Creating Healthy Land: The Four Ecosystem Processes

**Key Outcomes**
You will learn:
- How to view environments in a whole new way
- How to make the water cycle on your land more effective
- How to keep mineral nutrients cycling rapidly
- How to maximize energy flow and boost productivity
- How to enhance biological diversity
- What to do next to continue your learning and practice
- How to assess what you’ve learned so far

**Key Concepts**

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Creating Healthy Land

Now that you have the key Holistic Management principles for success under your belt, have defined your whole, created a holistic goal, and tested some decisions toward that holistic goal, it’s time to learn more about the ecosystem processes. Once you have a strong understanding of how these processes function and what to look for on the land to determine how well they are operating, you can work more effectively with Nature and create healthier, more productive land through your management.

Four Windows Into the Same Room

Ecosystem Basics

People tend to talk about various ecosystems—forest ecosystems, riparian ecosystems, grassland ecosystems, etc. However, each of these "ecosystems" is really part of a greater ecosystem that has no boundaries.

For our purposes, we will be referring to one ecosystem, and will speak in terms of different environments all of which function through four fundamental processes. These processes include:

- The Water Cycle: the movement of water from atmosphere to soil and back and how that movement affects plant and animal (including human) life.
- The Mineral Cycle: the movement of minerals or nutrients and how that movement affects plant, animal and human life.
- Energy flow: the movement of energy from the sun through all living (or once living) things.
- The Biological Community (Succession) has a never ending development and evolution that we influence.

If you were to consciously modify any one of these processes, you automatically modify them all in some way because they are really different elements of the same system. Another way to think about it is to view these four processes as four separate windows looking into the same room—you get four different perspectives of the same thing—our ecosystem.

Through one window you view the water cycle; through another, the mineral cycle, and so on. But they are all looking in on the same room—the ecosystem that sustains us.
The way to gain a true understanding of how well the ecosystem processes are functioning on your land is to get out there and walk on it. Reading the land, watching for symptoms of an ineffective water or mineral cycle, or poor energy flow or a stagnant biological community is like diagnosing a disease. You must understand what a healthy system looks like and then be able to recognize the signs of deteriorating health.

The Ecosystem Processes are a vital element in the Holistic Management® framework. The holistic goal—the guiding force behind Holistic Management® decision making—rests on the foundation of our ecosystem. When you begin to practice Holistic Management you define what you are responsible for managing and then develop a holistic goal. The holistic goal describes how you want your life to be (quality of life), what you must commit to in order to achieve it (behaviors, systems, and processes), and what must be in place to sustain what you produce far into the future (vision). For the land manager, this means, in part, describing how you not only want the land to look but how it must look and how the ecosystem processes must be functioning now and far into the future to sustain the quality of life described in your holistic goal.

If you want to have healthy, thriving land, you have to be a keen observer of the world around you and aware of how well the water and mineral cycles, energy flow and biological community are functioning. Knowing this will help you monitor the results of the decisions you make that affect the land. The next four sections will describe each of the ecosystem processes in greater detail, beginning with the water cycle.

Maximizing the Flow of Water Through Plants and Soils

The Water Cycle

Water is a finite resource that constantly cycles from the atmosphere to the earth and back to the atmosphere. The illustration on the next page shows the various paths taken by water falling on the land as rain, hail and snow. Some evaporates straight away off soil and plant surfaces back into the atmosphere. Some runs off into streams, rivers, dams, lakes, and eventually the sea before evaporating. Some penetrates the soil and of that a portion sticks to soil particles.

The rest flows on down to underground supplies. There it may remain for millennia or find its way back to the surface in river bank seepage, springs and bogs, or possibly through deep-rooted plants that pick it up and transpire it back into the air.

Of water held by soil particles, a small portion remains tightly held, but the bulk is either attracted to drier particles or drawn away by plant roots and transpired. Thus, one way or another all the water eventually cycles between earth and air.

Any water that penetrates the soil will be strongly attracted to drier soil particles. The water will keep moving until all of it has adhered to soil particles or passed on to underground reservoirs of free water.

Plants absorb water, and essential nutrients dissolved in it, through root hairs. They can do this as long as their ability to draw water can overcome the grip on the water exercised by dry soil particles. As drying particles yield less and less water, the plant slows its
growth rate. Eventually it begins to wilt in the heat of the day. Much can be done, however, to retain more moisture in the soil and thus extend the time during which plants can grow vigorously before wilting point is reached.

The key to an effective water cycle is the condition of the soil surface. If it is bare and/or capped, much of the water that soaks in will quickly evaporate, as the dry soil particles at the surface pull water from wetter soil particles below them. If the surface is covered with litter or closely-spaced plants, it will retain moisture and so will the soil particles below.

**Effective Water Cycles**

To sustain the maximum amount of life, in all but wetlands and true deserts, you need to maintain an effective water cycle in which plants can maximize their use of rainfall or melting snow. You want to manage in such a way that you create a situation where very little water evaporates off the soil, and any runoff that occurs happens slowly and carries little soil or organic matter with it. A good air-water balance exists in the soil, enabling plant roots to absorb water readily, as most plants require oxygen as well as water around their roots for optimal growth.

Most land managers know the average rainfall their land receives and manage accordingly. Unfortunately, rain can fall in higher and
lower amounts than average. An effective water cycle tends to even out these imbalances because when land is healthy the rain that does fall can be used much more efficiently. Effective rainfall soaks in and is available to plant roots, insects and microorganisms, and even replenishes underground water supplies. Very little runs off or evaporates off the soil surface.

**How To Create An Effective Water Cycle**

To enter the soil, water must first penetrate the soil surface—how deep will depend on the rate at which it is applied and the porosity of the soil surface. Management tools that break up a capped or thatched or sod-bound soil surface or increase the soil's organic matter speed up penetration. They create a surface that slows the flow of water, which allows more to soak in before running off. 

*More than any other single factor, an effective water cycle requires management that maintains the soil cover, followed by the buildup of organic matter, aeration, and drainage.*

When you have an effective water cycle, floods and droughts become fewer and less severe, even where rainfall is very erratic. The floods that do occur—as often happens with very high rainfall years or rapid snowmelt—tend to rise more gradually and subside more slowly. The floodwaters tend to be clear because they carry far less soil and debris.

The effects of droughts that do occur—as they will when there is little or no rainfall in the growing season—are far less severe because moisture received during the drought penetrates the soil more readily and is retained and used for a longer period of time. In general, an effective water cycle will ensure that far more water is available over a longer period of time for plant growth.

Effective water cycles have the following characteristics:
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- Soil surface is permeable, and the soil beneath the surface is well-aerated.
- Water runoff and evaporation losses off the soil surface are minimized.
- Seepage into underground aquifers is enhanced.
- The organic content of the soil is high.
- Transpiration by plants is high, and faster growth rates are achievable.
- Droughts and floods are less severe.

A covered soil surface is critical to creating and maintaining an effective water cycle.

**Non-effective Water Cycles**

When you have a non-effective water cycle, droughts occur more frequently and are much more severe because so much water is lost to evaporation or runoff. Good plant growth occurs, but only in short bursts, often a few days after a rain. Soon after this growth spurt, the plants begin to wilt and any growth is halted until the next rainfall. Plants start growing later in a new season since moisture from the previous season has not been stored in the soil. Rangelands and pastures produce far less forage and on croplands, crop yields are much less than they could be.

When rainfall is high or snow melts rapidly, floods often occur; but when you have a non-effective water cycle, they are much more severe. The greater the amount of bare ground, the higher the rate of water runoff. Bare soil can shed more than half the water falling on it—that's a lot of water that could be available for human and agricultural purposes and are now a water quality problem as manure or soil ends up in water sources where they shouldn't be, affecting many people and species within that watershed.

**Questions to Ask in Determining the Health of the Water Cycle on Your Land**

- In most of your pasture how wide is the plant spacing?
- As you look down between plants how would you describe most of the soil surface?
- Covered with litter, or bare and exposed to rain and sun?
- Capped, sealed and impervious, or broken and porous?
- Do you see signs of either xerophytic or hydrophytic plants, indicating an imbalance between air and water in the soil?
- Mostly plants with fine and narrow leaves or other signs of moisture conservation?
- Prevalence of micro-perennial grasses and or sedges in the pastures?
- Are most grass plants broad leafed and rapid growing?
- Do you notice shortly after rain that grass plants are dark green and growing rapidly or not?
Regardless of where the environment is on the brittleness scale, a non-effective water cycle has the following characteristics:

- Soil surface is exposed, sealed, or capped, and the soil beneath the surface is more compacted; both greatly reduce aeration.

![A Last Look at Effective and Non-effective Water Cycles](image_url)
- Water runoff is high and evaporation losses are very high through exposed soil surfaces.
- Decreased water penetration and increased losses through evaporation from exposed soil surfaces increase the severity of droughts, particularly in more brittle environments.
- Underground water supplies are diminished because water runs off or evaporates from the soil surface rather than seeping through into underground aquifers.
- There is lower organic content in the soil and thus poor aeration.
- Slower plant growth rates in all conditions, which leads to reduced production.

A covered soil surface enhances the effectiveness of the water cycle.

Conclusion

If your community is prone to flooding or water shortages, then based on what you've learned in this section, you know the water cycle is not effective and where to look to explain why it isn't. You'll learn next about the mineral cycle and its connections to effective water cycles.

Maximizing the Flow of Nutrients through Plants and Soils

The Mineral Cycle

Like water, minerals and other nutrients follow a cyclical pattern as they are used and reused by different organisms. Unlike the water cycle, however, it's much more difficult to see minerals in motion—we can watch water flow, soak in, run off, etc., but we can't do the same with nutrients as they flow through the system. It requires a different set of observational skills to watch for an effective, well-functioning mineral cycle. And, it is important to remember that the mineral cycle doesn't operate independently of the other three ecosystem processes. It is totally dependent on the dynamics of the communities of living organisms, and inextricably linked to the water cycle and energy flow. Remember, each of the processes represent a window looking in on the same room, the ecosystem.

You Do the Math

If 30 inches of rain were to fall on one acre of land, that would total 814,625 gallons of water. If a quarter of that water runs off, that's 200,000 gallons of water running off one acre of bare soil. If you multiply that figure by a million acres, the total amount of water running off would be over 200 billion gallons.

If you want to go metric then remember this simple formula: If 1mm of rain falls on 1 square meter of land, that would total 1 liter of water. Thus, a 10,000 hectare ranch that only gets 250 mm (10 inches) of rain would get a total of 2,500,000 liters of water per hectare (10,000 square meters per hectare x 250 mm = 2,500,000). That amount multiplied by 10,000 hectares is a great deal of water as long as you keep it in the soil to grow plants and replenish underground water sources!
A good **mineral cycle** implies a biologically active, living soil, with adequate aeration and energy underground to sustain an abundance of organisms that make up the soil food web (See diagram on page 10). Soil organisms need energy derived from sunlight, but often do not come up to the soil surface to get it for themselves. They depend on a continuous supply of decomposing plant and animal residues to provide their energy needs.

In order to be useful to humans, wildlife, and livestock, mineral nutrients have to be brought above ground by living plants. To gain maximum nutrient supplies in the active soil layers, minerals must continually be brought by plant roots and soil organisms to the surface from deeper soil layers. Then, after they're used above ground by plants and animals, they must be returned underground. There they will be held in the active root zones until used again or lost down to deeper depths.

**Reading the Land**

What do land managers look for in an effective mineral cycle? First and foremost, they look to see if the soil is covered either by living plants or plant litter. In non-brittle environments, breakdown is generally rapid because of the year-round presence of decaying organisms. But, land managers should look for a mix of plants with varying root depths so that nutrients can be brought up from many layers: fibrous-rooted grasses as well as the deeper-penetrating tap-rooted brush, forbs and trees. If the soil feels spongy when they walk across it, they know it is porous and likely to be full of life.

**Minerals to the Surface**

Plant roots are one of the main vehicles for bringing mineral nutrients to the surface soil layers. For a good mineral cycle, we need healthy root systems with many of those roots probing as deeply as possible into the lower layers of soil and decomposing rock. It's also important to have a variety of plant species in order to have many different root structures.

In the same way you'd recognize plants from above ground by their appearance, you can also identify them by their wide variety of root patterns. Some have abundant surface roots, while others reach deep beneath the soil itself into rock crevices and cracks, seeking water and nutrients, then move upward through the plant. Having a diversity of plants—balance between shallow-rooted and deep-rooted plants—is essential to the health of the whole community. Critically important trace minerals may be beyond the reach of shallow roots.
Plant roots aren’t the only vehicles transporting nutrients from underground to the soil surface. Earthworms, termites and other small insects along with rodents and other small animals also play an important role in mineral uplift.

**Above Ground to Surface**

![The Soil Food Web Diagram](image)

Once a plant has obtained nutrients from the soil (and sometimes the air), plant material—in the form of dead leaves, stems, bark, branches, seeds, flowers, crop residues, etc.—returns to the soil surface. Simply returning plant material to the soil surface doesn't make it immediately available for reuse. To be reused, dead material has to be broken down into fine particles, preferably by mechanical forces, such as rain, wind, hail, or trampling, or through consumption or decay by surface-feeding insects and other soil organisms or large grazing animals that convert the material to dung and urine. Sometimes plant material is broken down by fire or oxidation. When this happens, many of the nutrients take a gaseous form and the residue or ash is blown or washed away. At the same time, soil is exposed, which in turn reduces relative moisture and ultimately biological activity, both at the soil surface and underground.

Ideally, biological activity, rather than physical or chemical breakdown, should play the lead role in breaking down old plant material in all environments across the brittleness scale. There is one major difference, however. In non-brittle environments, the generally moist microenvironment at the soil surface supports very active communities of small organisms throughout the year. These
organisms can break down old plant material by themselves.

**Surface to Underground**

Once plant material has been broken down through biological activity, fire, oxidation, etc., how do the critical nutrients move underground? Two agents—water and animal life—bring this about naturally. This explains why when you're managing to enhance the mineral cycle, you will tend to apply tools that promote water penetration and animal activity.

One word of caution, however: the same water that carries nutrients underground can carry them down below the root zones of the plants you want to encourage. This process—called leaching—is often responsible for the loss of valuable nutrients, as well as a source of groundwater pollution. The primary factor that slows leaching is organic matter in the soil. The less organic material provided by dead plants and animals, and the less biological activity, the greater the tendency for leaching to occur. Leaching is more common in high rainfall areas.

**The Importance of the Soil Surface**

The key to the health of the mineral cycle—as with the water cycle—ultimately lies in the condition of the soil surface. As aeration decreases, so does life. As life decreases, so does organic material, which leads to a decrease in soil structure. As soil structure decreases, so does aeration. As this chain reaction ripples through the ecosystem, fewer plants produce less soil cover, increasing the amount of bare, capped soil.

Components of Soil Organic Matter
Adapted from The Soil Biology Primer, by Elaine R. Ingram, USDA Natural Resource Conservation Service

An ideal soil surface is one that is covered with closely-spaced living plants with mature, decaying plant material (litter) covering any bare ground between them. A good covering of litter between the plants (and on any other bare ground) will hold in moisture and regulate surface temperatures so that the many microorganisms present can carry out the breakdown process.

**Effective and Noneffective Mineral Cycles**

In the previous section we looked at effective and noneffective water cycles. What characterizes an effectively functioning
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mineral cycle? Take a look at the figure on page 30. Write down what you see happening in each picture. The table above will help you to read your land from the perspective of the mineral cycle. It outlines the characteristics of a good versus a poor mineral cycle and lists the indicators you will be looking for as you observe what’s happening on your land.

**Conclusion**

We’ve now looked at our ecosystem through yet another window—the mineral cycle. As with the water cycle, part of the future resource base description in your holistic goal should address how the mineral cycle must function. Even if you are not a land manager, effective ecosystem processes are important to sustaining what you have to produce to create the quality of life you want to live now.

**The Never Ending Development of Biological Communities (Succession)**

From the moment living organisms establish themselves in a puddle, on a rock, or on bare or recently disturbed soil, they begin to change their surroundings. Change begets change as the organisms interact with one another and with their microenvironment—the environment immediately surrounding them. Eventually a complex community made up of a great many life forms—from single celled microorganisms to large trees and mammals—develops, functioning as a
whole in an apparently stable manner.

Once any community has reached the highest level of development it is capable of, it can appear to remain stable for many years. However, when you examine it more closely, you notice the community is always in flux. Plants and animals are continually dying and being replaced.

Varying weather or other environmental conditions that promote the well-being of one species may diminish that of others. Because communities remain dynamic at every stage, we refer to the process of their never-ending development as biological community.

Soil Cover is Key

The key to the advance of any terrestrial biological community toward greater complexity is soil cover. When soil is bare and exposed, the community loses complexity and begins to break down. If bare soil is covered with living plants or dead plant material (litter), biodiversity and community complexity increases.

When a community is in the early stages of development, or is reduced from a complex to a simplified community of few species, it is less stable. Populations of a single plant, insect or small animal species can boom to annoying numbers, and we then label them weeds, pests, or invaders. The more complex and diverse communities become, the fewer the fluctuations in numbers within populations of species, and the more stable communities tend to be.

You can gauge a community's health by looking at the diversity of its species, the numbers within populations of those species and the age structure (how many young, adults, and old?) within those populations. The greater the diversity of species, the greater the complexity, which tends to promote greater stability within the community. If you want to protect a certain species, you can create an environment in which it thrives. Likewise, if you want to reduce the numbers within a species, you can create an environment that is less than ideal. In either case, look to the age structure to tell you which direction you're heading. If there are many young of the species in question, that species is likely to be increasing; if only mature members can be found, that species is likely to die out.

Communities of Wholes

You may recall that one of the key insights leading to the development of the Holistic Management® framework involved the concept of holism—that you can't influence one aspect of an environment or a community, without affecting many others. Each individual plant or animal is composed of billions of cells, each of which is also a whole. Individual plants or animals, in turn, belong to a whole community composed of many species, not simply to a whole population. It's important to make this distinction because a population of any one species doesn't represent an ecologically functioning whole. Its members cannot exist outside their relationship with millions of other species.

Some scientists suggest that our whole planet is a living organism that modifies the atmosphere surrounding it through the activity of biological communities on land and sea. It's incredible to think of ourselves—
individual, complex organisms comprised of trillions of diverse cells and cellular arrangements—as part of one large whole: the planet Earth.

We know that biological communities include all living organisms—from simple single-celled organisms to large animals, trees, corals, etc. This includes the complex web of life that exists within soils, where decomposing particles of rock, sand, clay and organic material interact. Many complex and mutually independent relationships exist among all levels—below and above ground and into the atmosphere.

Anything that changes above ground is likely to cause even greater changes below ground, simply because there's generally more life underground than above it. For example, a healthy pasture carrying large numbers of cattle has been calculated to carry a population of earthworms that alone are double the weight of the cattle. Likewise, the root structures of plants add to the biomass, as do the tons of microorganisms that inhabit an acre of healthy soil. It has been estimated that as many as a billion microorganisms live in a single teaspoon of healthy soil.

Changes in Biological Communities

The process of change in biological communities from bare rock or new pool to mature grassland, forest, or lake is a gradual, often staggered buildup of species diversity and biomass, along with changes in the microenvironment. This relatively orderly process of change has been given the name succession.

Complexity, productivity, and stability increase, and the microenvironment changes until something limits the progress of the succession. Often climate or other environmental factors obstruct further soil formation. Dry seasons, harsh winters, limited sunlight, and the amount and distribution of precipitation, define the kind of community that unhindered succession can produce. But whether the end result of this movement is jungle, desert, savannah, healthy productive lake, or coral reef, the community is always dynamic as deaths, decay, and rebirth foster ongoing change within it.

It's important to recognize just how much life exists beneath the soil surface. Excess soil compaction, exposure and capping of soil, inadequate drainage, over-fertilization, pesticide poisoning or other such actions alter the biological community below ground. And what happens underground will eventually show itself above ground.

The more complex and diverse communities become, the more stable populations within tend to be.
When do certain species thrive, in what numbers, and why? Typically a species will begin to appear and its population builds up as its requirements for establishment within the community are met. Communities are made up of numerous populations of other species, each of which have requirements for survival and each contributes something to the community. The continuing growth of this ever-evolving community encourages some populations to increase in number, as their needs are met. But as the community advances, a population may begin to decline as its requirements for growth and survival shift and are no longer optimal. The decline may continue to a point at which the species disappears entirely as the successional process moves beyond it. This rise and decline of various populations is part of the ever-changing dynamic of succession.

**Succession and the Brittleness Scale**

In non-brittle environments, succession starts with ease from any bare surface. The distribution of temperature and humidity promotes the rapid advance of succession nearly anywhere without the aid of physical disturbance.

**Management Implications**

Land managers who practice Holistic Management recognize the importance of biological community as they describe the future resource base in their holistic goal. The future resource base revolves around living organisms. Our food comes from living organisms, as do most of our diseases. Our landscapes include living organisms. It is critical that we learn to manage living organisms taking into account the community as a whole, rather than attempting to manage certain organisms in isolation.

If your holistic goal includes profiting from livestock or game, you may want a landscape that includes productive grassland. In a less brittle environment, that likely means preventing your pastureland from turning into forest. In either case, certain plants, insects, predators, and other forms of life may become either allies or foes, both of which you can increase or decrease through managing the successional process.

If you want to favor a particular species, then you need to direct the successional movement of the community toward the optimum environment for that species. (Simply protecting a species—though it may be an important interim step—will not necessarily save it. This will involve applying management tools that will produce an environment in which that species thrives. We'll talk more about using tools to manage the ecosystem in the Tools section of this guide.

If you start with a landscape that has large
numbers of undesirable species, the future landscape you describe will be one that is less than ideal for the problem species. Your task will then be to learn the basic biology of the various species. What stage in the life cycle is the species at its weakest point? What precise conditions does it need to survive at that weakest point? Knowing these answers will help you provide the conditions that greatly influence which species will increase in numbers and which will decline.

**Conclusion**

In forming your holistic goal, you must describe the land you are managing or influencing. You now have a better idea of how biological communities function, and you can better describe what you need: communities rich in plant and animal species, or biodiversity, and that refers to species both above and below ground. As you'll learn in the next section, what's visible above the ground will be an indicator of what's going on below ground. Knowing how to read the land will help you describe and manage for optimum energy flow—the fourth window on the ecosystem.

**Maximizing the Flow of Nutrients through Plants and Soils**

**Energy Flow**

All organisms require energy to live. And the vast majority of them depend on the ability of green plants to capture energy from the sun and convert it into a form they can use. Energy flow is simply the flow of solar energy through green, growing plants to all life, including humans.

The energy flow in our ecosystem is often confused with the carbon cycle, because the storage of energy in most living organisms involves carbon. But, where carbon is constantly cycling between earth and atmosphere, energy from the sun is a one-way flow. If we focus on the energy-carbon connection, then we miss a key understanding to managing the four ecosystem processes: that the natural living world runs on solar power and our management decisions dramatically affect how much is captured and put to use.

All life on the planet—including human civilization—depends on plants' ability to convert sunlight energy into edible form. It does this through the process of photosynthesis. Of all the various ways that power is converted for practical uses (for example photovoltaic, hydroelectric, wind and tidal power for electricity), only photosynthesis produces food for living organisms.

**The Energy Pyramid**

The flow of sunlight to food for life is often depicted as an energy pyramid. The figure on page 18 shows a basic energy pyramid.
Most of the sunlight that strikes the land and water is reflected back immediately, while some is absorbed as heat to be radiated back later. A very small portion is converted by green plants into food for their own use and that of other organisms in the food chain. Thus, green plants form the base or Level 1 of the energy pyramid and support almost all other forms of life, including humans.

On land, all of Level 1 energy conversion is at or above the soil surface, where algae and green parts of plants convert the energy. In water environments, what happens is slightly different. Around the shallow edges where plants can still grow and extend above the water surface, energy conversion still occurs as it does on land. Even over the rest of the area covered by a body of water, energy is still being converted by plant life far below the surface of the water, as far as sunlight can reach.

Level 2 represents the energy stored by animals that eat the plants on Level 1—fish, mammals, insects, birds, reptiles and humans. This energy is smaller than the amount expended as heat in the living processes of the feeders. This is no small amount—roughly 90% of the energy is lost as heat as you move from one level to the next.

Level 3 is the realm of predators—lower level carnivores including fish, birds and reptiles and, again, humans. This energy level, where those creatures who feed on eaters from Level 1 reside, is smaller still.

At Level 4, in addition to humans, we also find other predators dining on fish as well as those consumers that fed on Level 2. Again, the living processes of the feeders have diminished the bulk of the remaining usable energy by another 90 percent.

By Level 5, humans drop out of the pyramid. Scavengers and organisms of decay (decomposers) reduce the bulk of stored energy even further. Beyond Level 5, perhaps another level or two of decay organisms will use the last remaining useful energy and convert it to heat.

The energy pyramid is a useful diagram for understanding the principles of how sunlight is converted into forms useful to many living organisms. It isn't, however, nearly as tidy as depicted here. At all levels, a portion of the energy passes straight to decay level as waste products from animals and through microorganisms feeding on plants. With the high loss of energy at each level, the pyramid is probably flatter than shown in the diagram. However, the concept of ever increasing loss of energy at each level is consistent.

The energy pyramid also extends below ground (as shown on page 20) where the energy flow greatly affects the function of the other three ecosystem processes—water cycle, mineral cycle, and biological community. All three require a biologically active soil community that in turn requires solar energy to be conveyed underground by plant roots or surface-feeding worms,
termite, dung beetle, and other organisms.

**The Energy Tetrahedron**

The four key insights that led to the development of Holistic Management (which were outlined at the beginning of this guide) allow us to take this two-dimensional picture of energy flow and develop a model that allows for a more sophisticated way of managing energy flow. We begin to understand that if we can broaden the base of the triangle, which the face of energy pyramid represents, we can increase the size of the whole structure and have more energy available for use at every level. The two-dimensional model on page 20, showing energy above and below ground would indicate that there are very few ways of broadening the base.

Based on what we know from the four key insights, we have come to view the energy pyramid as two tetrahedrons joined at the bases (labeled A, B, and C) as illustrated on page 21. This three-dimensional pyramid shows that we now have options for greatly increasing energy flow at the vital first level: the soil surface. Level 1 now has three sides, which we'll refer to as time, density, and area.

On land, the right management can increase the volume of energy stored at Level 1 by doing three things:

- Increasing the *density* of standing vegetation on a unit of ground;
- Increasing the *time* during which the vegetation can grow and the rate at which it can grow; and
- Increasing the *leaf area* of individual plants to capture more energy.

Clearly, if we extend any of the three sides of the base, the greater the volume of energy humans can harvest at levels 2, 3,
and 4. On the other hand, shortening any single side decreases the amount of energy available for harvest all the way up the levels. The same ripple effects happen below ground as above.

**Duration and Rate of Growth (Time)**

The energy converted by plants while they are green and growing must support all life above and below the soil surface throughout the year. The longer plants are growing, the more productive the community as a whole. We can increase the growing time by lengthening the growing season or by increasing the growth rate within a given time. In practice, enhancing the mineral and water cycles and increasing the complexity of the biological community will extend the growing time in both ways (lengthening the season and increasing growth rates). For example, some farmers have extended their growing seasons from 180 days to 210.

In managing grasses, the growing time can also be used more efficiently if the bulk of the grazed plants are not taken down too far. The less taken from a plant during it’s active growth, the faster it regrows.

Growing time is affected by the effectiveness of the mineral and water cycles, as well as the complexity and diversity of species in the biological community. For example, in pastures, you’d want a mixture of both cool and warm-season grasses—enough to ensure that you are maximizing the length of the growing season. Pastures that have been poorly managed can be monocultures and few perennials exist to convert energy to fuel the rest of life around them. A change in management and the application of different tools could bring back more perennials and restore months of productivity to those pastures.

**Density of Plants**

The density side of the base refers to the number of plants growing on each square yard of land. Ten plants growing on the average square yard of ground can probably convert more solar energy than three plants per square yard. Farmers and ranchers have long been aware that plant spacing, or density, can greatly affect energy flow in their fields and have planted accordingly—striving for density that produces high yields.

In less brittle environments, plant spacing, even out in the wild, is relatively close. This is a function of the climate. Even though management can affect it, plant density is naturally high. However cropping is the exception to the rule and tillage practices are often used to keep soil bare rather than look at companion planting techniques or increasing soil health and aeration to allow for closer plant spacing.

**Area (of Leaf)**

Leaf area matters because a very dense stand of narrow-leafed plants may trap less energy than a moderately-dense stand of broader-leafed plants. So, if you want to expand the area side of the base, you would have to increase the number of broad-leafed plants.

In order to increase the energy tetrahedron, you may need to shift the plant community...
to include species that spread broad leaves to the sun and grow fast. In general, an effective water cycle will result in more broad-leafed grasses and forbs with faster growth rates. In addition to causing grass plants to grow more closely together, animal disturbance (impact) and severe grazing (versus overgrazing) cause many species to produce more leaves and less fiber, which in turn increases the flow of available energy to animals and humans.

**Conclusion**

In terms of your holistic goal, when describing the land in your future resource base, you will want to include what it would be like if energy flow were high. The soil would be covered in vegetation, plants would stay green and continue to grow much longer than they do now, and there would be a variety of plant species. Wildlife would be more plentiful and diverse as a result. In essence, if the water cycle is effective, minerals are cycling rapidly, and biodiversity is high, then energy flow will tend to be maximized.

Land managers are looking for and will describe a situation where the highest energy flow is achieved and sustained, whether on cropland, rangeland, or forest. In most cropland situations, you would strive to manage for an effective water and mineral cycle, and for a highly complex biological community (above and below ground), all of which will result in a high and sustainable energy flow.
On croplands, you would seek to maximize the time side of the tetrahedron's base by ensuring good daily growth rates and lengthening the season through polyculture cropping or at least two or more crops per year whenever possible. You would maximize density by planting with close spacing. You would strive to maximize the area of leaf that is open and exposed to the sunlight by creating good drainage, abundant organic matter in the soil and good crumb structure, and by providing adequate soil cover.

In most pasture situations, you would increase energy flow by manipulating the tools of grazing and animal impact, with both livestock and wildlife to produce and maintain maximum growing time, plant density and leaf area. The amount of energy you might have to buy from other producers on other land—to supplement what our own land doesn't provide—would be the measure of success or failure.

Finally, in most forest situations, you would strive to maximize energy flow by improving water and mineral cycles and by increasing the diversity of plant and animal species. This is particularly true in forests that have been simplified through industrial style forestry practices. And in aquatic environments, you would maximize energy flow by reducing pollution, sustaining highly complex biological communities and ensuring that on the land that surrounds them, and catches much of the water that feeds them, water and mineral cycles and biological communities are healthy.

Having looked through the fourth and final window, you now have gained a better understanding of how the water cycle, mineral cycle, biological community and energy flow function within the ecosystem that sustains us all.
Questions, Exercises, Resources

Quick Quiz

Answers to quiz appear at the end of this section

1. Holistic Management enables you to make decisions that balance ________________________, and _______________________. We call this the triple bottom line.

2. Which of the following statements are true about the Holistic Management® principles
   A. A holistic perspective is essential in management.
   B. Environments exist on different ends of a scale depending on how well humidity is distributed throughout the year and how quickly dead vegetation breaks down.
   C. All of the above are true.

3. The four ecosystem processes include:
   (a) ________________________,
   (b) ________________________,
   (c) ________________________,
   (d) ________________________.

4. True or false: A covered soil surface is vital to a healthy ecosystem.

5. How can you tell when a biological community is healthy?

   By looking at the __________ of its species, the __________ within populations of those species and the________________________ within those populations.

6. True or false: Bare soil is an indicator of a poor or ineffective water cycle.

7. True or false: Plant roots are the main vehicles for bringing nutrients to the soil surface.

8. True or false: In less brittle environments managers do not need to be worried about with bare and exposed soil surfaces.

9. Each statement below describes an aspect of the mineral cycle. Note if the statements indicate an effective or Non-effective mineral cycle, by writing the letter E or N in the spaces below.

10. ______________________________ is the process by which green plants use sunlight to synthesize nutrients from carbon dioxide and water.
**Creating Healthy Land: The Four Ecosystem Processes**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Effective or Non-Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil surface is porous and rich in organic matter</td>
<td></td>
</tr>
<tr>
<td>Shallow plant roots, many lacking deep penetration</td>
<td></td>
</tr>
<tr>
<td>Surface litter cover is sparse and immature, oxidizing material rests on the soil surface</td>
<td></td>
</tr>
<tr>
<td>Soil underground is porous, with abundant underground life</td>
<td></td>
</tr>
<tr>
<td>Plant spacing is wide, with large areas of exposed soil present</td>
<td></td>
</tr>
<tr>
<td>Rapid turnover of plant material, and old vegetation breaks down readily</td>
<td></td>
</tr>
<tr>
<td>High losses of minerals off the surface as well as losses due to leaching</td>
<td></td>
</tr>
<tr>
<td>Large numbers of surface insects and microorganisms present</td>
<td></td>
</tr>
<tr>
<td>Low mineral turnover rate</td>
<td></td>
</tr>
</tbody>
</table>

11. Which of the following statements is true of succession?
   A. Moving succession backwards from a mature community to an earlier stage is always bad.
   B. Succession on any land taken back to bare soil can skip stages and return quickly to a higher community because soil is still there.
   C. Succession in grasslands is poorly understood because the focus of keeping grasses in a highly vegetative state is considered critical for animal performance.
   D. All of the above

12. When we look at the energy tetrahedron (three dimensional model), we can increase the volume of energy stored at Level 1 by doing three things:

   A. Increasing the __________________ of standing vegetation on a unit of ground;

   B. Increasing the ___________ during which the vegetation can grow and the ________ at which it can grow; and

   C. Increasing the ______________ of individual plants to capture more energy.
Questions for Deeper Thought

1. Identify the role soil cover plays in each of the ecosystem processes by responding to the following questions.

   A. How does soil cover affect the functioning of the water cycle?

   B. How does soil cover influence effective functioning of the mineral cycle?

   C. What role does covered soil play in biological community/succession?

   D. How does soil cover affect energy flow?

2. What roles do grazing animals (correctly managed) play in maintaining a healthy mineral cycle?
3. In your holistic goal’s vision statement, how would you describe the land you are managing (or that surrounds you) in terms of the four ecosystem processes?

4. Take a look at the energy pyramid below. Fill in the blanks on the diagram, being sure to also label each of the levels in which energy is used. Write the letter H next to each of the levels where you would find humans.
Exercise: What’s Happening Here?

Given what you’ve just read about effective and non-effective water cycles, look at the picture below and answer the following questions:

1) Is the water cycle effective or non-effective?

____________________________

2) Describe what’s happening to the water in this picture.

____________________________
____________________________
____________________________
____________________________

3. Describe the soil surface – what do you notice about it? What’s happening at and beneath it?

____________________________
____________________________
____________________________
____________________________
____________________________
Exercise: Effective or Non-Effective? Part Two

Now take a look at the picture shown here and answer these questions

1. Is the water cycle effective or non-effective?

2. Describe what’s happening to the water in this picture.

3. Describe the soil surface—what do you notice about it? What’s happening on and beneath it?
Creating Healthy Land: The Four Ecosystem Processes

Energy Lost as Heat

1. __________________

2. ________________

3. __________________

4. __________________

5. __________________

6. ________
Based on what you’ve learned about the mineral cycle, which of these two pictures depicts an effective mineral cycle?

1. Describe what’s happening above and at the soil surface—what do you notice?

2. What’s happening beneath the soil surface?

Answers to Quiz: 1) social, economic, & environmental; 2) E; 3) water cycle, mineral cycle, energy flow, & community dynamics; 4) T; 5) diversity, number, and age structure; 6) T; 7) T; 8) F; 9) E, N, N, E, N, E, N; 10) Photosynthesis; 11) C; 12) A. amount, B. time, C. leaf area.