

Rain, Grass and Pronghorn: Ten Years on the Sage Flats

Learning target: I can graph and calculate from a dataset to show how a resource (grass) depends on rainfall and how a population (pronghorn) depends on that resource, and I can say what the data can and cannot prove.

Data and graphing

About 45 min

Individual

MS-LS2-1 · assesses

data analysis

independent practice

Standards connections

MS-LS2-1 (assesses): Students analyze and interpret a ten-year dataset to provide evidence that resource availability (grass, driven by rainfall) affects the size of a pronghorn population during abundant and scarce years. This is the PE as written, using clearly labeled simulated data.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

Part A: The dataset

A wildlife team watched one valley, the Sage Flats, for ten years. Each year they recorded the total rainfall, clipped and weighed the grass that grew on sample plots to estimate how much grass the whole valley produced (in kilograms per hectare; a hectare is a square 100 meters on each side), and counted the pronghorn herd from a small plane in late summer.

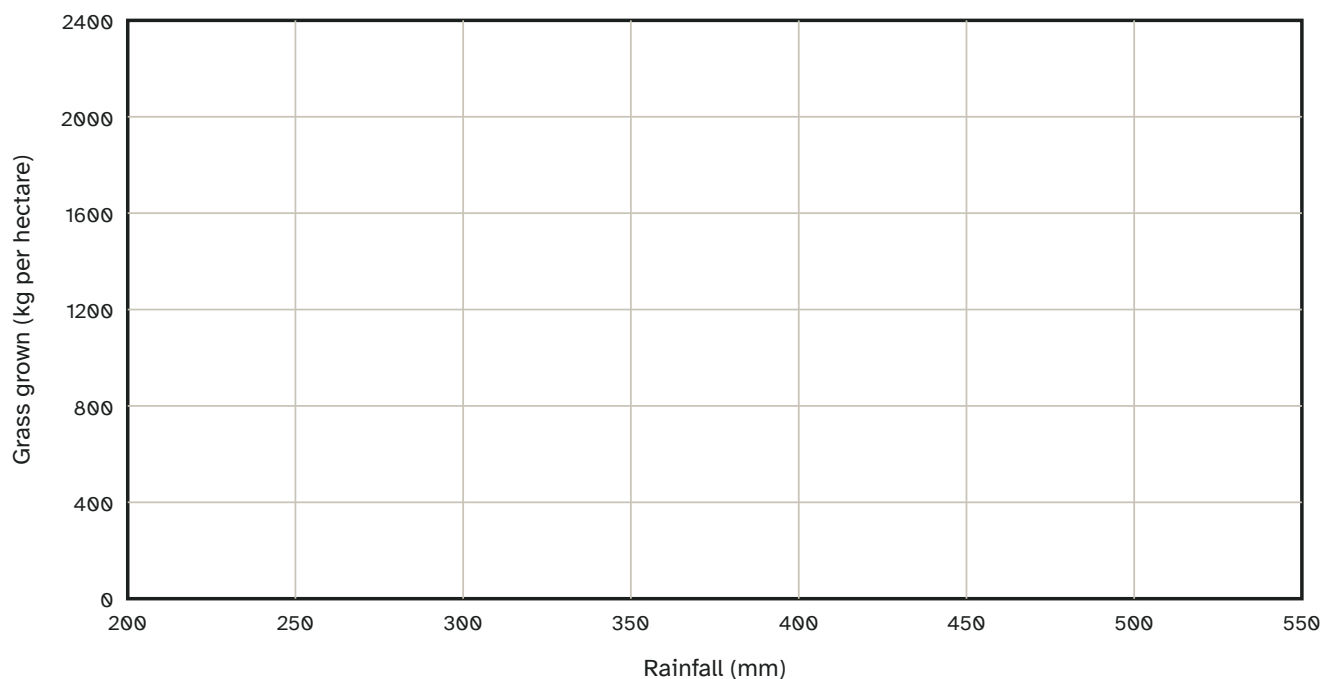
Sage Flats: rainfall, grass and pronghorn, Years 1-10 (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Year	Rainfall (mm)	Grass grown (kg per hectare)	Pronghorn counted
1	350	1400	120
2	420	1700	128
3	480	1950	142
4	300	1150	160
5	250	950	138
6	380	1500	112
7	450	1800	118
8	520	2100	136
9	510	2050	158
10	330	1300	172

Simulated data for teaching. Rainfall is the yearly total; grass is the amount grown that year; pronghorn is the late-summer count.

Grass grown versus rainfall (one point per year)



1. Find the range of rainfall (wettest year minus driest year) and the range of grass grown (most minus least). Name the years.

Answer: Rainfall range: 520 mm (Year 8) – 250 mm (Year 5) = 270 mm. Grass range: 2,100 kg/ha (Year 8) – 950 kg/ha (Year 5) = 1,150 kg/ha.

Why: Both maxima occur in Year 8 and both minima in Year 5, which already hints at the relationship.

Also acceptable: None; both differences are exact.

2. Grass is recorded in kilograms per hectare, not as a number of plants. Explain what this unit measures and why it is a more useful measure of the pronghorn's food supply than counting grass plants.

Answer: Kilograms per hectare is the mass of grass grown on each hectare of land, a measure of how much plant material (biomass) the valley produced. It is more useful than counting plants because grass plants vary enormously in size and many plants are clumps that are hard to separate; what a pronghorn needs is the amount of food, and mass measures that directly.

Why: This item makes the unit explicit; the textbook's own graph labels biomass as 'population size,' which is a mislabel worth correcting.

Also acceptable: Accept 'how much grass there is to eat on each hectare.'

- Mass per area
- Explains that mass measures the food supply better than a plant count

3. Describe the pattern in your graph. How close do the points lie to your line, and what does that tell you about the relationship between rainfall and grass?

Answer: The points rise from lower left to upper right and lie very close to a single straight line; no point is far off. This means grass grown is strongly and consistently related to rainfall across these ten years: more rain, more grass, in nearly fixed proportion.

Why: In the simulated data every point lies within about 50 kg/ha of the line $\text{grass} = 4 \times \text{rainfall}$.

Also acceptable: Accept 'almost perfectly proportional.'

- Rising, straight-line pattern
- Points close to the line
- Interprets as a strong relationship

4. Calculate the grass grown per millimeter of rain for Year 1 and for Year 8 ($\text{grass} \div \text{rainfall}$). Show both calculations with units. Are they close?

Answer: Year 1: $1,400 \text{ kg/ha} \div 350 \text{ mm} = 4.0 \text{ kg/ha per mm}$. Year 8: $2,100 \text{ kg/ha} \div 520 \text{ mm} \approx 4.04 \text{ kg/ha per mm}$. Yes, they are nearly identical (about 4 kg of grass per hectare for every millimeter of rain).

Why: A nearly constant ratio across the driest-to-wettest span is the numerical form of the straight line.

Also acceptable: Accept 4.0 and 4.0 if rounded.

5. Using the rate from q4, predict how much grass would grow in a year with 400 mm of rain. Show the calculation. Then check your prediction against your line on the graph.

Answer: $4.0 \text{ kg/ha per mm} \times 400 \text{ mm} = 1,600 \text{ kg/ha}$. On the graph the line passes through about 1,600 at 400 mm, so the prediction matches the line.

Why: Interpolation within the measured range (250-520 mm) is justified by the tight linear pattern.

Also acceptable: Accept 1,580-1,620 from reading the drawn line.

Part B: From grass to pronghorn

6. Look at the pronghorn column. The wettest, grassiest year was Year 8, but the herd was largest in Year 10. Compare the grass column with the pronghorn column year by year and describe the pattern you find. Then suggest a biological reason for it. (Hint: fawns are born in spring, and a female's health in the previous year affects how many fawns survive.)

Answer: The pronghorn count follows the grass with a one-year delay: Year 3's high grass (1,950) is followed by the Year 4 rise to 160; Year 4 and 5's poor grass (1,150 and 950) are followed by drops in Years 5 and 6 (138, 112); the recovery in grass from Year 6 on is followed by rising counts from Year 7 on; Year 9's good grass (2,050) is followed by the Year 10 peak of 172. Biological reason: this year's grass affects how well-fed females are going into winter and how many fawns are born and survive the next spring, so the count responds the following year.

Why: Students must look across the two columns row by row. The lag is deliberate in the dataset: each count tracks the previous year's grass.

Also acceptable: Accept 'the herd takes time to grow or shrink because animals are born once a year.'

- Identifies the one-year lag with at least two examples
- Gives a reproduction or survival mechanism for the delay

7. Calculate the percent change in the pronghorn count from Year 4 to Year 6. Show your work, and state which years of grass you think caused this change.

Answer: $(112 - 160) \div 160 \times 100 = -48 \div 160 \times 100 = -30\%$. The herd fell 30 percent. The cause was the low grass in Years 4 and 5 (1,150 and 950 kg/ha), the two poorest years, acting with the one-year delay.

Why: The percent change uses Year 4 as the base; the lag means the drought years just before the decline are the cause.

Also acceptable: Accept '30 percent decrease' without the minus sign if the direction is stated.

8. Predict whether the Year 11 pronghorn count will be higher or lower than Year 10's 172, and give the evidence from the table that supports your prediction.

Answer: Lower. Year 10's grass (1,300 kg/ha) was the third-poorest year, and every previous poor grass year was followed by a lower count the next year (Year 4 to 5, Year 5 to 6). So the Year 11 count should drop below 172.

Why: The prediction applies the lag pattern established in q6.

Also acceptable: A student who predicts 'lower, perhaps around 150' is reasoning from the size of past drops. A student who compares grass per pronghorn (Year 10: $1,300 \div 172 \approx 7.6$ kg/ha per animal, close to Year 4: $1,150 \div 160 \approx 7.2$, which was followed by a drop) has made the strongest case; Year 1 (1,400 grass, a rise) had about 11.7 per animal.

- Predicts lower
- Cites Year 10's low grass and the lag pattern

9. A student uses the rate from q4 to predict that a year with 900 mm of rain would grow about 3,600 kg of grass per hectare. Give two reasons this prediction is not trustworthy, one about the data and one about the ecosystem.

Answer: Data reason: 900 mm is far outside the measured range of 250-520 mm, so there are no data showing the line continues; a straight line can bend or stop outside the range where it was measured. Ecosystem reason: beyond some amount of rain, water is no longer the limiting resource for grass; soil nutrients, growing-season length or temperature take over, so extra rain adds little grass. Very wet conditions might also let shrubs or trees take over and shade out grass, or wash away soil.

Why: Extrapolation and the shift of the limiting resource are the two intended ideas.

Also acceptable: Accept 'the grass might drown or flood' as the ecosystem reason.

- Names extrapolation beyond the measured range
- Names another resource or condition that would limit grass at high rainfall, or a change in the plant community

10. The graph shows a pattern: more rain goes with more grass, and more grass goes with more pronghorn the next year. A pattern by itself does not prove cause and effect. For each link (rain to grass; grass to pronghorn), state the **mechanism** that makes the cause produce the effect, and describe one investigation the team could do to test whether grass really is what limits the herd.

Answer: Rain to grass: rain supplies water, a resource grass must have to grow, so more water allows more growth until something else runs short. Grass to pronghorn: grass is the pronghorn's food, so more grass means better-fed females, more surviving fawns, and fewer deaths in winter; less grass means the opposite. Investigation: fence off some plots or supply extra hay to part of the valley in a dry year and compare fawn survival or herd size there with an untreated area; or compare two valleys with similar rainfall but different grass (one grazed by cattle), to see whether the herd tracks grass rather than rain itself.

Why: The answer must move from pattern to mechanism for both links and propose a test that changes the suspected cause while holding other things constant.

Also acceptable: A student who proposes measuring the pronghorn's body condition in good and poor grass years has proposed a reasonable observational test; give full credit if a comparison is included.

- Mechanism for rain to grass (water is a resource for growth)
- Mechanism for grass to pronghorn (food affects survival and reproduction)
- An investigation that manipulates or isolates grass supply

Teacher notes

The dataset is simulated: grass was set at about 4 kg/ha per mm of rain (realistic for a dry grassland), and the pronghorn counts were built to lag grass by one year so that students must read across rows rather than down a single column. All values and keys were recomputed: ranges 270 mm and 1,150 kg/ha; ratios 4.0 and 4.04; prediction 1,600 kg/ha; percent change –30%. Two accuracy points: grass is measured as biomass (kg/ha), not as a population count, and a tight correlation plus a known mechanism is what justifies the cause-and-effect claim, not the correlation alone. Discourage extrapolating beyond 250–520 mm. Real pronghorn eat mostly forbs (wildflowers) and shrubs such as sagebrush, with grass a smaller share except in spring; the directions say so and treat the grass crop as a stand-in for total forage, which also tracks rainfall. Extension arithmetic: $200 \text{ cattle} \times 6 \times 600 \text{ kg} = 720,000 \text{ kg}$; the valley at Year 6 grows $1,500 \text{ kg/ha} \times 2,000 \text{ ha} = 3,000,000 \text{ kg}$, so cattle take about 24 percent. (Six pronghorn per cow puts a cow near 10 kg of forage a day, a realistic intake.)

Scaffold offered to students: Plotting and dividing without mistakes

To plot a point, find the rainfall on the bottom axis first, slide straight up to the grass value, and make a small dot; write the year beside it. For q4 and q5, 'per millimeter' means grass divided by rainfall; the unit of the answer is kilograms per hectare per millimeter. For q7, percent change = $(\text{new} - \text{old}) \div \text{old} \times 100$; a negative answer means a decrease. Work through Part A's rows in order and pencil the one-year-later pronghorn count next to each grass value before you answer q6.

Extension: A second herd and a shared resource

Suppose that in Year 6 a rancher begins grazing 200 cattle on the Sage Flats, and each cow eats about as much as six pronghorn. Estimate how much of the valley's grass the cattle take in a year like Year 6 if each pronghorn eats about 600 kg of grass per year and the valley is 2,000 hectares, then predict how the pronghorn pattern in Years 7-10 would change. Write a paragraph that uses the terms competition between species, limiting resource, and carrying capacity, and explain why the rainfall-to-grass line would not change but the grass-to-pronghorn relationship would.