

Sun, Shade or Forest? Choosing a Coffee Farm Design

Learning target: I can write a claim, evidence and reasoning argument that evaluates competing farm designs for how well they maintain biodiversity and ecosystem services while meeting economic and social needs.

Claim, evidence, reasoning

About 45 min

Individual

MS-LS2-5 · assesses

MS-ETS1-2 · practice

writing

data analysis

independent practice

Standards connections

MS-LS2-5 (assesses, evaluating competing design solutions using scientific, economic and social criteria): Students judge three competing farm designs against agreed criteria for biodiversity (birds), ecosystem services (soil protection, pollination) and the economic and social needs of the farmers, then argue for one. That is the PE as written, with the kinds of constraints its clarification statement names.

MS-ETS1-2 (practice): Parts A and B have students check each design against every criterion in a table before arguing, a systematic comparison that builds toward the full weighted evaluation in W9.

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

Answers with reasoning

The scenario

Las Nubes is a coffee cooperative of 40 families in the mountains of Central America (the cooperative is invented for this worksheet). Each winter, black-and-white warblers and other songbirds that nest in North American forests and parks fly south and spend the winter in forests and shaded farms like these. The cooperative must replant 50 hectares of old coffee and is choosing among three designs. **Design A, full sun:** coffee plants alone in rows, with more fertilizer and pest control. **Design B, light shade:** coffee under one kind of planted shade tree, *Inga*, a fast-growing tree that adds nitrogen to the soil. **Design C, diverse shade:** coffee under several kinds of native trees in layers, like a thinned forest. Only Design C can earn a bird-friendly certification, which pays a higher price, but only if a buyer signs a contract.

The four criteria the cooperative agreed on before seeing any results — **1. Economic:** net income of at least \$2,000 per hectare per year. **2. Scientific, biodiversity:** at least 25 bird species on the yearly survey, including wintering warblers. **3. Scientific, ecosystem services:** soil loss below 10 tonnes per hectare in the rainy season, and at least 10 bee visits to coffee flowers per 10 minutes (bees raise the number of coffee berries). **4. Social:** at least half the member families (20 of 40) willing to farm that way.

Three years of trial plots at Las Nubes, per hectare per year (teaching dataset)

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

Measurement	A: Full sun	B: Light shade	C: Diverse shade
Coffee harvested (kg of beans)	1600	1250	950
Standard price (\$ per kg)	2.50	2.50	2.50
Certified price after the certification fee (\$ per kg, only with a buyer's contract)	not eligible	not eligible	3.20
Other products sold: fruit, firewood, timber (\$)	0	250	450
Yearly costs: fertilizer, pest control, labor (\$)	1900	1250	1150
Bird species counted	10	28	52
Wintering warblers seen per survey	0	3	9
Soil washed away in the rainy season (tonnes)	18	7	3
Bee visits to coffee flowers (per 10 minutes)	5	11	16
Families willing to farm this way (out of 40)	31	27	21

Simulated data for teaching. The direction of each difference (lower yield but more birds, less erosion and more pollinators under shade) matches published studies of coffee farms; the exact numbers are invented.

Part A: Calculate

- Calculate net income per hectare: (kg × price) + other products – costs. Do Design C twice, once at each price.

Answer: A: $1,600 \times \$2.50 = \$4,000$; $+ \$0 - \$1,900 = \$2,100$. B: $1,250 \times \$2.50 = \$3,125$; $+ \$250 - \$1,250 = \$2,125$. C standard: $950 \times \$2.50 = \$2,375$; $+ \$450 - \$1,150 = \$1,675$. C certified: $950 \times \$3.20 = \$3,040$; $+ \$450 - \$1,150 = \$2,340$.

Why: Net income = coffee income + other products – costs. Full sun has the biggest harvest but also the biggest costs, so its net income is about the same as light shade.

Also acceptable: Minor arithmetic slips with correct method earn partial credit.

- All four net incomes correct
- Work shown for each

Part B: Check every criterion

- Write yes or no in each box. For Design C's income, write the answer for both prices.

Answer: A: income yes (\$2,100); birds no (10 species, 0 warblers); soil and bees no (18 t, 5 visits); families yes (31). B: income yes (\$2,125); birds yes (28, warblers seen); soil and bees yes (7 t, 11 visits); families yes (27). C: income no at the standard price (\$1,675), yes at the certified price (\$2,340); birds yes (52, warblers seen); soil and bees yes (3 t, 16 visits); families yes (21, just above 20).

Why: B meets all four criteria; C meets all four only with a buyer's contract; A fails both scientific criteria.

Also acceptable: None.

- At least 11 of 12 boxes correct
- C income given for both prices

3. Describe the main tradeoff between Design A and Design C in one or two sentences. What does each design give up to get what it does best?

Answer: Design A gives up birds, soil protection and bees to harvest the most coffee (1,600 kg). Design C gives up about 650 kg of coffee per hectare, and income if no contract is signed, to keep forest birds, hold soil and support bees.

Why: A tradeoff names what is gained and what is given up on each side.

Also acceptable: Accept a comparison of A with B if C is also mentioned.

- Names what A gains and gives up
- Names what C gains and gives up

Part C: Make your argument

Answer: Model answer (Design B): Las Nubes should choose Design B, light shade. It is the only design that meets all four criteria without depending on a contract: net income \$2,125 per hectare (above \$2,000), 28 bird species with wintering warblers, soil loss 7 tonnes (below 10) and 11 bee visits, and 27 of 40 families are willing. Shade trees give birds food and shelter, their roots and leaf litter slow rain and hold soil, and they support bees that help coffee set berries, so B keeps biodiversity and ecosystem services that full sun loses (10 species, 18 tonnes of soil). Design C protects even more birds (52) but earns only \$1,675 without a contract, which fails the families' income criterion. Alternative model answer (Design C, conditional): Choose C if a buyer signs a contract, because it then earns \$2,340 and protects the most birds, soil and bees; without a contract, start with B.

Why: Either B or a conditional C is defensible from the data. A is not defensible as the best choice because it fails both scientific criteria that the cooperative agreed on.

Also acceptable: Accept a hybrid claim (for example, plant B now and add native trees toward C as contracts are secured) if supported by the evidence. A claim for A earns credit for evidence use only if it argues to change the agreed criteria and explains the consequences for soil and birds.

- Claim names a design and any condition it depends on
- At least three accurate pieces of evidence, including economic, scientific and social
- Reasoning explains how shade supports birds, soil and bees
- Reasoning addresses why failing an agreed criterion matters

4. A member says: 'Design A harvests the most coffee, so it is obviously the best.' Write a respectful reply that uses at least two numbers from the dataset, including one about soil.

Answer: Example: Design A does harvest the most coffee, 1,600 kg, but it also costs \$1,900 a year, so its net income (\$2,100) is about the same as Design B's (\$2,125). It loses 18 tonnes of soil per hectare every rainy season, more than twice the limit we agreed on, and topsoil lost to rain takes a very long time to rebuild, so future harvests could fall. It also has only 10 bird species and no warblers.

Why: The reply should show that one measure (harvest) is not the whole set of criteria and that ecosystem services such as soil have long-term economic value.

Also acceptable: Accept replies using net income and bee visits in place of birds.

- Respectful tone
- At least two numbers from the dataset
- One number about soil, with its long-term consequence

5. Name one more piece of information that would make you more confident in your claim, and explain how it could change the decision.

Answer: Examples: whether a buyer will sign a multi-year contract for certified coffee (this would make C meet the income criterion); results from more than three years, because shade trees take years to grow and yields vary; how each design handles coffee leaf rust or drought; how prices for coffee change; whether soil loss in A reduces yields over time.

Why: Good decisions name the uncertainty that could change the outcome.

Also acceptable: Accept 'ask the 9 to 19 families who were unwilling why' as a social piece of information.

- Names specific missing information
- Explains how it could change the decision

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States a clear design choice that answers the question and names any condition it depends on (for example, a buyer's contract).	States a clear design choice; a condition that matters is missing.	Claim is vague or names more than one design without choosing.	No claim, or a claim unrelated to the question.
Evidence	Three or more accurate data points or calculations, including at least one economic, one scientific and one social piece.	Three accurate pieces, but one kind of criterion is missing.	One or two pieces of evidence, or evidence with errors.	No evidence from the dataset.
Reasoning	Explains how shade trees support birds, soil and bees, and why meeting all agreed criteria matters; connects to maintaining biodiversity and ecosystem services.	Explains the link to biodiversity or ecosystem services, but the mechanism or the criteria logic is incomplete.	Restates evidence without explaining why it supports the claim.	Reasoning missing or contradicts the evidence.
Tradeoffs and counterargument	Names the main tradeoff and answers the 'most coffee' argument with numbers, including the long-term cost of soil loss.	Names the tradeoff and answers the counterargument without numbers.	Names a tradeoff or answers the counterargument, but not both.	No tradeoff or counterargument.

Teacher notes

The cooperative and all numbers are invented and the dataset is labeled simulated. The directions of the differences follow published research: shade coffee generally yields fewer beans but supports many more bird species and less soil erosion, and bees visiting coffee flowers raise fruit set even though arabica coffee can pollinate itself. Black-and-white warblers do winter in Central America, and *Inga* is a common nitrogen-fixing shade tree. The textbook's claim that 'most' coffee is grown in full sun is not tested here. Accept

Design B or a conditional Design C; the strongest papers notice that only B meets every criterion without depending on a contract. Use W8 to widen the comparison to other kinds of solutions.

Scaffold offered to students: Sentence frames for the argument

Claim: 'Las Nubes should choose Design ____ (if ____).' Evidence: 'Design ____ earned \$____ per hectare, which is above/below the \$2,000 criterion. It had ____ bird species compared with ____ for full sun. Soil loss was ____ tonnes...' Reasoning: 'Shade trees give birds places to feed and shelter, their roots and fallen leaves hold soil in heavy rain, and flowering trees support bees, so _____. Design ____ fails criterion _____, so _____.'

Extension: What if the climate warms?

Shade trees keep coffee plants cooler, and arabica coffee grows poorly when it gets too hot. Suppose models predict the region will warm by about 1 to 2 °C over the coming decades. Write a paragraph explaining how this new information should change how the cooperative weighs its criteria, and whether it strengthens or weakens the case for each design. Then propose one measurement the cooperative should add to its trial plots.