AP ENVIRONMENTAL SCIENCE

School Year: 2025-2026
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Welcome to the wonderful world of environmental science!

We will explore the following topics: earth systems and resources, the living world, population, land and water use, energy resources and consumption, pollution, and global change. You can read more about the course on the College Board website.

This is a college level course and as such the workload and expectations are high. All work, including summer assignments, will be submitted in person by the due dates specified. If you have questions, please email me.

BOTH SUMMER ASSIGNMENTS ARE DUE on the 2nd day of class, Friday, AUGUST 15, 2025.

1. Summer Assignment #1: 25 points

   VIDEOS and READING ANALYSIS - "THE TRAGEDY OF THE COMMONS"

2. Summer Assignment #2: 25 points

   READING and DISCUSSION - "6,000,000,000 CONSUMPTION MACHINES"

3. Summer Assignment #3: 50 points

   MATH REVIEW

Summer Assignment #1: 25 points

"THE TRAGEDY OF THE COMMONS" READING ANALYSIS

Directions:

- **WATCH THIS VIDEO: https://www.youtube.com/watch?v=CxC161GvMPc**
- **WATCH THIS VIDEO: https://www.youtube.com/watch?v=bs2P0wRod8U**
- **READ ATTACHED ARTICLE, "The Tragedy of the Commons: A Deep Dive into Environmental Depletion"** by *The Environmental Literacy Council*, 3 Aug. 2024
- **ANSWER QUESTIONS: Using the information from the article, type your answers to the following questions *in your own words* on a separate sheet of paper**.

Analysis Questions:

1. Describe the concept of "tragedy of the commons".
2. Identify and explain the four defining characteristics of a commons.
3. In Garrett Hardin's classic example, why does each herdsman add more cattle to the shared pasture?
4. How does overfishing illustrate the tragedy of the commons?
5. Other than fisheries, describe two environmental resources mentioned in the article that are impacted by this phenomenon?
6. What are some behavioral patterns that contribute to the tragedy of the commons?
7. How can privatization help mitigate the tragedy of the commons?
8. How can education and public awareness contribute to solving the tragedy of the commons?
9. In what ways might informed individuals or communities make a difference in managing shared resources responsibly? Provide a specific example.
10. What role can technology and innovation play in preventing or mitigating the tragedy of the commons? Provide specific examples.

The Tragedy of the Commons: A Deep Dive into Environmental Depletion

The phrase “tragedy of the commons” might conjure images of a Greek play, filled with dramatic irony and downfall. While the concept does indeed carry a tragic weight, it is not a theatrical narrative but a deeply relevant and observable phenomenon in environmental science. It describes a situation where individuals, acting independently and rationally in their own self-interest, ultimately deplete a shared resource, even when it is clear that doing so is detrimental to everyone in the long run. Understanding this tragedy is crucial for addressing many of the most pressing environmental challenges we face today, from climate change to deforestation and overfishing.

UNDERSTANDING THE CORE CONCEPT

The tragedy of the commons was famously articulated by ecologist Garrett Hardin in his 1968 essay published in *Science*. While not a new idea, Hardin provided a powerful and accessible framework for understanding how the pursuit of individual gain can lead to the collective ruin of a shared resource.

THE CLASSIC EXAMPLE: THE PASTURE

Hardin’s original essay uses the example of a pasture open to all. Imagine several herdsmen, each raising cattle on this common grazing land. Each herdsman is incentivized to add more cattle to their herd because they accrue all the benefit (more cattle for sale) while the cost of grazing is shared by all. This is the crux of the problem: individual benefit outweighs the distributed cost. The rational behavior for each herdsman is to maximize their herd size.

However, as every herdsman pursues this same rational self-interest, the pasture becomes overgrazed. The land can no longer support the increasing number of cattle, leading to its eventual degradation. The once-productive pasture becomes barren, and all the herdsmen suffer the consequences. **This is the tragedy – individually rational actions lead to collectively disastrous outcomes.**

KEY CHARACTERISTICS OF A COMMONS

Several characteristics define a resource as a "commons" where this tragedy can occur:

- **Rivalrous Consumption:** One person's use of the resource diminishes its availability for others. The grazing land in Hardin's example is a clear illustration. One cow consuming grass leaves less for other cows.
- **Non-Excludability:** It is difficult, costly, or impossible to prevent individuals from accessing and using the resource. The pasture is open to all herdsmen, with no barrier preventing them from using it.
- **Shared Ownership (or Lack Thereof):** The resource is not privately owned by any one individual but is instead commonly held or, in some cases, owned by no one at all. This is a critical characteristic as it removes individual responsibility and stewardship.
- **Individual Incentive for Overexploitation:** Each individual benefits directly and disproportionately from increasing their consumption of the resource, while the negative consequences are shared by all. This imbalance of incentive is the engine of the tragedy.

EXAMPLES BEYOND THE PASTURE

While Hardin's pasture is a powerful illustration, the tragedy of the commons applies to a vast array of resources and situations:

Fisheries

Ocean fisheries are a prime example. Fishing boats are driven by the desire to maximize their catch. However, with each boat trying to haul as many fish as possible, the overall fish stocks diminish, impacting not only the ecosystem but also the long-term viability of the fishing industry itself. This has led to the collapse of several once-abundant fisheries.

Air Quality

The atmosphere, a shared resource, is heavily impacted by pollution. Individual factories and vehicles generate emissions that contribute to air pollution, smog, and climate change. While each emitter benefits

from their economic activity or individual transportation, the collective consequence is a degradation of air quality that impacts everyone's health and well-being.

Water Resources

Shared aquifers and rivers face similar threats. Individual farmers or industries might over-extract water for their needs without regard for the collective impact, leading to dwindling water tables, reduced river flow, and desertification. The Aral Sea provides a stark example of a resource decimated by unsustainable overuse.

Forests

Forests act as both carbon sinks and habitats. When individuals or corporations engage in deforestation for timber, agriculture, or other reasons, the shared benefits of these forests are diminished, leading to a loss of biodiversity, soil erosion, and contributing to climate change. Again, individual gains translate to widespread environmental and social costs.

THE ROLE OF HUMAN BEHAVIOR

The tragedy of the commons is deeply rooted in human behavioral patterns. Several factors contribute to the problem:

Short-Term Thinking

Individuals often prioritize short-term gains over long-term consequences. The immediate benefit of over-grazing, overfishing, or polluting is often more tangible than the abstract and distant threat of environmental degradation.

Lack of Trust

When people lack trust in others to act responsibly, they may be less inclined to show restraint themselves. They fear that if they do not exploit the resource to the fullest, others will, leaving them at a disadvantage.

Inadequate Communication and Cooperation

A lack of communication and cooperation among those sharing the resource can exacerbate the problem. Without a means to collectively agree on limits or rules, the rational individual approach wins the day.

The "Free Rider" Problem

The temptation to "free ride" on the restraint of others is also a challenge. If most individuals cooperate and use the resource responsibly, a free rider might be tempted to exploit the situation, benefiting from the others' restraint without contributing to it.

POTENTIAL SOLUTIONS AND MITIGATION STRATEGIES

While the tragedy of the commons can feel like an insurmountable challenge, there are several strategies to mitigate or overcome it:

Privatization

One approach is to divide the commons into private parcels. By assigning individual ownership, users have a direct incentive to manage resources sustainably, as they directly bear the consequences of degradation and reap the rewards of stewardship. This approach, however, is not feasible for all resources, such as the air or the deep ocean, and can also raise equity issues.

Regulation and Enforcement

Governments can impose rules and regulations to limit resource use, such as fishing quotas, pollution permits, or logging restrictions. These measures can be effective if properly enforced and if backed up by credible penalties for non-compliance. The effectiveness hinges on the enforcement and equitable application of the regulations.

Community-Based Resource Management

Local communities, deeply connected to the resource, can sometimes manage it effectively through traditional ecological knowledge and collaborative governance. This approach relies on strong social norms, trust, and effective monitoring systems. Many indigenous communities have successfully managed shared resources for centuries through systems of shared management and common rules.

Education and Awareness

Raising public awareness about the tragedy of the commons and the consequences of unsustainable resource use is critical to fostering behavioral change. Education can help shift perceptions of self-interest and emphasize the long-term benefits of cooperation.

Technological Solutions

Technology can play a role, for example, in developing more efficient resource utilization, monitoring pollution, and implementing sustainable resource management practices. Technologies for renewable energy, cleaner industrial processes, and resource recovery all contribute to reducing the pressure on common resources.

International Cooperation

When resources transcend national boundaries, like the oceans or the atmosphere, international cooperation and agreements become essential. Global treaties, like the Paris Agreement on climate change, exemplify the necessity of collective action to address shared environmental challenges.

CONCLUSION

The tragedy of the commons is a powerful framework for understanding the challenges inherent in managing shared resources. It highlights the conflict between individual self-interest and the collective good, and explains why individually rational behaviors can lead to environmental degradation. While there are no easy solutions, a combination of strategies—including privatization, regulation, community-based management, education, and technological innovation—are necessary to move towards a more sustainable future. The key is to acknowledge the core dilemma of the tragedy of the commons and to work collaboratively to ensure the long-term health of our shared environment. It is a tragedy of our own making, but ultimately, we hold the power to rewrite the ending.

Team, Enviroliteracy. “What Is the Tragedy of the Commons Environmental Science?” *The Environmental Literacy Council*, 3 Aug. 2024, enviroliteracy.org/what-is-the-tragedy-of-the-commons-environmental-science/.

Summer Assignment #2: 25 points

"6,000,000,000 Consumption Machines"
READING and DISCUSSION

DIRECTIONS:

- **Read the article below**: "6,000,000,000 Consumption Machines - Environmental Aspects of Population Growth."
- **FRQ questions**: Using the information from the article, type your answers to the following FRQ questions *in your own words* on a separate sheet of paper. A digital copy of this document will be submitted to *Turnitin* alongside the hard copy submission on Friday, 8/15.

FREE RESPONSE QUESTIONS:

This article identifies human population growth as a central force behind environmental degradation. Although it was published in 1999, the issues it highlights — including water scarcity, pollution, deforestation, and biodiversity loss — have only intensified over time. In fact, the global population has since surpassed 8 billion, amplifying the environmental pressures discussed in the piece.

Using information from the article, answer the following FRQ questions *in your own words* typed on a separate sheet of paper:

a. Describe two environmental consequences of rapid population growth.

b. Using evidence from the article, describe one way in which developed nations contribute more significantly to environmental degradation compared to less developed nations.

c. Identify one strategy mentioned in the article that aims to reduce environmental degradation and evaluate its effectiveness.

d. Propose a policy solution that could help mitigate the environmental impact of global resource consumption.

e. How does the article "6,000,000,000 Consumption Machines" illustrate the concept of the *Tragedy of the Commons*? Use specific examples from the text to explain how shared global resources are being overused or degraded due to individual and national consumption patterns.

ARTICLE

6,000,000,000 Consumption Machines - Environmental Aspects of Population Growth

International Wildlife, Sept-Oct, 1999

As Earth's human population surges to new records, what will be the impacts on natural systems?
SOMETIME on October 12, 1999 -- most likely in China or India, according to demographic probabilities -- the Earth's six billionth human will be born.

As a consumer of water and food, forest products and clean air, animals and the ocean's bounty, this newborn will make but a tiny dent on natural resources during its sojourn on the planet. But put Baby Six Billion together with all the other human consumption machines already here, and alarm bells go off.

Can Earth's natural resources and ecological systems withstand the additive impact of this latest member of our species? Worse yet, what will happen in the year 2025, when Baby Eight Billion is projected to be born?

If this latest addition to the human family arrives in a developed country -- say, the United States -- he or she will automatically be in the top 20 percent of the human race, at least in terms of good housing, potable water, proper sanitation, a high school or college education, sound medical care, jobs, disposable income and leisure time. But Baby Six Billion will also be part of an elite that consumes in record numbers. In all, 270 million Americans use up nearly 10 billion metric tons of materials a year, 30 percent of the planet's total. And the world's one billion richest people -- which also include Europeans and Japanese, among others -- consume 80 percent of the Earth's resources.

If, on the other hand, Baby Six Billion is indeed born in the Third World, where three-quarters of humanity is already concentrated, he or she stands a good chance of being thrown into misery and deprivation. One-third of Earth's people -- two billion of them -- already subsist on just $2 a day or less. Half of all people on Earth have improper sanitation facilities. A quarter has no access to clean water. A third lives in substandard housing, many in tin-roofed shacks with dirt floors. A sixth will never learn to read, and 30 percent who enter the global workforce will never get adequate job opportunities. The other five billion people on Earth make do with just 20 percent of the planet's resources.

Rising expectations and the inevitable quest for improved living conditions in the Third World are likely to exacerbate this assault on resources. The average American consumes 37 metric tons of fuels, metals, minerals, food and forest products each year. By contrast, the average Indian consumes less than one metric ton. According to the United Nations, if the entire population of the Earth were to have the same level of consumption as the average American or West European, it would take three Planet Earths to supply the necessary resources.

Regardless of where Baby Six Billion is born, he or she will contribute to the relentless collective consumption that continues to devour global resources at rates most experts say are non-sustainable. And in the process, the human newcomer -- along with his 5,999,999,999 companions -- will produce enormous quantities of waste.

Whether Earth has the ability to absorb more people and provide for their ever-growing needs is not a closed question. Some technocrats have argued that the Earth's greatest resource is the innate capacity of human beings to invent or engineer their way out of population and resource crises. If that is so; however, human ingenuity is not keeping pace with human consumption as measured in the degradation of virtually every natural system -- from the chilly North Atlantic with its vital fisheries to the steamy rain forests of Amazonia with their incomparable array of plants and animals.

When all is said and done, human activities caused by population growth and consumption patterns are taking a heavy toll on our planet's life-support systems -- and on Earth's other species, which are disappearing at record rates as human numbers rise. The following report looks at the collective effect of six billion consumption machines on six aspects of the natural world. It is a grim picture, with only flashes of hope.

Don Hinrichsen is an environmental reporter who specializes in covering the developing world. For the last 12 years, he has also been a consultant on population for the United Nations system, principally the UN Population

Fund. His analysis is based on an in-depth review of available sources, including government agencies, environmental groups, think tanks, international entities and individual experts.

WATER - Squandering the Planet's Lifeblood

WATER IS THE LIQUID of life. Without it, the blue planet would be a dead and barren wasteland. Fresh water is also the most finite of Earth's resources. There is no more water on Earth now than there was 2,000 years ago when the human population was less than 3 percent of its current size. But population growth and rising use have put the squeeze on available resources.

Today, 31 countries with a collective population of half a billion people are experiencing chronic water shortages for all or part of the year. But within just 25 years, that figure will explode to 50 countries and 3 billion people -- 35 percent of all the people projected to be living on Earth in 2025.

Experts cite two reasons for this drastic increase: population growth plus the increasing demands of agriculture, industry and urban areas. During this century, the world's population has tripled, while the amount of water withdrawn from the planet's finite total has increased by more than six times. Since 1940, annual use of water has grown twice as fast as global population.

While population growth and escalating consumption patterns mean there is less water available per person, water resources are increasingly fouled with all manner of wastes. These include raw sewage and garbage from urban areas, toxic industrial effluents and such agricultural runoffs as fertilizers, pesticides and animal wastes. The UN Food and Agriculture Organization (FAO) estimates that each year roughly 450 cubic kilometers of wastewater -- an amount equal to the entire renewable freshwater resources available to Malaysia on a yearly basis -- are discharged into rivers, streams and lakes. More than 13 times that amount of clean water is required just to dilute and transport this dirty water. If current trends continue, the FAO projects, the world's entire river flow will be needed just for pollution transport and dilution by the middle of the twenty-first century.

As a global average, agriculture accounts for the lion's share (70 percent) of water taken for human use. Farming also accounts for the largest amount (70 percent in the U.S. and Europe, 50 to 60 percent in developing countries) of pollution to surface and ground waters. Disease carried by dirty water kills more than 12 million people a year, mostly women and children. And nearly all these deaths take place in the Third World.

There is another sinister side to the water crisis. As of 1996, the world's human population was expropriating 54 percent of all the accessible fresh water contained in rivers, lakes and underground aquifers. By 2025, population growth alone will push this figure to 70 percent. As humankind withdraws more and more water to satisfy its unquenchable thirst, less is available to maintain vital wetlands, like the Everglades in Florida.

The wholesale loss and degradation of life-giving riverine, lake and wetland habitats translates to a dramatic decline in populations of other species. Globally, close to one-quarter of all freshwater fish species are either endangered, vulnerable or on their way to extinction. Southeast Asia's Mekong River alone reports a two-thirds drop in fish catch due to dams, deforestation and the conversion of nearly 4,000 square miles of mangrove swamps into rice paddies and fish ponds.

Caught between finite and increasingly polluted water supplies on one hand and rapidly rising demand from population growth and development on the other, many countries face uneasy choices. The World Bank warns that the lack of fresh water is likely to be one of the major factors limiting economic development in the decades to come. It is also likely to spawn wars.

Recycling Works

The successful reuse of treated urban wastewater for irrigation is on the rise. In Mexico City, wastewater irrigates and fertilizes alfalfa used for small-animal feed. In Asmara, the capital of Eritrea, it waters one-third of all vegetables grown. And in Lusaka, Zambia, one of the city's biggest squatter settlements irrigates its vegetable crops with liquid from nearby settling ponds.

FOREST - Earth's Green Lungs Begin to Fade

THE EARTH'S green mantle of forests provides humankind with multiple benefits. Forests absorb carbon dioxide and produce oxygen, regulating climate. They anchor soils and prevent erosion. They regulate water flow and protect watersheds. And they provide habitat for countless species of plants and animals. Yet over the course of the past half century, this green mantle has been reduced to tattered remnants.

Currently, about 39.5 million acres of forest, an area roughly the size of Nepal, are cut, bulldozed or burned each year. According to the World Resources Institute (WRI), an environmental think tank based in Washington, D.C., half of the world's original forest cover has been lost, with most of the destruction taking place during the last four decades. WRI reports that only one-fifth of the world's remaining forests are classified as "frontier forests" -- pristine areas that have not been disturbed or degraded by human activities.

In Europe, despite green belts and conservation areas, only a tiny patch of the continent's original forest remains, cloistered in Bialowieza National Park in southeast Poland, hard against the border with Belarus. Here 1,000-year-old linden, oak and hornbeam stand cathedral-like -- silent reminders of what has been lost irrevocably. Old-growth forests in the United States have been decimated, too; in the contiguous 48 states, 99 percent of frontier forests are gone -- an empty echo of what once was. Most experts link the loss of such forests, directly or indirectly, to human population growth and the insatiable demands of people. Lester Brown of the Washington-based Worldwatch Institute, which monitors human use of resources, reckons that 75 percent of the historical growth of population and 75 percent of the loss in global forest cover has taken place in the twentieth century. "The correlation makes sense," reasons Brown, "given the additional need for farmland, pastureland and forest products as human numbers expand. But since 1950, the advent of mass consumption of forest products has quickened the pace of deforestation."

In the Third World, conversion of forest resources to meet everyday human needs is significant. Dirk Bryant, a senior researcher at WRI, estimates that fuelwood collection and overgrazing by domestic animals are now responsible for degrading about 14 percent of the world's remaining frontier forests, nearly all of which -- disregarding northern Canada and Russia -- are found in developing countries.

But the relentless and rapidly escalating consumption of forest products by rich countries is also responsible for whittling away much of the remaining pristine forests. The use of paper and paperboard per person has nearly tripled since 1960, with the developed countries of North America, Europe and Asia accounting for most of it. North America, Europe and Japan, with just 16 percent of the global population, consume two-thirds of the world's paper and paperboard and half of its industrial wood.

Researchers at Friends of the Earth in the United Kingdom have determined that humanity's demand for forest products is already 25 percent beyond the point of sustainable consumption. What this means is that given population and income growth in the developing world and continued demand for forest products in the industrialized world, the future of the world's frontier forests and all the ecosystem benefits they provide to humankind are in jeopardy.

Sustainable Living

Increasingly, core forest areas are being set aside as sustainably exploited reserves to enable indigenous people to generate income. In Ecuador's Andes, Queche Indians gather more than 3,600 plant species for use in pharmaceuticals and traditional medicines, leading to regionwide conservation. The Queche also use forests for building materials and agro-forestry products.

AIR - Dark Skies, Changing Climates

CLEAN AIR is the life-giving resource most people take for granted. Yet increasingly, as human population spirals and consumption rises, the air we breathe is becoming both an agent of illness and the vehicle for modifying Earth's climate.

Few experts dispute the simple fact that more people means more air pollution. Even with the availability of vastly improved technologies to limit pollution, population growth translates directly into more use of energy, more cars on the road, more factories and hence more dirty urban air.

In turn, that often results in severe health problems. Today, more than one billion people suffer from dangerously high air-pollution levels. Most of those live in sprawling Third World cities where industries and power plants have few, if any, pollution controls and where traffic jams are a perpetual feature of urban life. Up to 700,000 of those people die every year from the air they breathe.

Cities such as Bangkok, Manila and Beijing are often entombed in a sickening pall spewed out from a rapidly growing fleet of vehicles and uncontrolled industrial emissions. In these cities and 17 others, air pollution -- most commonly in the form of sulfur oxides, oxides of nitrogen, carbon monoxide and ozone -- is one of the leading causes of respiratory infections and premature death. Just breathing the air in Mexico City has the same health effect as smoking three packs of cigarettes a day.

On the consumption side, the distribution of energy is uneven. Currently, the richest fifth of humanity consumes close to 60 percent of the world's energy, while the poorest fifth uses just 4 percent. The benefits of the fossil-fuel revolution, which drives industrial nations, have still not reached a full third of humanity -- the two billion people who must burn fuelwood and organic waste for heating, cooking and lighting.

The other side of the atmospheric pollution problem is climate change, often called global warming. When carbon from burning of wood, coal, oil and other fossil fuels is released into the atmosphere, it combines with oxygen to form carbon dioxide, the gas responsible for two-thirds of human-induced changes in the world's climate. Atmospheric concentrations of carbon dioxide in 1997 reached 363.6 parts per million, the highest in more than 160,000 years.

Altogether, carbon emissions are rising faster than the rate of population growth. In 1997, according to the Worldwatch Institute, global emissions of carbon totaled 6.3 billion tons. Since 1950, world carbon emissions have increased fourfold. Though western industrialized countries currently account for close to half this output, developing countries have increased their share dramatically in the past decade and are collectively responsible for 40 percent of global carbon emissions. China is now the world's second largest emitter, after the United States, with a 14 percent share.

Over the course of the next century, atmospheric concentrations are expected to double, triggering potentially devastating climatic changes on a regional and global scale. By 2100, according to the U.S. National Academy of Sciences, sea levels may rise by up to one meter, inundating vast swaths of coastal land, while average surface temperatures may increase by up to 3.5 degrees Celsius. Destabilization of the Earth's climate engine is expected to result in more intense heat waves, more severe droughts and floods, more devastating storms (tornadoes and hurricanes) and more frequent forest fires. These events, in turn, can add to the problem. The six months of extensive forest fires in Asia in 1997 and 1998 released more carbon into the atmosphere than Western Europe emits in an entire year.

Blowing in the Wind

Clean wind-generated electricity, already produced in Europe and the United States, has become increasingly competitive with fossil-fuel-fired power plants. Wind-powered generators using advanced engineering are being manufactured in Germany, Denmark, India, Spain and the United States. The electricity they generate is valued at $2 billion a year, up by 25 percent annually.

SOIL - From Bare Earth: Hunger Amid Plenty

THE WORLD'S topsoils, the "bottom line" in food production, are increasingly eroded and degraded by the demands both of large-scale mechanized agriculture and the desperate needs of subsistence farmers. We could be

entering what some experts call the "century of scarcity," as rising demand for food is paralleled by a corresponding drop in supply.

Food shortages may seem an incredulous idea to those who subscribe to the "horn of plenty" scenario of agricultural productivity. After all, since the end of World War II, food production has tripled while population has only doubled. And the daily calories available per person in the Third World have increased from an average of 1,925 in 1961 to 2,540 in 1992.

Yet the prospects are unsettling. Much of the expansion of food production since the post-war days is explained by the adoption of crop rotation, mass production, use of petroleum-based fertilizers, chemical pesticides and expanded irrigation. Since the early 1960s, the introduction of genetically superior, disease-resistant cultivated crops -- a signature part of what is known as the Green Revolution -- also contributed heavily to food-production gains. But many of these successes have been accompanied by a downside -- widespread land abuse and inappropriate agricultural policies, including $228 billion worth of subsidies spent on price supports and outright payments.

The gains in food output are not universal either: There is still widespread hunger in the midst of this plenty. The world has 840 million chronically malnourished people, mostly women and children, while an additional one billion suffer from protein malnutrition. Also, despite slower rates of population growth over the past decade, grain supplies per capita have actually fallen worldwide.

Declines in food production are particularly critical in many poor countries. Between 1985 and 1995, food production lagged behind population growth in 64 out of 105 developing countries. Africa, where food production per person fell in 31 out of 46 nations, fared the worst of all. It now produces nearly 30 percent less food per person than it did in 1970.

The change in direction in food availability in these areas is due primarily to two trends. On the one hand, rapid population growth and changing diets have increased demand. On the other, higher population densities in traditional agricultural areas, fragmentation of small farmsteads, poor land management and inappropriate agricultural and economic policies have suppressed supply.

Together, population growth, rapid urbanization and land degradation have also combined to reduce the amount of food-producing land available for each person on Earth. In developing countries as a whole, the average amount of arable land per person fell from about 0.3 hectares (a hectare equals 2.47 acres) in 1961 to less than 0.2 hectares in 1992.

On top of these alarming developments, nearly 2 billion hectares of crop and grazing land -- an area larger than the United States and Mexico combined -- suffer from moderate to severe soil degradation. The main causes are soil erosion, loss of nutrients, damage from inappropriate farming practices (including poorly built irrigation systems) and the misuse of agricultural chemicals. In the Philippines, for instance, nearly one-quarter of all cropland has been severely degraded.

According to WRI projections, by 2025 about 3 billion people, 35 percent of the global population, will live in land-short countries, with less than 0.07 hectares of fertile land per person. That is roughly the size of two tennis courts.

Increasing Yields

Farmers in 400 villages in Burkina Faso, one of the poorest countries in West Africa, have hiked farm yields by 50 percent. They did so thanks to the rediscovery of an ancient -- and simple -- technique for using scarce water more efficiently. To slow runoff and spread the water across a wider area, they place long lines of stones along the contours of gently sloping ground.

OCEANS - Trouble in Earth's Liquid Heart

OCEANS, where life first evolved 3.5 billion years ago, cover 70 percent of the globe's surface. They wrap around the planet like an insulating blanket, making life possible on Earth today.

Oceans are the engines that drive the climate, defining weather and storing huge quantities of solar energy. They also make up the liquid heart of the planetary hydrological cycle, enabling roughly 430,000 cubic kilometers of water to evaporate every year.

But even this vast watery world is coming under increasing pressure from human activities. Just over half of humanity -- some 3.2 billion people, according to some estimates -- live and work within 120 miles of a sea coast, on just 10 percent of the Earth's land area. Two-thirds live within 250 miles of a coast.

These mounting human numbers and the development that follows in their wake have taken a grim toll on ocean resources nearby. Half the world's coastal wetlands, including salt marshes, for instance, have disappeared. And close to 70 percent of the world's beaches are eroding at rapid rates because of human impacts.

Coastal ecosystems, valuable because they function as nurseries for fish and other sea life, have been especially hard hit. Over the past century alone, 25 million hectares of mangrove forests -- multi-rooted trees on the edge of the sea -- have been destroyed or grossly degraded. Seagrass beds -- underwater meadows in coastal shallows -- have fared little better and are in retreat near virtually all inhabited coastal areas.

Coral reefs, the rain forests of the sea with perhaps 1 million species, are being pillaged as well. They are poisoned by sewage outfalls, overfished, dynamited, pummeled by ship's anchors, broken by recreational divers and bleached by unseasonally warm temperatures. Of the world's 230,000 square miles of reef-building corals, 60 percent could be lost within 40 years, marine biologists fear. Over 80 percent of the reefs in Southeast Asia alone are in peril.

One of the biggest threats to the integrity of ocean ecosystems is directly attributable to people and their insatiable demand for protein: the relentless hunt for fish. Of the world's 15 major oceanic fisheries, 11 are in decline. The catch of Atlantic cod has dropped 70 percent since 1970, while bluefin tuna stocks have declined by 80 percent over the same period.

A fivefold growth in seafood consumption since 1950 has pushed these and other fisheries to the brink and beyond. Between 1991 and 1995 the world's commercial fleets hauled in, on average, 84 million tons of seafood a year. Since seafood provides close to 20 percent of the world's total animal protein intake -- up to 90 percent in the South Pacific and parts of Southeast Asia -- the decline in fish catches is eroding food security for a number of poor countries in the tropics.

The overcapacity of the world's fishing fleets has itself become a threat to the integrity of ocean ecosystems. Currently, 5.8 million square miles of ocean bottom are trawled each year, the marine equivalent of strip-mining. Since bottom trawls are indiscriminate harvesters of marine life, the by-catch from these operations constitutes a horrendous waste of potential food. Every year, 10 pounds of fish and shellfish are discarded for every person on Earth -- up to 40 million tons.

In too many places, the sea has also become a dumping ground for oil and a giant cesspool to collect the runoff of poisons from inland sources. Each year, for instance, effluents flowing from the Mississippi River system leave a lifeless dead zone 30 miles out into the Gulf of Mexico.

Reclaiming Mangroves

On the Philippine island of Negros, fisherman Wilson Vailocos talked his neighbors into planting mangrove trees along the coast to stabilize eroded shoreline and provide feeding and nursery areas for valuable fish. He also formed seagoing patrols to enforce a ban on dynamite and cyanide fishing. Result: Mangroves have reclaimed 100 hectares of land, and the illegal fishing has been eliminated.

ANIMALS - Plundering the Planet's Species

HUMAN LIFE cannot exist in the absence of complicated interactions of millions of species in biological systems. Yet we live in a period of the greatest loss of plant and animal species since the mega-extinctions of the Jurassic Period 65 million years ago.

Every year over the course of the coming decades, 50,000 plant and animal species are likely to disappear, ecologists warn. The percentage of birds, mammals, fish, reptiles and amphibians threatened with extinction is now in double digits, and the loss of insects and microorganisms is incalculable. Overall, human-induced habitat loss, killing by bushmeat hunters in the Tropics, and the introduction of nonnative species, among other problems, has conspired to change the lineup of species on Earth.

Loss of biodiversity is not limited to wildlife. Since 1900, about three-quarters of the genetic diversity of agricultural crops have also disappeared, according to FAO estimates, along with half the wild gene pool upon which domestic cattle are dependent for improving their resistance to diseases, pests and changing environmental conditions.

Increasing population density and pressure for faster but unmanaged economic development are largely to blame. In a study of 50 countries in Asia and Africa, the United Nations Population Fund found that the loss of natural habitat was greatest in high-density areas and least in low-density areas. In the 10 countries that had lost the most habitat, population density averaged close to 200 people per square kilometer. In the 10 countries that had lost the least amount of habitat, the population density averaged just 29 people per square kilometer.

The outlook is particularly bleak in some of the most biologically rich countries of the Third World, where population growth and unsustainable exploitation of natural resources is savaging habitat in "biodiversity hotspots" -- ecosystems with a superabundance of plant and animal species. So far, 24 of these hotspots containing half the planet's land species have been identified. Overall, five of the six most biologically diverse countries could see more than two-thirds of their original habitat destroyed or grossly degraded by the middle of the next century.

Meantime, the world's last great expanses of pristine, mostly uninhabited tropical forests now face imminent destruction. These large tracts of land -- in the Guayana Shield region of northern South America, Amazonia, Africa's Congo and the island of New Guinea -- are prime targets for logging. Together, they are about the size of the state of Alaska.

In other areas, the introduction of nonnative, or exotic, species contributes to extinction woes. Hawaii's native fauna and flora have been decimated by species brought in, deliberately or by accident, by people. On the U.S. mainland, exotics have been implicated in close to 70 percent of all fish extinctions this century. In Europe, much of the Black Sea's fauna has been eliminated by a combination of overfishing, pollution and exotics. Its commercially valuable fish species have declined from 26 to 5 in a decade.

On top of all that, an ominous new term has been added recently to the biologists' lexicon of threats to animals: "defaunation," also referred to as "the empty forest." From Laos to Congo, Brazil to Madagascar, impoverished people desperate to put food in the pot are killing whatever moves. Now, vast areas of tropical forest have been scoured nearly clean by hunters of bushmeat. For the first time, there are large areas of available habitat with few birds or mammals to live in them.

Saving Europe's Wolf

Thanks to the tireless work of countless wildlife groups, the gray wolf has expanded its range in Europe. In a stunning comeback, it is recolonizing Germany, Austria, France and Switzerland. In Slovakia, the WOLF Forest Protection Movement aims to have 52 WOLF groups, at least one in each of 42 major watersheds threatened by large-scale logging.

Summer Assignment #3: 50 points

MATH REVIEW

Directions:

Complete the following Math Review. Each section includes a problem set and an optional video to help you review content.

- Print this document and write your answers in the space provided.
- Calculators are permitted but you must SHOW ALL YOUR WORK.
- Please circle or DRAW A BOX AROUND YOUR ANSWER.
- Do not forget to INCLUDE UNITS in your setup and answer.
- Write neatly and legibly.

Show your work Show all work. No work, no credit. Show all units in each step and in the answer. Units provide valuable information.
APES FRQs award one point for the correct setup and one point for the correct answer (with units) so always show your work. It will be required on all your class assignments and tests. Use dimensional analysis for problems involving unit conversions. Be sure to write down anything you type into your calculator – all equations and answers, even if it's something simple.

Check your answers Reread the question to be sure you answered what was asked. Review each step to make sure you did not make mistakes in your calculations or forget units. Check to see if your answer makes sense. If you get an answer that seems unlikely, it probably is - no one could eat 13 million pounds of corn in a year.

Tutorials are provided at the beginning of each section for your review. Click the link "Tutorial" to watch a review video on the math skills.

A. PERCENTAGES Environmental science problems often include working with percentages. *Tutorial*

1. What percentage of 150 is 30?

2. Thirteen percent of a 12,000-acre forest is being logged. How many acres will be logged?

3. 240 acres, or 15%, of a forest is being logged. How large is the forest?

4. A water heater tank holds 280 gallons. Twenty percent of the water is lost as steam. How many gallons *remain* to be used?

B. METRIC UNITS Most problems will require you to make unit conversions. B *Tutorial*

5. 14000 millimeters = ? meters

6. 1200 kilograms = ? grams

7. 7. 10 megawatts = ? kilowatts

8. 17 m^2 = ? mm^2

C. SCIENTIFIC NOTATION This ensures we do not gain or lose zeros when working with very large or very small numbers. *Tutorial*

Place the following in scientific notation:

9. 145,000,000 =

10. 435 billion =

11. 0.000348 =

12. $(4 \times 10^3)(3 \times 10^2)$ =

13. $(3.6 \times 10^9) \div (9 \times 10^3)$ =

14. The Greenland Ice Sheet contains 2,850,000 cubic kilometers of ice. It is melting at a rate of 0.005% per year. How many cubic kilometers are lost the first year?

D. DIMENSIONAL ANALYSIS Dimensional analysis is simply the "unit cancellation" method. It is a way to convert a quantity given in one unit to an equal quantity of another unit by lining up all the known values and multiplying. In APES it is often an integral part of a larger word problem. Write out the full setup with units to see places to simplify the math. *Tutorial*

15. Sixty kilometers per hour = ? miles per hour (1 km = 0.62 mi)

16. A city that uses 34 billion BTUs of energy each month uses how many kilowatt-hours (kWh) of energy? (1 kWh = 3,400 BTUs)

17. How many BTUs are in 5 kWh?

18. A 2.5 million square mile forest is how many hectares? (1 square mile = 640 acres) [1 hectare (Ha) = 2.5 acres]

19. If one barrel of crude oil provides 1.6 million BTUs of energy, how many BTUs of energy will one liter of crude oil provide? (1 barrel of oil = 160 liters)

20. Fifty-eight thousand kilograms of solid waste is equivalent to how many metric tons? (1 metric ton = 1000 kg)

21. 5 mm of rain falls in a 100 m^2 field.
(1 cubic meter = 1000 liters) (1 gram water = 1 mL water)

    a. What volume of rain (in m^3) fell in the field?

    b. If 20% of that rain ran off into the city stormwater drains, how many liters would that be?

    c. How many kg?

22. A new offshore wind project will consist of 200 wind turbines, each with a capacity of 4 megawatts (MW). Each turbine costs $1.2 million to build. Electrical demand in the area to be served by the project is expected to be 2.0×10^6 MWh per year. (MWh = MW x hours)

    a. Calculate how much electricity (in MWh) the wind project needs to generate per year in order to provide 80% of the annual electrical demand in the service area.

    b. Customers in the service area pay $0.20/kWh for electricity. Calculate how much revenue will be produced if the wind turbines provide 80% of the annual electrical demand in the service area.

    c. Assuming all turbines are operating, calculate how many hours the wind turbines must operate to provide 80% of the annual electrical demand in the service area.

E. PERCENT CHANGE ***Tutorial***

23. If the concentration of mercury in a water supply changes from 65 parts per million (ppm) to 7 ppm in a ten-year period, what is the percentage change of the mercury concentration? How much per year?

24. a) If a car fuel tank holds 15 gallons of gas, what would it cost to fill a tank in 1987 when gas was $0.89/gal? In 2022, when gas is $4.12/gal?

b) What is the percent change in gasoline prices from 1987 to now? (Round to the nearest whole number.)

25. a) If the concentration of mercury in a water supply changes from 35 parts per million (ppm) to 7 ppm in a ten year period, what is the percentage change of the mercury concentration?

b) How much per year?

Percent Change

$$\text{Percent Change} = \frac{\text{New Value} - \text{Old Value}}{\text{Old Value}} \times 100\%$$

If the result is positive, it is an increase.
If the result is negative, it is a decrease.