties add their own permit.

Ponds and earthworks in or near water.

- **Clean Water Act Section 404.** Placing fill in "waters of the United States," including many wetlands, needs a permit from the US Army Corps of Engineers. Construction and maintenance of farm or stock ponds and irrigation ditches is generally exempt, and so is normal farming on established operations. But these exemptions does not apply if the work is a new use that reduces the reach or flow of regulated waters, and converting a wetland to upland generally needs a permit.[42] The Supreme Court's 2023 *Sackett v. EPA* decision narrowed federal wetland jurisdiction, so state wetland laws now matter more.
- **Swampbuster (wetland conservation compliance).** If you take part in USDA programs such as EQIP, CSP or subsidized crop insurance, converting a wetland can cost you eligibility. Participants generally file form AD-1026 with their Farm Service Agency office and can ask NRCS for a wetland determination before you dig.[43]
- **Dam safety.** Embankments above a set height or storage volume need state dam safety review. Thresholds vary. NRCS Pond standard Code 378 is a good design reference even for small ponds.[5]
- **Fish and wildlife.** Work in or across a stream may need a state fish and wildlife permit, such as Washington's Hydraulic Project Approval, and diversions may need fish screens.

Local permits. County grading, floodplain and stormwater rules can apply to ponds, swales and large earthworks. Construction that disturbs an acre or more may need stormwater coverage, although some agricultural work is exempt.

The table below pulls the US rules above and the Canadian rules that follow into one view. It shows what is typically involved, not every permit your site may need.

Project	Typically involved in the US	Typically involved in Canada	First call
New well	Licensed well driller, well log filed with the state, setbacks; a water right in western states unless exempt (exempt wells may still need registration); sometimes a county permit	Provincial well construction rules; a licence for non-domestic groundwater use in British Columbia; Ontario Permit to Take Water above 50,000 litres per day	State or provincial water agency
Off-stream pond for storage	Water right for storage in western states; state dam safety review above set height or volume; county grading and floodplain rules	Licence to store water in British Columbia; conservation authority permit near wetlands, floodplains or shorelines in Ontario	Conservation district or NRCS (US); conservation authority or provincial agriculture ministry (Canada)
Pond, crossing or fill in a stream or wetland	Clean Water Act Section 404 permit from the Army Corps unless a farm pond exemption applies; Swampbuster (form AD-1026) for USDA program participants; state fish and wildlife permit	Fisheries and Oceans Canada review if fish habitat could be harmed; federal approval for navigable waters; provincial authorization (for example, Quebec)	NRCS wetland determination, then the Corps district (US); Fisheries and Oceans Canada (Canada)
Diversion or pumping from a stream or lake	Water right in western states; registration or permit above a volume threshold in eastern states; Great Lakes Compact limits on large withdrawals; fish screens	Licence to divert in British Columbia; Ontario Permit to Take Water above 50,000 litres per day; licence or registration in Alberta, Saskatchewan and Manitoba	State water agency or watermaster; provincial water ministry
Swales and large earthworks	County grading, floodplain and stormwater rules; stormwater coverage if an acre or more is disturbed, with some farm exemptions	Conservation authority permit near wetlands, floodplains or shorelines (Ontario); municipal rules	County or municipal planning office

8.2 Canada

In Canada, provinces own and allocate water, and federal law protects fish habitat and navigable waters.

- **British Columbia.** Under the Water Sustainability Act, in force since 2016, you need a licence to divert or store surface water and to use groundwater for non-domestic purposes such as irrigation. Household groundwater use is exempt, but wells must meet construction rules.[47]

- **Ontario.** A Permit to Take Water is needed to take more than 50,000 litres per day from a lake, stream, pond or groundwater, unless the taking is exempt or covered by a simpler registry.[46] Conservation authorities also regulate development in wetlands, floodplains and near shorelines, so a pond can need their permit even when no water permit applies.
- **Prairie provinces and Quebec.** Alberta licenses water use and offers a simpler registration for traditional agricultural uses such as livestock watering. Saskatchewan and Manitoba also license water use and regulate drainage works. Quebec requires authorization for larger withdrawals and for work in wetlands and water bodies. Ask your provincial ministry for current thresholds.
- **Federal.** If your project could harm fish or fish habitat, check Fisheries and Oceans Canada's "Projects near water" guidance and request a review if needed.[48] Works in navigable waters can also need federal approval.

WHO TO CALL FIRST, IN ORDER

Your conservation district or NRCS office (US), or your conservation authority or provincial agriculture ministry (Canada). They offer free site visits and design help, and in the US NRCS makes wetland determinations.

Your state or provincial water agency or local watermaster (the state official who administers water rights). Ask whether your use needs a water right, licence or registration, and whether any exemption applies.

The US Army Corps of Engineers district office (US) or Fisheries and Oceans Canada (Canada) if the project touches a stream, wetland or shoreline.

Your county or municipal planning office for grading, floodplain, building and stormwater permits.

A licensed well driller or engineer for wells and for dams above minor size.

NUMBERS FROM THE RULES CITED ABOVE

50,000 L/day
Ontario threshold for a Permit to Take Water

5,000 gal/day
Washington exempt domestic groundwater use

15,000 gal/day
Oregon exempt household groundwater use

2016
British Columbia began licensing non-domestic groundwater

9. Phasing a hub: start with one connection, then add

A common mistake is trying to build every piece at once. A phased approach lowers risk, spreads costs and lets you learn.

Phase 1: one connection. Choose a loop where you already have both ends. Examples include composting existing manure and spreading it on pasture, capturing roof water from one barn for

livestock, or planting a windbreak that protects an existing building. Set up your baseline measurements at the same time.

Phase 2: link a second system. Add a connection that builds on the first. Compost could feed a market garden. Captured water could run drip irrigation on that garden. A small solar array could power the pump. A brewing station or a Johnson-Su bioreactor can be added here at low cost.

Phase 3: bring in partners. Accept food scraps from a school or grocer for your compost. Share cold storage or a washing line with neighboring growers, and design its water cascade from day one. Explore a community solar or shared digester arrangement.

Phase 4: perennial and long-cycle elements. Expand agroforestry, food forest guilds, buffers, ponds and permanent infrastructure as you gain confidence and data. Clear water and wetland permits before this phase, because they can take a season or more.

Start trees and soil building in Phase 1, even on a small scale, because they take years to mature.

ILLUSTRATION: HOW ONE LIVESTOCK FARM MIGHT PHASE A HUB

Phase 1. Build a covered compost pad for barn manure and spray each layer with a brewed fermented culture. Spread finished compost on the nearest pasture. Take baseline soil samples on those fields and plant one windbreak on the north side of the barn.

Phase 2. Add gutters and a tank on the barn roof to water livestock. Start a small market garden on composted ground, with one Johnson-Su bioreactor to make seed-coating inoculant, and keep an untreated control strip.

Phase 3. Take food scraps from a nearby school under a written agreement. Add a small solar array to run the pump and a walk-in cooler, and a wash station whose rinse water drains to a vegetated area.

Phase 4. After an NRCS wetland determination and a water right check, add a small pond above the garden. Extend trees into silvopasture and a food forest edge, and plant a riparian buffer along the creek below the compost pad.

This is a hypothetical sequence for illustration, not a case study.



Cover crops, grazing and solar on the same farm. Each piece was added as a connection to what was already working.

10. Governance, partnerships, community benefit and measuring outcomes

A hub that involves more than one landowner, a tribe or First Nation, a town or a cooperative needs clear agreements. Who owns the compost? Who maintains the pond and holds the water right? Who gets the electricity, and who pays when the pump fails?

Governance options. Common models include a single farm with outside partners under contract, a farmer cooperative, a community organization or community land trust, or a tribal or municipal enterprise. Each has different rules for ownership, liability and eligibility for funding. Talk with a lawyer or cooperative development center before choosing. The Beacon Food Forest in Seattle shows one public model: volunteers steward city-owned land in partnership with the city's P-Patch community gardening program.[50]

Community benefit. Spell out who benefits, such as through local food access, jobs, training or cleaner water downstream. Writing this down early builds trust and strengthens funding applications.

Measuring outcomes. Pick a short list of indicators you can actually track. Copy this log and keep it with your records:

What to record	How	How often	Where it is kept
Soil organic matter, pH, nutrients	Lab test at marked points	Baseline, then every 2 to 3 years	_____
Water used, including wash water	Meter, rotameter or pump hours	Monthly	_____
Rainfall	Rain gauge	After each event	_____
Fertilizer, feed and fuel bought	Invoices	Each purchase	_____
Material composted or diverted	Loads or estimated tons	Each load	_____
Ammonia and odor at barns and compost	Handheld meter or test strips, odor log	Weekly	_____
Energy produced and used	Inverter and utility bills	Monthly	_____
Yield and income by enterprise	Sales and harvest records	Each season	_____

The Soil Health Institute and NRCS publish guidance on soil health indicators.[17]

PUT THESE IN WRITING BEFORE YOU SHARE ANYTHING

Who owns each shared asset (compost pad, pond, water right, solar array, cooler, brewing station)

Who maintains it, on what schedule, and who pays for repairs

How outputs are split: compost, water, power, income

How decisions are made and how disputes are settled

What insurance each party carries and who is liable if something fails

How a partner leaves and what happens to their share

Funding pathways. Several federal programs can support parts of a hub. Program names, rules and funding levels change, so treat this as a starting list.

- **NRCS Environmental Quality Incentives Program (EQIP)** provides financial and technical help for conservation practices such as cover crops, nutrient management, composting facilities, ponds, irrigation efficiency and windbreaks.[3]
- **NRCS Conservation Stewardship Program (CSP)** supports producers who are already managing conservation and want to do more across the whole operation.[4]
- **USDA Rural Development Rural Energy for America Program (REAP)** offers grants and loan guarantees to agricultural producers and rural small businesses for renewable energy systems and energy efficiency improvements.[6] As of November 2026 no REAP application window is open, and an October 2026 rule discourages solar on cropland; check the program page before planning around it.
- **SARE grants** fund on-farm research and education, which can help you test a new connection such as a microbial culture or bioreactor trial.[8]

State agriculture departments, conservation districts, tribal programs and private foundations often add their own options. Start at your local USDA Service Center.

> **CANADIAN READERS**
>
> The same design approach applies in Canada, but the programs differ. The federal-provincial Sustainable Canadian Agricultural Partnership (2023 to 2028) funds many cost-share programs delivered by provincial agriculture ministries, such as Environmental Farm Plan follow-up and beneficial management practice programs.[18] Agriculture and Agri-Food Canada's Agricultural Clean Technology Program has supported on-farm clean energy and efficiency projects.[19] Water rights, compost rules and solar interconnection are set provincially, so check with your provincial ministry and local conservation authority.



Step-by-step: from idea to first phase

1. **Gather your people.** List everyone who owns, works or depends on the land, and agree on two or three shared goals.
2. **Map the site.** Use the Web Soil Survey, aerial photos and a walk of the property to mark soils, slopes, water, buildings and access. Add permaculture zones and sectors.
3. **Inventory the flows.** Estimate what comes in (fertilizer, feed, fuel, water, power) and what goes out or is wasted (manure, runoff, wash water, residue, heat).
4. **Find matches.** Use the connections matrix below to spot outputs that could replace inputs.
5. **Pick one connection.** Choose the one with the lowest cost, highest learning value and fewest permits.
6. **Check permits.** Before any pond, well, diversion or earthwork, run through the call list in Section 8.
7. **Set a baseline.** Take soil samples, start a water log and record current purchases. Mark an untreated control strip for anything you want to test.
8. **Visit your local USDA Service Center and extension office (or provincial ministry).** Ask about technical help, practice standards and current program windows.
9. **Build and run Phase 1 for at least one full season.**
10. **Review the data with your group.** Decide what worked, what to fix and what to connect next.

A FIRST-YEAR PLANNING CALENDAR

When	What to do
Winter	Do the flow audit, sketch zones and sectors, pull soil maps, list existing water rights and wells, and book a conservation district visit
Early spring	Take baseline soil samples. Ask for a wetland determination and permit check before any pond or earthwork. Set up the brewing station or build a bioreactor
Late spring and summer	Run Phase 1. Keep the water log, purchase records and odor or ammonia notes. Mark untreated control strips
Fall	Plant trees and shrubs where fall planting suits your region, sow cover crops and spread finished compost
End of year	Review results with your group. Ask your USDA Service Center or provincial ministry about program ranking deadlines, which in many places fall in autumn or winter

Who to call, and what to ask for. Every office below is named earlier in this report. Bring your site map and flow audit to the first visit.

Need	United States	Canada	Ask for
Soils and site design	NRCS office or conservation district, using the Web Soil Survey[2]	Provincial agriculture ministry and soil survey	A site visit and help with your soil map
Conservation cost share	NRCS: EQIP and CSP[3, 4]	Sustainable Canadian Agricultural Partnership programs, via the provincial ministry[18]	Eligible practices and the next ranking deadline
Practice design	NRCS practice standards, such as Pond (378) and Composting Facility (317)[5]	Provincial agriculture ministry; Environmental Farm Plan workshops for manure storage and spreading	The standard or plan your project must meet
Water and permits	State water agency, Corps district, county planning	Provincial water ministry, conservation authority, Fisheries and Oceans Canada[48]	Which permits apply and how long they take
On-farm trials	SARE grants and extension[8]	Provincial extension or ministry specialists	Trial design help and result sharing
Renewable energy	USDA Rural Development (REAP: no open window as of November 2026)[6]	Agricultural Clean Technology Program[19]	Current status before you budget around it

READY TO START PHASE 1?

Two or three shared goals, written down and agreed by everyone involved

One connection chosen, with both ends already on the farm

Permit check done for anything touching water, wetlands or earthworks

Baseline soil samples taken and an untreated control strip marked

A simple log set up for water, purchases and outputs

A budget that still works with no grant, so funding is a bonus rather than a condition

Worksheet: site resource map and connections matrix

Part A: Site resource map prompts

- Total acres: _____ Main soil types (from Web Soil Survey or provincial soil survey): _____
- Annual rainfall: _____ Main water sources: _____
- Existing water rights, licences or well logs: _____
- Roof area available for water capture (square feet): _____
- Wash water used per week (gallons or litres), and where it goes now: _____
- South-facing open area for solar (acres or square feet): _____
- Livestock type and number: _____ Estimated manure per year (tons): _____
- Crop residues or food waste available on site or nearby (tons per year): _____
- Current energy use (kWh per year) and main loads: _____
- Existing trees, windbreaks, buffers or wetlands: _____
- Nearby partners (schools, processors, towns, other farms): _____

Part B: Connections matrix

For each row, ask: can this output become an input for the column? Write "yes", "maybe" or "no", with a short note.

Output from / Input to	Soil	Crops and pasture	Livestock	Energy	Water
Manure	_____	_____	_____	_____	_____
Crop residue	_____	_____	_____	_____	_____
Food scraps	_____	_____	_____	_____	_____
Roof and field runoff	_____	_____	_____	_____	_____
Produce wash water	_____	_____	_____	_____	_____

Output from / Input to	Soil	Crops and pasture	Livestock	Energy	Water
Household greywater					
Solar or biogas power					
Waste heat					
Wood and prunings					

Circle the one connection you will start with: _____

Common mistakes to avoid

- **Starting with the most expensive piece.** Big equipment rarely fixes a weak soil or water system. Start with the foundation.
- **Skipping the baseline.** Without year-one data, you cannot show improvement to yourself, partners or funders.
- **Testing without a control.** A microbial product, compost tea or bioreactor trial with no untreated strip proves nothing either way.
- **Ignoring nutrient balance.** Bringing in outside food waste or manure can overload your land with nitrogen and phosphorus if you have not done the math.
- **Digging before asking.** A pond in a wetland or a diversion without a water right can mean fines, restoration orders and lost USDA eligibility.
- **Mixing water qualities.** Recycled wash water or greywater on edible crops can break food safety rules and make people sick.
- **Killing your own cultures.** Running brewed microbes through chlorinated lines or sprayers used for disinfectants wipes them out.
- **Planting trees in the wrong place.** Mature trees can shade future solar arrays or block access. Map mature size before planting.
- **Leaving governance vague.** Unclear ownership of shared assets causes more hub failures than technical problems.
- **Relying on a single grant.** Programs change. Build a plan that still works if one funding source falls through.

Glossary

- **Agrivoltaics:** Using the same land for both solar energy production and agriculture, such as crops or grazing under or between panels.
- **Agroforestry:** Intentionally combining trees or shrubs with crops or livestock to gain environmental and economic benefits.
- **Anaerobic digestion:** A process in which microbes break down organic material without oxygen, producing biogas and a nutrient-rich digestate.
- **Blackwater:** Wastewater from toilets and kitchens, with high pathogen and organic loads.
- **Bokashi:** A sealed fermentation of food scraps or manure with bran inoculated with beneficial microbes, done before composting or burial.
- **Digestate:** The material left after anaerobic digestion, which can be used as a fertilizer.
- **Effective Microorganisms (EM):** A mixed culture of lactic acid bacteria, yeasts, phototrophic bacteria and other groups, developed by Dr. Teruo Higa. EM is a trademark of EM Research Organization.
- **Food forest:** A planting designed like a young woodland, with layers of useful trees, shrubs, herbs, ground covers, roots and vines.
- **Frass:** Insect excrement mixed with leftover feed and shed skins, often from black soldier fly larvae, used as a soil amendment.
- **Greywater:** Lightly used water from laundry, showers and bathroom sinks.
- **Guild:** A group of plants arranged around a central tree so that each supports the others.
- **Johnson-Su bioreactor:** A static, unturned compost cylinder with vertical air channels that produces fungal-rich compost.
- **Land equivalent ratio (LER):** A measure comparing how much land separate systems would need to produce what a combined system produces on one area. An LER above 1 means the combined system is more land efficient.
- **Mother culture:** The starter microbial culture that is extended on site with molasses and water.
- **Mycorrhizal fungi:** Fungi that form partnerships with plant roots, trading water and nutrients for plant sugars.
- **Nutrient management plan:** A plan that matches the amount, source, timing and placement of nutrients to crop needs and soil conditions.
- **Permaculture:** A design approach, from "permanent agriculture," that arranges plants, animals, water and buildings to work like a natural ecosystem.
- **Prior appropriation:** The western US water law rule of "first in time, first in right."
- **Riparian rights:** The eastern US rule that landowners next to water may make reasonable use of it.
- **Soil organic carbon:** The carbon held in soil organic matter, a key indicator of soil health.
- **Swale:** A level ditch dug on contour, with a mound on the downhill side, that catches and soaks in runoff.

Watch and read: videos and free guides

These are the videos and documents cited in this report, chosen because they are widely viewed, come from the people who developed the method, or come from a public agency. View counts were checked in November 2026.

Topic	Title and source	Why watch or read
Johnson-Su	*Johnson Su Bioreactor*, David & Hui-Chun Johnson (12 min, about 221,000 views)[27]	Build walk-through by the developers
Johnson-Su	*Johnson Su Bioreactor Build! Why Is This A Superior Compost?*, Country Living Experience (15 min, about 843,000 views)[28]	The most watched homestead build
Johnson-Su	*The Benefits of Johnson-Su Bioreactor Compost*, podcaster Diego Footer with Dr. David Johnson (9 min)[29]	Why fungal-rich compost matters
Johnson-Su	*Best Management Practices: Johnson-Su Composting Bioreactors*, NMSU (free PDF)[25]	Materials list and step-by-step build
EM	*How To Activate Effective Microorganisms*, Smiling Gardener (5 min)[30]	Simple brewing method at home scale
EM	*EM in the World: Summary 1 by Prof. Higa*, EM Research Organization[31]	The founder on uses around the world
Microbes and soil	*How microbes can help feed the world*, Louis Elwell III, Solve for X (12 min)[32]	The case for biological fertility; read with the full report[33]
Water and microbes	*Margarita Correa News Report* (6 min)[34]	Beneficial microbes in Colombian town water systems
Wash water	*Vegetable Wash: water recycling*, Farm & Food Care Ontario (6 min)[35]	Practical water savings in a Great Lakes vegetable district
Wash water	*Vegetable and Fruit Washwater Treatment Manual*, Ontario (free)[37]	Treatment options and design
Greywater	*How to Recycle Waste Water Using Plants*, Andrew Millison (10 min, about 3.7 million views)[41]	Constructed wetlands and branched-drain greywater
Food forests	*CityStream: Beacon Food Forest*, Seattle Channel (6 min)[51]	Public food forest in Cascadia
Food forests	*Mark Shepard: Agroforestry Farm Tour*, Savanna Institute (9 min, about 90,000 views)[52]	Commercial perennial farm in Wisconsin
Food forests	*Permaculture Orchard Masterclass: The Movie*, Stefan Sobkowiak (about 260,000 views)[53]	Commercial permaculture orchard in Quebec
Food forests	*A Forest Garden With 500 Edible Plants*, National Geographic (3 min, about 890,000 views)[54]	Martin Crawford's 30-year forest garden
Syntropic farming	*Ernst Götsch's bluevision* (8 min, about 156,000 views)[55]	How syntropic agriculture began

Topic	Title and source	Why watch or read
Earthworks	*10-Year Timeline of the Greening the Desert Project*, Geoff Lawton (4 min, about 325,000 views)[56]	Swales and mulch on a barren site

Next steps

If you want to keep learning, the free resources at Funding Regeneration are a good place to start. The Integrated System page at fundingregeneration.earth/integrated-system/ explains how energy, food, water and waste connect, and the Resources page gathers guides, articles and reports like this one.

YOUR NEXT THREE MOVES

- This week: do the 30-minute flow audit in Section 1, sketch your zones and sectors, and draw your first connection lines.
- This month: pull your parcel in the NRCS Web Soil Survey, book baseline soil tests, and find out what water rights or licences already come with the land.
- This season: visit your local USDA Service Center (or provincial ministry in Canada) with your chosen Phase 1 connection and ask what help is open now.

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