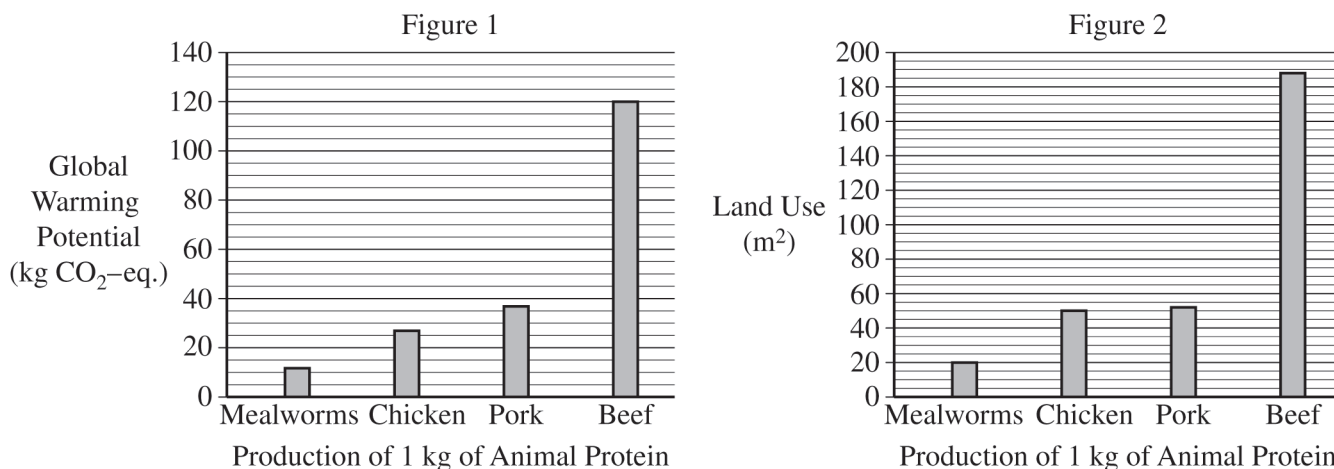


2. As the human population continues to grow, the demand for animal protein is expected to double by 2050.

Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent ( $\text{kg CO}_2\text{-eq.}$ ). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared ( $\text{m}^2$ ).

## Global Warming Potential and Land Use from Animal Protein Production



- (a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

- (b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.
- (c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.

An individual's diet choices affect greenhouse gas emissions and land use.

- (d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.

Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

- (e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.

Agricultural practices can have negative impacts on rivers and streams.

- (f) **Describe** how water quality can be altered by cattle grazing that occurs near a stream or river.
- (g) **Propose** a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.
- (h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.
- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.
- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

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**Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.**

**Question 2: Analyze an Environmental Problem and Propose a Solution****10 points**

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(a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein. **1 point**

- 50 m<sup>2</sup>

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(b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle. **1 point**

- Type III

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(c) **Explain** why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population. **1 point**

Accept one of the following:

- Darkling beetles reproduce quickly, which allows for a large amount of protein to be produced in a short period of time.
- Darkling beetles have many offspring, which allows for a large amount of protein to be produced in a short period of time.

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(d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage. **1 point**

Accept one of the following:

- Chicken production has a lower global warming potential than pork production, so it would cause less environmental damage because chicken production releases less greenhouse gas.
- Chicken production has a lower land use than pork production, so it would cause less environmental damage because there would be less deforestation/habitat destruction/soil erosion/fossil fuel use.

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(e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have. **1 point**

Accept one of the following:

- Beef has a larger impact because methane has a high global warming potential.
  - Beef has a larger impact because methane is a greenhouse gas.
  - Beef requires more land use, which results in loss of forests/habitat/grasslands leading to release of CO<sub>2</sub>/reduction in carbon storage.
-

- (i) **Justify** the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion. **1 point**

Accept one of the following:

Solution proposed in (h)	Justification of solution with additional advantage other than the reduction of soil erosion
Switch to perennial plants	<ul style="list-style-type: none"> <li>Reduces the use of fossil fuels.</li> <li>Reduces the cost of farming.</li> <li>Increases/maintains carbon storage in soils.</li> <li>Preserves habitats for organisms in soils.</li> </ul>
Plant crops on terraces	<ul style="list-style-type: none"> <li>Allows areas to be farmed that are otherwise too steep.</li> <li>Sediments and other contaminants settle out behind the terrace ridge reducing the amount of soil that runs off.</li> <li>Increases groundwater absorption.</li> </ul>
Implement contour plowing/farming	<ul style="list-style-type: none"> <li>Allows areas to be farmed that are otherwise too steep.</li> <li>Increases groundwater absorption.</li> </ul>
Use no-till farming/cover crops	<ul style="list-style-type: none"> <li>Reduces the use of fossil fuels.</li> <li>Reduces the cost of farming.</li> <li>Increases/maintains carbon storage in soils.</li> <li>Preserves habitats for organisms in soils.</li> <li>Cover crops can be used as green manure.</li> </ul>

- (j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change. **1 point**

Accept one of the following:

- Crop production/yields could decrease because of:
  - Increased drought
  - Increased flooding
  - Increased insect infestation from warmer temperatures
  - Increased temperature
  - Changes in seasonal rain patterns (or temperatures)
  - Expansion of geographic range of invasive pests/species
  - Climate may be outside range of tolerance of crops

**Total for question 2 10 points**