AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4

(a) Reply to the following questions based on the data in the graph.

Four points can be earned: 1 point for the correct answer in each section.

(i) Calculate the increase in the area of land used for growing GM [genetically modified] crops in developing countries from 1999 to 2003. Express your answer as a percentage of the 1999 value.

1999 (10 million hectares) to 2003 (20 million hectares)
Increase of 10 million hectares = 100 percent increase

(ii) Calculate the annual rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999.

1999	30 million hectares	
1997	10 million hectares	
2 years	20 million hectares	20 million ha/2yr = 10 million ha/yr

Must have units of "hectares" or "hectares/yr"

Note: Percentage answer accepted only if both years are calculated as independent percentages.
First year 100 percent Second year 50 percent Ave. Ann. 75 percent

(iii) Using the rate you calculated in part (ii), project the area of land that would have been expected to be used for GM crops in industrialized countries in 2004.

1999	----------	30 million hectares
5 years	10 million hectare increase/yr	50 million hectares
2004		80 million hectares (*must have units*)

Note: Students who incorrectly calculate (ii) can still get points if the solution is correct in (iii).
For example: 5 million hectares/year in (ii)
5 years @ 5 million hectares/year = 25 million hectares, for a total 55 million hectares.

(iv) Identify one likely cause for the difference between the projected land area for GM crops in industrialized countries in 2004 and the actual land area for GM crops in industrialized countries in 2004.

Genetically modified crops faced:

- Increased public resistance (toward perceived risks, due to increased awareness following labeling of products)
- Decreasing market demand for products containing genetically modified organisms (GMOs)
- Governmental regulation/controls/limitations/bans that limited the planting/use of GM crops

Note: "Decrease in available land" is not acceptable.

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

(b) Describe one environmental advantage and one environmental disadvantage of using GM crops.

Two points can be earned: 1 point for a description of a viable advantage and 1 point for a description of a viable disadvantage.

Environmental Advantages: 1 point **(Score only the first advantage provided by student)**
Higher yields per acre and hence less acreage needed/impacted by agriculture Permits low-tillage agriculture (due to herbicide resistance in GM crops), which: • Reduces soil exposure/erosion • Reduces energy consumption associated with farm machinery (plowing, harrowing, etc.) • Can reduce evaporative water loss GM crops may exhibit: • Lower fertilizer requirements, which reduces negative impacts of fertilizers • Insect resistance and the associated reduced impact of insecticide/pesticide use/production/exposure • Drought resistance and the associated decreased need for irrigation • Disease resistance and the associated decreased need for fungicide applications • Salinity tolerance, which decreases the need for flushing of soils with water • Frost resistance, which extends seasonal productivity and decreases crop loss • Perennial life span (rather than annual), which reduces the need for tillage (see above) • Firmer tissues/peels/shells reduce waste as a result of increased shelf life and reduced spoilage

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

Environmental Disadvantages: 1 point
(Score only the first disadvantage provided by student)

Low-tillage agriculture often depends on:

- High dosage/frequent application of herbicides to control competitive weeds that are normally controlled by tillage

GM crops with:

- Insect resistance (e.g., Bt gene) may impact beneficial insects (e.g., pollen toxic to monarch butterflies)
- Drought-resistance gene may lead to agricultural use of currently marginal, semi-arid areas, leading to increased human pressures/loss of natural landscape
- Salinity-tolerance gene may lead to agricultural use of currently marginal, saline soils, leading to increased human pressures/loss of natural landscape
- Altered genes may impact human health with altered proteins and/or subsequent toxins

Native plant diversity may be impacted by the spread of genes to nonengineered crops.

Higher yields per acre often require higher inputs (fertilizer, etc.) and often lead to greater soil depletion and erosion.

GM crops are often engineered to have lower genetic variability than non-GM crops, thereby making GM crop monocultures more vulnerable to mass mortality than non-GM crop monocultures exposed to disease or pest outbreaks or severe environmental changes. (***Note:*** To earn this point, the student must clearly contrast GM and non-GM crops and emphasize genetic variability and monoculture agriculture.)

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

(c) Describe one economic advantage and one economic disadvantage of using GM crops.

Two points can be earned: 1 point for a description of a viable economic advantage and 1 point for a description of a viable economic disadvantage.

Economic Advantage: 1 point
(Score only the first advantage provided by student)

For farmers specifically

Permits low/reduced-tillage agriculture resulting in:

- Reduced soil erosion
- Retention of soil nutrients
- Reduced energy consumption associated with farm machinery (plowing, harrowing, spraying, etc.)
- Reduced water loss that lowers associated costs
- Reduced greenhouse gas emissions from agricultural activities and associated costs (carbon sequestration)

Increased profits/reduced costs due to use of GM crops that have:

- Higher yields per acre
- Lower fertilizer/pesticide/herbicide requirements
- Insect resistance, resulting in reduced insecticide cost
- Disease resistance, resulting in reduced fungicide/viral control cost
- Healthier appearance (e.g., reduced viral spotting of skin of papaya)
- Drought resistance, resulting in lower costs for irrigation or expanded land area under cultivation
- Saline resistance, resulting in lower cost for irrigation/mitigation or increased use of marginal lands
- Less worker exposure to fertilizer/pesticides/herbicides and lower associated health-care costs
- Increased nutritional value
- Pharmacological value
- Frost resistance—extends seasonal productivity
- Firm tissue/peels/shells—less spoilage of crops in transit

For society in general

- Decreased health-care costs:
    - Due to reduced worker exposure to pesticides
    - Better-nourished people ("golden rice")

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

Economic Disadvantages: 1 point
(Score only the first disadvantage provided by student)

For farmers specifically

Higher yields per acre often lead to greater soil depletion, requiring higher costs of mitigation.

Low-tillage agriculture often depends on:

- Costly high dosage/frequent application of herbicides to control competitive weeds that are normally controlled by tillage

Decreased profits/increased costs due to use of GM crops that:

- Have increased fertilizer demand to reach yield potential
- Require investment in a new generation of pesticides because the GM crop has promoted target insect pest resistance
- Increase the amount and frequency of pesticide applications to mitigate nontarget pests whose virulence increases (when pests targeted by the GM crops are suppressed)
- Have patented seeds (which commit the farmer to annual purchase of seeds that are often too expensive for poor farmers)
- Have sterile seeds, committing the farmer to annual seed purchases
- Risk consumer rejection/import restrictions that result in lower demand for GM crops

For society in general

Costs of/for:

- Tracking and labeling GM crops in the food supply
- Litigation surrounding use of GM crops
- Controlling pest species to which the new gene has been inadvertently transferred
- Unexpected health issues related to GM crops
- Research and development

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

(d) A healthy soil ecosystem is of primary importance in sustainable agriculture. Describe TWO viable agricultural practices that farmers can use to maintain or improve soil quality.

Two points can be earned: 1 point for each description of a viable agricultural practice. Score only the first two answers provided by the student; answers must provide a description of the practice or/and include a linked advantage.

Practice	Description	Advantage
Fertilizing or supplementing	Application of nutrients (compost, organic, inorganic)	• For optimum nutrient availability • Less-soluble/mobile nutrients in organic fertilizer
Monitoring or adjusting	• Doing soil tests • Balancing soil nutrients	• Optimum nutrient (N, P, K, Ca, Fe, etc.)/pH balance
Contouring or terracing	Building/installing water bars, terraces, etc.	• Reduces soil erosion
Crop rotation	Planting different crops in subsequent planting periods	• Lower herbicide/insecticide requirements • Adds nutrients back to the soil • Takes advantage of nitrogen-fixers (e.g., legumes)
Cover crops	• Interspersing crops/planting between the rows • Planting cover vegetation during a fallow period	• Adds nutrients • Reduces erosion
Windbreaks	Planting rows of trees or shrubs	• Lowers soil loss to wind erosion • Traps moisture of winter snows
Mulching	Applying organic matter to the surface of the field/soil	• Lowers water loss • Increases water-holding capacity • Increases nutrient availability • Increases permeability/infiltration
Reduced or no tillage	Planting with reduced or no mechanical turning of the soil	• Decreases evaporation • Decreases soil erosion
Fallowing	Allowing soil to rejuvenate with a noncrop year; resting soil	• Rests/recharges soil • Adds nutrients • Lowers erosion

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

Practice	Description	Advantage
Small-scale, slash-and-burn agriculture (*milpa*; swidden)	• Forest is cut in small patches • Some shrubs/herbaceous plants remain • Crops planted together among existing vegetation	• Conserves soil nutrients • Allows nutrients time to replenish • Erosion losses are minimized
Tiling	Installing underground drainage	• Reduces water saturation • Reduces capillary rise of salts
Polyculture/inter-cropping	Use of a diversity of species to take advantage of beneficial interactions	• Lowers soil exposure • Takes advantage of different root depths • Breaks monoculturing and its negative effects • Takes advantage of attributes of multiple species (nitrogen-fixer, insect resistance)
Rotational grazing	Moving cattle to benefit grassland health	• Ensures healthy regeneration of grasslands
GM crops	Planting GM crops (must suggest soil improvement)	• Environmental advantage must refer to improving soil quality, such as the nitrogen-fixing quality of GM crops
Pesticide reduction	Eliminate overuse of pesticides or fertilizers or herbicides	• Removes products that compromise soil ecology or health
Tillage or soil structure alteration	• Mechanical or physical alteration • Harrowing, plowing in loam, sand, clay, organic matter to improve soil attributes	• Aerates soil • Increases permeability • Increases water/nutrient holding capacity, permeability, workability
Irrigation	Distribution of water (pumps, piping, wells, center pivot)	• Increases effectiveness of fallowing • Increases decay/composting of vegetation • Drip irrigation avoids oversaturation/ waterlogging and/or salinization problems
Permaculture	Designing the agricultural system to mimic a healthy soil ecosystem (includes many other practices, e.g., composting, intercropping)	• Increases ecological diversity associated with cropping landscape • Reduces erosion/nutrient loss and/or increases nutrient retention, soil biota, humus

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 4 (continued)

(e) Identify and describe one environmental advantage and one economic advantage of consuming locally grown produce.

Two points can be earned: 1 point for an environmental advantage and 1 point for an economic advantage.

Environmental Advantages: 1 point **(Score only the first advantage provided by student)**
Decreased transportation of food, which results in: • Decreased fossil fuel consumption • Decreased greenhouse gases, climate impacts, or carbon footprint • Decreased combustion-related air pollutants/emissions (GHG, VOCs, ozone, particulates, smog) • Decreased extraction impacts (drilling, transport, spills) • Decreased transport impacts (oil spills) • Decreased transport of pest species with crops Consumers can more easily influence environmental choices of growers by: • Supporting organic or permacultural practices and community-supported agriculture (CSA) • Knowing what farming strategies are used (encouraging low pesticide or herbicide use) Consumers can avoid packaging waste Not exporting nutrients—nutrients remain locally compostable

Economic Advantages: 1 point **(Score only the first advantage provided by student)**
Lower cost associated with: • Transportation (fossil fuels, vehicle maintenance) • Storage (warehousing, refrigeration, ripening agents, preservation) Boost in local economy with: • Revenues remaining in local area • Support for local labor or increased number of jobs • Use of community-supported agriculture (CSA) Lower health-care costs associated with local food because it can be more nutritious (less time in transit, picked in riper condition)

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

a (i) 10 million hectares in 99
20 million hectares in 03

increase of 10 million hectares
100% increase from 99–03

a(ii) 1998 = 10 million hectares
98 = 20 million hectares
99 = 30 " "

30 million hectares
−10 million hectares
20 million

annual rate of increase of
10 million hectares a year

a(iii) 10 million hectares / year

99 = 30 million
2000 = 40 million
2001 = 50 million

2002 = 60 million
2003 = 70 million
2004 = 80 million

projected value = 80 million hectares

a(iv) One reason could be that there was a huge population boom in the 90's which called for an increase in food production but if the population quit going up as rapidly as it did then there would be less hectares needed to produce food.

B) One advantage is that you can have a higher yield of crop which means using less land for the same amount of crop. A disadvantage is that some of the genetics they put into the crop could negatively affect what eats the crop for example some wheat is

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

is being given peanut gmos which could cause in serious allergic reactions that could kill some people.

C) An economic advantage is that you get a better yielding crop which gives you more profit per hectare of crop land. An economic disadvantage is that you could have to pay more money for seeds and you take a bigger loss if a flood wipes out your field.

D) One agricultural practice is crop rotation. When you rotate crops such as corn and soybeans or beans it allows the ground to replace crucial nutrients taken out by certain plants. Another agriculture practice is edging a field with trees so less wind can erode soil that has been plowed which will allow for soil to stay healthier.

E) An environmental advantage to by buying local food is that you are not sending the soil nutrients to other parts of the country which means the nutrients you eat will end up back in the local ground. An economic advantage is that you keep local small businesses open and in stead of giving money to big business you give money to people who will use money in the local economy.

ADDITIONAL PAGE FOR ANSWERING QUESTION 4

a) (i) $\frac{30 \text{ million hectares} - 10 \text{ million hectares}}{10 \text{ million hectares}} = 100\%$ increase

(ii) $\frac{30 \text{ million hectares} - 10 \text{ million hectares}}{1999 - 1997} = \frac{20 \text{ million hectares}}{2 \text{ years}} = 10 \text{ million hectares/year}$

(iii) 10 million hectares + 10 million hectares × 7 years = 80 million hectares

(iv) One cause for the difference between the projected land area and actual land area for GM crops in 2004 is that resources available to these crops are limited, so the cannot grow at the same rate forever. There is limited land to them in, as well as limited freshwater, especially since this land and water is also being used on plants that are not genetically modified.

b) One advantage of GM crops is that they can be modified so that they do not need to have fertilizers and pesticides added to them. Without these extra chemicals, there will be less harmful effects due to excess nutrients in runoff (less eutrophication). One disadvantage is that these modified crops could reproduce and be planted in natural environments. These plants, with the ability to have their own fertilizer and resist pests, would be able to outcompete the native species, messing with the entire ecosystem since some organisms that consume these native plants

will be losing a source of food.

c) One economic advantage of GM crops is that, since they can be modified to be grown in certain areas with certain nutrients, they will be able to be used as a good source of trade with other countries. They can be sold to countries that lack crops of good nutritional value in order to stimulate our economy. One disadvantage of GM crops is that they can start to decrease the profit made from selling normal / locally grown crops, which are necessary to some people in order to make money.

d) A practice that helps maintain soil quality is checking the pH and adding proper amounts of acids, bases, or buffers to maintain it properly. Also, adding fertilizers can help make sure there is enough nitrogen, phosphorus, and potassium present.

e) One environmental advantage of consuming locally grown produce is that it promotes the growth of the natural / native crops. Also, it helps to stop large-scale farming, which contributes to erosion, weathering, etc. An economic advantage is that it promotes the local economy by helping get money to these local farmers who need it.

a

(a) (i) The increase in land used for GM crops in developing countries from 1999 to 2003 was 100% of the 1999 value.

(ii) The rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999 was 10 million hectacres per year.

(iii) The projected area of land used for GM crop growing ~~from~~ calculated from the rate of increase from 1997 to 1999 for the year 2004 is 80 million ~~hectacres~~ hectacres.

(iv) One possible reason for the difference between the projected and the actual land use for GM crops in 2004 is the decreased rate of population growth in industrialized countries in recent years.

(c) One economic advantage is that growing GM crops is cheap, but one disadvantage is that the farmers don't get as much profit.

(b) One environmental advantage is that they're easy to keep growing, but one disadvantage is that there is little biodiversity

(d) One way to improve soil quality is to plow under older organic matter. Another way is to practice such farming techniques as contour farming to prevent erosion.

© Locally grown produce has environmental advantages and disadvantages. One advantage is that it reduces CO_2 emissions by eliminating having to ship the produce cross-country. One disadvantage is that it may not stay fresh as long as other produce because it doesn't have preservatives in it.

AP® ENVIRONMENTAL SCIENCE
2009 SCORING COMMENTARY

Question 4

Overview

This question assessed students' knowledge of the environmental and economic implications of current agricultural practices for food production and distribution, focusing specifically on the environmental and economic implications of genetically modified crops. The question also tested students' abilities to interpret data and trends from a graph and to describe currrent farming practices that help maintain a healthy soil profile. The question also measured the ability to describe the environmental and economic benefits of eating locally grown produce.

Sample: 4A
Score: 10

In part (a) the response shows units and arithmetic processes, which help the student organize the work and check for accuracy. The response shows accuracy and efficiency of calculations and computations in parts (a)(i), (a)(ii), and (a)(iii) and earned 1 point in each part. No point was earned in part (a)(iv) because "the population quit going up as rapidly" is not an acceptable response.

In part (b) the response earned 1 point for providing an environmental advantage by correctly stating that less land will be used for crop production if the genetically modified (GM) crop produces a higher yield per acre. As an environmental disadvantage, the response correctly states that a GM crop may lead to serious allergic reactions due to altered proteins associated with the altered genes, thus earning a second point.

In part (c) the response provides an economic advantage of increased profits associated with GM crops, which produce a higher yield per acre, earning 1 point. The stated economic disadvantage, which refers to the potential cost of the GM seeds ("pay more money for seeds"), earned a second point.

In part (d) the response correctly states that crop rotation can replace nutrients and illustrates that assertion with soybeans replacing nitrogen when in rotation with corn, earning 1 point. For the second point, the response correctly describes how planting trees along the edges of fields serves as a windbreak to protect the soil from wind erosion.

In part (e) the student understands that when crops are not transported from a particular area, soil micronutrients are more likely to remain in the local soil, earning 1 point. The response also correctly states that consuming locally grown crops keeps money in the local economy and keeps businesses open. This would have earned a point, but the response had already earned the maximum of 10 points.

Sample: 4B
Score: 8

The response shows accuracy and efficiency of calculations and computations in parts (a)(i),(a)(ii), and (a)(iii) and thus earned 3 points. It also shows units and arithmetic processes, which help the student organize the work and check for accuracy. The response earned no point for an incorrect answer in part (a)(iv).

In part (b) the response provides an environmental advantage and correctly states that eutrophication will be less of a problem from nutrient-laden runoff when GM crops are less dependent on fertilizer, earning 1 point.

In part (c) the response earned 1 point by providing an economic advantage of increased profits associated with the trade of GM crops, which contain "certain nutrients" (a nutritional advantage over non-GM crops). No point was earned for describing the economic disadvantage of using non-GM crops.

Question 4 (continued)

In part (d) the response correctly states that monitoring and adjusting pH levels of the soil is a good practice, earning 1 point. For the second point, the student correctly describes how nitrogen, phosphorus, and potassium levels in the soil can be supplemented by fertilizers.

In part (e) the student understands that putting money in the hands of local farmers promotes a stronger local economy and thus earned 1 point.

Sample: 4C
Score: 6

The response provides correct answers in parts (a)(i), (a)(ii), and (a)(iii). No point was earned in part (a)(iv) because "decreased rate of population growth" is not an acceptable answer.

No point was earned in part (b) because the response ("easy to keep growing" and "little biodiversity") is vague and not specific to GM crops.

No points were earned in part (c) because the statements "growing GM crops is cheap" is incorrect and "farmers don't get as much profit" is unsupported.

Two points were earned in part (d). One point was earned for the statement that soil quality may be improved by the plowing-in of organic matter. The student earned the second point for describing the prevention of erosion through contour farming.

One point was earned in part (e) for stating that "eliminating having to ship produce cross-country" that is locally grown leads to reduced emissions. No point was earned for describing locally grown produce as less fresh.