

INVESTIGATION
**The Fenceline Photo:
Seeing and Understanding Changes
in Landscape Function**

Grade Levels: 2nd through Adult

Time Required: 45 minutes to 3 hours



Photo Credit: Kroon Family

Summary: This photograph of two neighboring but differently managed landscapes—one in the process of desertification, and the other in the process of grassland regeneration—offers a wonderful entry point for a discussion of whole systems landscape function and the impact of management on natural systems. This first investigation starts with learning to see flows of water, carbon, nutrients, and heat through the matrix of soil and plants. (In the second investigation, participants will engage in a “forensic” group discussion to figure out what happened in this landscape, and why.)

Participants make as many observations as they can about the photo, then answer a series of questions that get them to think about the structure and function of the land on either side of the fence. For example:

- › *If it rained, which side do you think water would evaporate on more quickly, and why?*

- › *Which side do you think is accumulating more carbon in the soil over time, and why?*
- › *If you buried a pair of cotton underpants in the soil on each side, which would biodegrade faster, and why?*

In the process, participants learn to notice and interpret signs and symptoms of change over time in a grassland ecosystem. They finish this investigation by guessing what happened to make the landscape so different on each side of the fence, as preparation for the next investigation.

Materials

- ✓ Projector for large class, *or* large print-out of the Karoo fenceline photo image, *or* a computer that everyone can gather around to look at the image (for small class)
- ✓ PowerPoint slide of the Karoo fenceline photo (available at www.soilcarboncoalition.org/learn)
- ✓ A bell or other sound to begin and end the observation period

Purpose:

- To heighten visual observational skills of whole-systems landscape function
- To provide a context for understanding feedback loops and relationships between the carbon, water, and nutrient cycles in actual landscapes
- To develop skills in evaluating human impact on natural systems
- To engage students in a discussion in which they can share observations and ideas, and develop individual and group hypotheses

Goals:

Participants will be able to:

- Compare details of a degraded grassland with a regenerated grassland
- Begin to see flows of matter and energy—such as water, carbon, nutrients, sunlight, and heat—in two different landscapes based on visual cues
- Use visual cues to roughly compare the structure and function of two neighboring landscapes in terms of:
 - carrying capacity
 - soil compaction/density
 - soil temperature
 - ambient temperature
 - nutrient cycling
 - carbon gain or loss



- moisture-holding capacity of soils
 - evapo-transpiration
 - biological diversity
 - socio-economic value
- Use these comparisons to begin to evaluate the human impact of different land management strategies on a natural system.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:

HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species

Science and Engineering Practices:

Analyzing and Interpreting Data; Engaging in Argument from Evidence; Obtaining, Evaluating, and Communicating Information; Constructing Explanations and Designing Solutions; Asking Questions and Defining Problems

Disciplinary Core Ideas:

LS1.A Structure and Function; **LS1.C** Organization of Matter and Energy Flow in Organisms; **LS2.A** Interdependent Relationships in Ecosystems; **LS2.B** Cycles of Matter and Energy Transfer in Ecosystems; Ecosystem Dynamics, Functioning and Resilience; **LS4.C** Adaptation; **LS4.D** Biodiversity and Humans

Crosscutting Concepts:

Patterns; Cause and Effect; Systems and System Models; Energy and Matter: Flows, Cycles, and Conservation; Structure and Function; Stability and Change



Common Core State Standards

SL 9-10 and 11-12.1

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

SL 9-10 and 11-12.4

Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

RST 9-10.7

Translate information expressed visually or mathematically (e.g., in an equation) into words.

RST 11-12.9

Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.



ACTIVITY

Observing

Quietly observing all the details of a landscape before attempting to make meaning out of one's observations is a step that is often overlooked when evaluating landscapes or other complex systems. This helps to focus the participants' minds, and create a neutral baseline from which the group can build a fresh perspective. Without this step, people will tend to notice only those things that fit the constructs they already have, and will jump to conclusions about what is happening based on an incomplete set of details. It is also a simple and inviting exercise that all participants can participate in equally, regardless of their previous knowledge base.

Tell the group:

- › *When I ring this bell, I'd like you to take one minute of silence to notice everything you can see in the picture: colors, shapes, textures, details. You'll see things you know the names of and things you don't know the names of. After one minute, I'll ring the bell again, and then we'll list off everything we are seeing.*

After one minute, ask:

- › *What do you see here? What do you notice? Let's go around the room and each person can say one thing.*

Participants may notice things like: A fence, with barbed wire. On the right there is bare soil and just a few plants. On the left there is a lot of grass. Yellow and white flowers. Trees in the distance. There are some tire tracks in the grass. Hills in the distance, a clear blue sky....

Write their answers on the board. If people try to come to conclusions about what they are seeing, direct them back to the task at hand: to simply collect a set of observations.

Keep asking "*What else do you see?*"

Focusing Questions

This next set of questions is intended to get participants thinking about various elements of landscape structure and function. Most people haven't thought much about these things, even though they have experienced them in a multi-sensory way while walking outdoors, digging, watching rainstorms, etc., and likely we all have some cultural or genetic memory of them from times not that long ago when human survival depended more acutely on connecting visual cues to read land and weather.



As you listen to your group discussing these questions, you will get a sense of their current level of understanding, but keep in mind that this may grow considerably as they hear each other thinking out loud during this exercise.

- **NOTE:** It's okay if they don't get everything right. In fact, for most groups, rather than correcting participants as they go along, you will probably engage them more deeply by simply letting them answer all the questions in whatever way they think is correct (allowing them to debate a bit between themselves) and saying nothing more than "*hmmm... interesting!*" yourself.

However, I have included brief answers so that later on, you can return to the points where participants were way off. At that point you can discuss the questions in more detail, and help them to rethink and adjust their working models of how landscapes function.

You can have participants discuss the questions in small groups first, if you have time, and then share in a larger group discussion, but either way is okay. There are several places in the list where similar questions circle back around again—this is on purpose, as the information may start to make more sense when participants hear it again in a different context.

Another good question to add onto some of the more experiential questions, is "*What experience do you have that gives you that idea?*" or "*What makes you think that?*" (with a light and interested tone.) I have left that off of the list, other than in the first two examples, simply to save space, but keep it in mind as an option to help students make connections.

Ask some or all of the following questions, depending on the age and experience of your group.

Sunlight, Temperature, and Heat

- › *Which side do you think would be hotter to stand on? What experience do you have that gives you that idea?*
The right side would be hotter.
- › *If it rained, which side would evaporate faster? Why? What makes you think that?*
The right side would evaporate much faster primarily because soil temperature is higher.



- › *How would that evaporation impact the amount of water getting to the plant roots?*
A lot less water getting to plant roots.
- › *Which side do you think gets more sun?*
Partly a trick question, but helps to get them oriented—and some may correctly note that the soil on the left is absorbing less heat from the sun, but also creating more with the sun that it gets.
- › *What is the sunlight doing on the left side?*
Lots of photosynthesis—creating more life.
- › *What is the sunlight doing on the right side?*
Lots of heating of soil and evaporation of water, not much photosynthesis.
- › *If the air temperature was 90 degrees Fahrenheit, what do you think the soil temperature would be on each side?*
The soil temperature would likely be higher than 90 degrees on right, and lower than 90 degrees on left.
- › *If a whole continent changed to become more like the right side, would you expect that continent to be cooler or warmer than one that looked like the left side? Why?*
Hotter, for a variety of reasons, including that ambient air temperatures would be affected by higher soil temperatures.
- › *What places in the world look like the right side? What are typical temperatures and rainfall there?*
- › *What about the left side?*

Plant Cover

- › *Which side has more plant cover?*
- › *In what ways do you think the increased plant cover on the left would impact the soil temperature?*
It would lower the temperature by shading the soil, reflecting more of the incoming solar radiation via the albedo effect, by keeping the soil more moist, and cool the area through transpiration.
- › *How would the plant cover affect water infiltration into the soil?*
Plants and plant litter create millions of tiny dams that keep water in place for longer, allowing it to infiltrate, cool the soil so that water doesn't evaporate as quickly, and reduce the compacting effect of raindrops hitting the soil.



- › *Which side do you think has more roots in the ground?*
- › *How do plant roots affect water infiltration into the soil? Why?*
Plant root exudates and decomposing plants feed a variety of soil microbes and other living things that all help to create soil aggregates with pore spaces between them—so soil is more like a sponge. As roots die off, they also leave open channels in the soil where water can move.
- › *Where is there more transpiration happening?*
- › *What effect do you think that has on the ambient temperature and local weather?*
It dissipates heat from the surface to the atmosphere via latent heat fluxes creating a cooler ambient temperature. Depending on other factors it could also help draw rainclouds to the area by creating a cooler and/or lower pressure air column.

Water

- › *Which side would rain have an easier time soaking into the soil? Why?*
The left side. Pore spaces in covered soil stay open during rain and have less crusting from rain impact. Plant cover and plant litter creates millions of tiny dams that keep water in place for longer.
- › *Which side do you think is holding more moisture in the soil? Why?*
The left side, for a variety of reasons including less evaporation, more pore space due to root and microbial activity.
- › *What might the combined effect of increased soil moisture and increased transpiration have on the creation of water vapor?*
Because the plants have more water to draw from in the soil reservoir, and there are more plants overall, the left side would create more water vapor through transpiration.
- › *If the land was sloping, which side would the water run off of more quickly?*
The right side.
- › *Which side would be more prone to flooding?*
The right side, because the rain is less likely to soak in to the soil.
- › *Which side would be more prone to drought?*
Again, the right side because rain is less likely to soak in to the soil—it is very common for there to be both flooding and drought in the same landscape, and for similar reasons.

- › *Which side do you think plants have easier access to water? Which side would there be more competition for water?*

The plants on the left would have easier access to water, even though there are more plants. Likely more competition on the right due to less available water in the soil.

- › *Which side do you think gets more rain?*

Partly a trick question to highlight the fact that one can have very different landscapes with the same inputs of rain. However, some may take the question and imagine a larger landscape and correctly point out that the plant life will influence the water cycle in the area—therefore it is possible that the left side does actually get more rain.

Soil Structure and Density

- › *On which side do you think the soil is more compacted, has less pore space, and has higher density?*

Likely the right, because it has fewer plants, which means there is less life in the soil to create aggregates and pore space—plant roots, microbes, worms, etc.

- › *Which side do you think it would be easier to push a metal probe into?*

Left.

- › *Which side do you think has better aggregate structure? (i.e. which is more like flour, and which is more like bread?) Why?*

The left probably has better aggregate structure because plant life above ground feeds microbial life below ground that, in turn, creates soil aggregates.

- › *If you weighed a cup of soil from each side, which do you think would be heavier?*

Probably the right, because there is likely less pore space, so it is more dense and compacted.

- › *How do you think it got that way?*

In a desertifying landscape, the lack of plants reduces the food source for underground life, which means that there is no mechanism for the mineral particles—sand, silt, and clay—to form, maintain, or regenerate aggregate structure and other pore spaces from worms, insects, small mammals, etc. The mineral particles become prone to compaction from rain impact, collapse of biologically maintained structures, hoof impact, vehicles, or other forces.

Carbon

- › *Which side looks more alive? Why?*
- › *Which side do you think has more carbon in the biomass above ground? How about in the soil below ground? Overall?*
The left, both above and below ground.
- › *Where is the carbon?*
In the living things, the dead things, and the very dead things...plants, animals, fungi, microorganisms, viruses, and soil organic matter (humus and glomalin.) Also in the air, in the form of CO₂. Possibly some calcium carbonate in the soil if this used to be an ocean or lakebed.
- › *Which side do you think is accumulating more carbon in the soil over time? Why?*
Probably the left, due to more plants, therefore more root exudates decomposing plant litter feeding soil life and accumulating organic matter and soil carbon.
- › *If most of the land mass in the world looked like the right side, would we have more or less CO₂ in the atmosphere than if it looked like the left side?*
Probably there would be more CO₂ in the atmosphere, because there would be less photosynthesis happening, more oxidation happening, and less carbon in the soil and in living things.

Nutrient Cycling

- › *If you buried a pair of cotton underpants on each side, which pair do you think would biodegrade the fastest? Why?*
Likely the pair on the left would biodegrade faster, because a landscape with more plants will generally have more microbes in the soil that can decompose plant-based organic matter, and cotton is made out of plants.
- › *If a plant died on the left and on the right, what do you think would happen to each plant, and the carbon in each plant, and why?*
The plant on the left would likely be decomposed by soil microorganisms, and at least some part of the plant's carbon would become relatively stable soil carbon, with some of it also being respired by soil organisms. The plant on the right would likely dry up and decompose more slowly, though the mechanisms are not entirely understood, it would include oxidation through a slow "burning" from ultraviolet light and heat, with more of the carbon



returning to the atmosphere as CO₂, and less of the plant's carbon going back into the soil. The carbon in the plant on the right would also be at more risk to oxidize through natural burning from fire, due to the dryness of the landscape.

- › *The mineral substrate (and content) of the soil is the same on both sides. Do you think one side would grow food with more minerals and other nutrients in it? If so, which side?*
Likely the left side
- › *How is that possible if the mineral content is the same?*
Because the additional plants are feeding more microorganisms—such as mycorrhizal fungi and nitrogen fixing bacteria—in the soil, which in turn help the plants gain access to the nutrients.
- › *Which side could support more grazing animals on it?*
The left.
- › *Which side do you think the animals would be healthier on? Why?*
Probably on the left: more food/forage, more nutrient density in the forage, more water available within the forage, cooler ambient and soil temperatures and therefore less stress.

Biodiversity

- › *Which side do you think has more biodiversity of animals, insects, plants, fungi, and microorganisms?*
Probably the left side, but not necessarily.
- › *How about underground?*
Hard to say as there are microbial communities in all sorts of settings.
- › *What kinds of animals would prefer to live on which side?*
- › *What animals could survive on one side, but not on the other?*
- › *If the whole region changed to look like the right, or the left, how would do you think the species living there would respond?*
Some might adapt, some would move to another region, some would flourish, new species might move in, and some could risk extinction.
- › *What sorts of species might be at particular risk?*
Various answers, but in particular any species that are uniquely adapted to that particular niche.



Socio-economic

- › *Without changing anything, which side do you think is capable of producing more food for human consumption? Why?*

The left is well suited for grazing animals, as long as there is a water source. The soil is almost definitely more fertile and has better water infiltration on the left as well, so growing crops would likely be more easy on the left.

- › *If the price of the two pieces of land was the same, which one do you think would be better to invest in, and why? What would you do with it if you were an investor?*

Feedback Loops

- › *What sorts of feedback loops do you think are happening in the two landscapes?*

Various, but one example would be lack of water infiltration is making it harder for plants to grow on the right, which in turn makes water infiltration even harder.

- › *How are the different parts we have discussed influencing each other?*

Many possible answers, for example: the lack of grass on the left makes it harder for grazing animals to live there, which changes the microbial ecology of the soil due to lack of dung, which then changes the rate of decomposition of organic matter as well as the soil moisture.

What happened?

Ask participants to get into pairs or groups of three and answer these questions:

- › *What do you think the story is behind this picture?*
- › *What do you think happened to make it so different on the two sides of the fence?*
- › *What are all the possible explanations for the difference on the two sides?*

Large Group Discussion

After they have a chance to think in small groups, encourage an open brainstorming session, without critique, of all the possible reasons this landscape might have gotten to look so different on two sides of the fence. Take notes on the board of all the ideas, making it clear that you are just collecting ideas.

Once you have at least 8 reasons on the board, allow them to discuss the possible explanations they have come up with, and build on each other's ideas.

Participants may become focused on the tire tracks and the fence—as a sign of human intervention, which is correct: the two sides are both being managed by humans, in different ways. (The tire tracks are on both sides of the fence, if you look carefully.) They may make guesses about animal impact, which is correct, animals have influenced the landscape. They may think that one side has had more fertilizer and other chemical inputs put on it, seeds purposefully planted in it, or that one side has been irrigated.

Ask each small group to regroup and come up with three questions:

- › *What are three “yes” or “no” questions you would most want answers to, in order to make a reasonable guess about what happened here? For example, “Did anyone plant seeds?” “Did they used to look the same?”*

Make a list of the questions.

After this discussion, tell them:

“These are two neighboring sheep ranches in Africa. At first, the whole landscape looked somewhat like the left, then the whole landscape looked like the right side. Now they look different. Our mystery is, who did this?”

Tell them that the next time you meet, they will do some “forensic” sleuthing work together to figure out what happened.

Follow up

The facilitator should watch Allan Savory’s TED talk “How to Green the World’s Deserts and Reverse Climate Change” before the next meeting.

