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Markscheme

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Environmental systems and societies

Higher level

Paper 2

25 pages

Subject details: Environmental systems and societies HLP2 Markscheme

Mark allocation

Candidates are required to answer:
- **ALL** questions in Section A **[40]** and **TWO** questions in Section B **[40]**.
- The maximum total = **[80]**.

1. Environmental systems and societies uses marking points and markbands to determine the achievement of candidates

When using marking points (<u>All of this paper except</u> Section B, part (c) questions):

i. A markscheme often has more marking points than the total allows. This is intentional
ii. Each marking point has a separate line and the end is shown by means of a semi-colon (;)
iii. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **<u>precise point</u>** where it becomes clear that the candidate deserves the mark. **<u>One tick to be shown for each mark awarded</u>**
iv. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

When using markbands (<u>Only</u> for Section B, part (c) questions):

i. Read the response and determine which band the response fits into
ii. Then re-read the response to determine where the response fits within the band
iii. Annotate the response to indicate your reasoning behind the awarding of the mark
Do not use ticks at this point
iv. Decide on a mark for the response
v. At the end of the response place the required number of ticks to enable RM Assessor to input the correct number of marks for the response.

2. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

3. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

4. Words that are <u>underlined</u> are essential for the mark.

5. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect).

6. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

7. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.

8. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

Section A

1. (a) (i) Identify the environmental impact whose source is 78 % from agriculture. **[1]**

Eutrophication

(ii) State **one** pollutant responsible for the environmental impact named in (a)(i). **[1]**

Nitrates/nitrites/phosphates/ammonia/fertilizer/sewage/manure/feces/detergents/ atmospheric NOx;

Note to examiners: *Do not credit nitrogen, phosphorous on their own.*
Do not credit wastewater, run-off without reference to the pollutant they contain.

(iii) Describe **two** ways ecological services may be affected by the environmental impact of land use, shown in **Figure 1**. **[2]**

Guidelines
State an environmental impact of agriculture shown in Fig.1: GHG emitted, land use, freshwater withdrawal, eutrophication, mammal biodiversity, (no mark for that; allow credit even if environmental impact is implicit)

For 1 mark, statements need to connect an agricultural or urban land use pattern to a relevant negative or positive impact:

Land use patterns worth no mark yet (note: mere reference to "agriculture/urbanization" may suffice, if ecological service impact is valid):
a. Monoculture / permanent plantations
b. Intensification / Excessive fertilizer/pesticide use / excessive irrigation
c. Expansion / Conversion of forests and grasslands to croplands/pastures / landscape/watershed alteration (e.g. ditches, canals, river diversions, artificial reservoirs)
d. Any pattern relevant to urbanization (increased use of fossil fuels / concreting surfaces / ecological urban planning)

Negative impacts on ecosystem service:
e. Reduce/alter biodiversity / introduction of pests/urban exploiters/invasive species/non-native crops/breeds;
f. Pollute water (used as habitat or to drink) / increased run-off adding nutrients/pesticides/bacteria/sediment/causing floods/reduced groundwater recharge/changing abiotic factors of water stores (salinity/pH/BOD/oxygen);
g. Reduce photosynthesis / carbon sequestration/sinks / increase CO_2 emissions;
h. Loss of pollination;
i. Reduced soil fertility / increased erosion / soil degradation;
j. Fragmentation of habitats / reducing ecosystem stability/resilience;
k. Loss of natural pest regulation;
l. Loss of natural flood control;
m. Reduce aesthetic/recreational/spiritual/educational value of landscape or production system;
n. Decrease food/water/goods provision;
o. Alteration of water cycle / e.g. reduced evapotranspiration drying local climate;

Note to examiners: *Sustainable/regenerative agriculture & ecological urban planning may have similar, but converse impacts; (it is expected that most responses will relate to negative impacts of agriculture);*
Allow 2 impacts linked to the same land use pattern.
Do not credit responses explicitly linking to industrialization, as this is not mentioned in Fig.1 (but may allow if industrialization is part of urbanization).
Do not allow credit on describing ecological services provided by natural forests, shrublands, freshwater named in Figure 1 as "land use", as this would inflate the scope of this question.

(b) Calculate the percentage of greenhouse gas emissions that originate from food, shown in **Figure 1**. **[1]**

26-26.2 (%) [13.7 / (13.7 + 38.7) = 26.15%];

(c) Outline **two** actions that households can take to reduce the percentage of greenhouse gas emissions that originate from food. **[2]**

a. Buy local foods/grow at home/avoid out-of-season food to reduce GHG from transportation;
b. Reduce food waste in order to reduce amount of food bought/shipped / e.g. eat leftovers/compost food waste/plan meals/eat less;
c. Research/buy foods that have been sustainably produced (e.g. using less inorganic fertilizers/fossil fuel) / prefer less processed/organically grown food;
d. Reduce amount of meat products consumed;
e. Choose unpacked /minimally packed food items to reduce GHG from the production of packing items;

Note to examiners: *Do not credit any action linked to increasing GHG/CO_2 absorption.*

(d) Describe possible reasons for the difference between the biomass of livestock and wild mammals, shown in **Figure 1**. **[2]**

a. Increasing proportion of meat (beef, pork, mutton) in diet of richer countries/as LEDCs develop;
b. Improvements in technology allow production to increase (foodstuffs, hormones, vaccines etc.);
c. Selective breeding led to growth optimization / current livestock breeds grow faster/more efficiently;
d. Increased investment in livestock production / as a major source of income;
e. Increased pressure on wild habitats (conversion to pasture/urbanization) / increased poaching/hunting reducing wild mammal populations;
f. (Growing human population) increased demand on food (and eating meat from domesticated animals is embedded in most cultures) / intensifying food production including livestock;

Note to examiners: *Do not credit population growth/overpopulation on its own (see last MP). Credit only statements that understand that livestock biomass percentage is much higher than that of wild mammals.*

(e) Discuss how a rights-based ethical approach to the environmental impacts associated with agriculture in **Figure 1** may be controversial within society. **[3]**

Guidelines:
State an environmental impact of agriculture shown in Fig.1 (no mark for that; allow credit even if environmental impact is implicit)
and explain why it is considered ethical or unethical (1 mark each), according to the rights-based (deontological) approach.
No mark for definition of the approach.
Then allow up to 2max, either for drawing a conclusion or stating an opinion presenting, at least, one conflicting argument explaining where the controversy lies.
Allow 2max if a controversy is not evident in the ethical discussion of any impact.
Allow 1max if no impact, presented in Figure 1, (GHG emissions / land use / freshwater withdrawal / eutrophication / mammal biodiversity) is discussed

There are 3 alternative ways of gaining full marks:
1. discussing the conflicting ethics of at least two environmental impacts of agriculture (even without reaching any conclusion/opinion) [2max for each impact]
2. drawing conclusions/stating opinions on a controversy, as in MPs below for up to 3 environmental impacts of agriculture [may gain 1 or 2 marks per impact]
3. a combination of 1 & 2 for just one environmental impact of agriculture [2max for ethical vs unethical + 2max for controversy]

e.g.
GHG emitted:
Intense farming methods use large amount of fossil fuel to maximize their production (tractors, fertilizer/pesticide production) *[no mark yet]*…
…which is ethical as it satisfies the basic need of people to eat enough food and of high quality in order to survive (especially when justifying meat production and consumption);
However, it is unethical as it violates the rights of people, animals, ecosystems harmed by the adverse impact of climate change;
Opinion/conclusion on controversy: ***[2max]***
The controversy lies in asking developing countries to reduce their GHG emission, thus also their food production, when more developed countries have the ability to apply efficient systems that reduce GHG emissions without sacrificing food and economic output;
more developed countries may buy carbon permits and continue high production and revenue;
The most severe consequences of climate change are borne by the people least responsible;

Land use:
Natural habitats (forests, grasslands) are continuously turned into arable land (crops, animal feed, pastures) reducing biodiversity/degrading habitats/altering landscapes *[no mark yet]*…
…which is ethical as societies/individuals have the right to improve “unused” land to make it more productive/profitable (property rights);
It is unethical as ecosystems have intrinsic value, too, and a right to exist irrespective of their utility to humans / deforestation might lead to flood/erosion/relocation of forest-dwelling indigenous community violating the right of others to protect their own house (from flood)/live in a healthy environment (without dust)/maintain a way of life without agriculture (indigenous communities);

Opinion/conclusion on controversy: ***[2max]***
Even if a land is owned by someone, how can they decide for the modification of a land without the consent of other stakeholders that are affected by their decision (including also the future generations and the organisms living there that can’t raise opposition)?;
if the land cleared is public/free (tragedy of commons), why do (even democratic) governments have the right to determine the fate of a landscape/ecosystem?;

2. (a) State the motivational factor with the highest percentage of "very important" responses, as shown in **Figure 2(a)**. **[1]**

Support conservation;

(b) Identify the approximate percentage of citizen scientists who stated they record all species they see "often/very often", as shown in **Figure 2(b)**. **[1]**

56-59 (%) (80-22=58%; accept range: 79 or 80 minus 21 to 23);

(c) Outline possible reasons for the differences between citizen scientist responses to "Wetlands / waterbodies" and "Urban parks", as shown in **Figure 2(c)**. **[2]**

They are <u>more</u> likely to investigate wetlands/waterbodies than they are urban parks, because:

a. There is a better chance of seeing rarer species in wetlands/waterbodies than urban parks/wetlands;
b. In Fig 2b most citizens never record common species, thus they wouldn't be interested to search urban parks (as most species would be common);
c. Water bodies need more protecting than urban parks / Fig2a suggest high interest on supporting conservation;
d. Motivating factors (Fig2a) include gaining (scientific) knowledge, thus they prefer the less explored wetlands;
e. They may prefer wetlands/waterbodies because it's more fun/interesting/challenging/important / e.g. the only chance to see migratory birds landing there for breeding/stopover;

Note to examiners: *No ECF allowed, if response considers that urban parks are searched more often than wetlands (opposite trend).*

(d) Outline **one** method by which citizen scientists can collect data from the locations shown in **Figure 2(c)**. **[1]**

Dichotomous keys/online apps/audio recordings/photos to identify species and record them in field journals/mobile apps / as they move along a transect / aerial photography from drones / pitfall traps to identify insects/ soil invertebrates / biotic index to assess water quality through the use of indicator species /kick sampling / net sweeping;

Quadrats to measure plant abundance/diversity / search for animal nests/droppings;

Participate in organized (by universities, NGOs, GOs) bird counts / long-term monitoring projects of nesting success / tagging animals for mark-recapture / putting GPS collars for remote tracking / camera traps for visual surveys of species;

Note to examiners*: Do not accept techniques that measure abiotic factors (turbidity, acidity, etc.) or questionnaires on socio-economic issues.*

(e) With reference to the **Figure 2(a)**, **Figure 2(b)** and **Figure 2(c)**, evaluate the use of citizen science in collecting, monitoring and managing biodiversity data. **[4]**

Pros include: ***[3max]***

a. Many more people can significantly increase amount of data collected;
b. Improve/contribute scientific knowledge on various species/regions / e.g. data collected can help identify trends such as species decline /invasive species spread;
c. Primarily a voluntary role, so expenses are minimal;
d. Local people often have far more knowledge of their local area for more efficient data collection;
e. Raises public awareness of local sustainability issues;

Cons include: ***[3max]***

f. Understanding of scientific methods may not be strong, leading to errors/biases/disturbing species/habitat;
g. A significant percentage records only the interesting species, thus collection is limited;
h. Collection may be limited by preference to wetlands/meadows;
i. Knowledge of species/sustainability issues maybe limited;
j. As volunteers, times/days for data collection may be inconsistent;
k. Motivation may wane after some time;
l. Managing would require scientific expertise/equipment/funding;

Appraisal: ***[1max]***

While the methods of data collection may be biased or unreliable at times, citizen science can provide a valuable source of large sources of data collection that wouldn't, otherwise, be possible;
Data collection/monitoring efforts would be more efficient if they were organized by NGO/GO taking into consideration preferences (expressed in Fig.2c);

Note to examiners: *Accept any other reasonable evaluative argument.*

3. (a) Calculate the change in the number of severe coral bleaching events from 2015 to 2016 shown in **Figure 3**. **[1]**

26-28 (43 or 42 – 15 or 16);

(b) Outline **two** possible reasons for the coral bleaching events shown in **Figure 3**. **[2]**

a. Increased CO_2 absorbed from atmosphere/ocean acidification / local acidification by acid rain is possible;
b. Increased ocean temperatures/El Niño/La Niña events; / lack of nutrient upwelling may increase heat stress (actually fail to cool the water);
c. Increased land-based runoff/waste containing nutrients/plastics/debris/chemicals / linked with events of severe storms / nutrient upwelling may exacerbate bleaching in already nutrient-heavy waters;
d. Increased sedimentation blocking sunlight;
e. Extreme low tides (perhaps due to El Niño/La Niña events) exposing corals to air/sunlight (UV);
f. Increased salinity due to increased evaporation / decreased salinity due to extreme influx of freshwater (extreme monsoons);
g. Exposure to (limited amount of) oil (*do not credit large oil spills, as they kill corals rather than bleaching*);
h. Lack of upwelling nutrients may weaken the corals;
i. Shock wave from dynamite fishing may cause bleaching (*do not credit the blast, as it destroys corals rather than bleaching*);
j. Depletion of stratospheric ozone in the Tropics increasing UV levels has been linked with bleaching, (especially in surface waters);

Note to examiners: *Do not credit ocean/sea-level rise, contact with scuba divers, overfishing or anything that causes death of severe irreversible damage to corals (e.g. breaking).*

(c) Describe how coral bleaching events may impact the economies of coastal societies. **[2]**

a. Decreased tourism because coral reefs no longer colourful/popular species habitat disappearing;
b. Decreased yields from fishing due to fish stock collapse/habitat loss;
c. Important medicinal properties lost from unique coral reef species;
d. Removal/damage to natural coastal protection may imply greater expenditure on coast defences/reparation after floods;
e. High restoration cost of the coral system;

Note to examiners: *Accept any other reasonable impact.*

(d) Outline **two** limitations of environmental laws in addressing coral bleaching events. **[2]**

a. Can't stop natural factors playing a key role (e.g. El Niño);
b. Oceans are large/coral reefs may extend across international maritime boundaries / impossible to monitor;
c. Climate change/(causing) ocean warming can ‘t be resolved by national laws / needs global co-operation/international agreemnts (can also link to ocean vastness);
d. Difficult to regulate non-point source pollutants;
e. Hard to enforce existing laws due to conflicting interests/lacking resources/political will;
f. Creating/agreeing on regulations may take years;
g. Current (local) laws are inefficient / address local threats / do not completely prevent destruction, only limit it;
h. Even if international regulations exist, there is no system of global accountability / laws may be ignored / international agreements not ratified by countries;

Note to examiners: *Accept any other reasonable point.*

(e) Describe how the concept of eco-economic decoupling might help reduce the potential for future coral bleaching events. **[2]**

eco-economic decoupling aims at: **[1max]**

a. Eliminating the waste/pollutant causing coral bleaching;
b. Recycling products and materials (to extend their lifetime) / moving to circular economy /reducing resource consumption;
c. Regenerating nature and ecological processes;
d. Separating economic growth from environmental degradation / break the traditional link between economic expansion and environmental damage;

strategies mitigating coral bleaching: **[1max]**

e. Reduce CO_2 emissions/acidification/GCC by transitioning to renewable energy / reforestation / reduce fossil fuel use / eating less meat / reduce food waste / improve home-heating efficiency / technological innovation leading to more efficient processes;
f. Regulate by law/educate citizens to reduce run-off/ocean pollution by limiting inorganic fertilizer use / promoting compost / treating industrial/urban wastewater / restoring mangroves / managing stormwater run-off / banning/recycling plastics / banning boat cleaning near corals;
g. Regulating destructive fishing/tourist activities;
h. Establishing/effectively managing Marine Protected Areas;

Note to examiners: *For full credit, need to link one element of eco-economic decoupling to any sustainable strategy mitigating coral bleaching (or underlying causative agents mentioned in Q3b). MPs a & b (recycling) may be both a decoupling and a strategy (or part of it); credit only once. Accept any other valid strategy.*

4. (a) Describe the overall trend of flash droughts between 1981–2000 and 2001–2020 in Asia, shown in **Figure 4(a)** and **Figure 4(b)**. **[2]**

a. In both time periods (1981-2000 & 2001-2020), some Asia regions had higher frequencies of flash droughts than others / e.g. Kamtchatka/Japan/India/SE Asia;
b. Mongolia/NE China/a region central to Arabian Peninsula (including North Saudi Arabia, Iraq, Syria, Jordan) had the smallest/smaller than other regions frequency of flash droughts in 1981-2000;
c. There was a trend of increased flash droughts in 2001-2020 vs. 1981-2000 in many regions / e.g. in regions North of the Black Sea and Caspian Sea/in some parts of Siberia/S&E China...;
d. ... but this was not consistent throughout Asia / e.g no difference in Kamtchatka/Japan/SE Asia/the region central to Arabian Peninsula (including North Saudi Arabia, Iraq, Syria, Jordan);
e. ...while other regions/e.g. India experienced decreased frequency of flash droughts in 2001-2020 relative to 1981-2000 / had more droughts in 1981-2000;
f. Not easy to draw conclusion on overall trend for the whole continent of Asia / maybe flash droughts are more or less the same (in total) / if there is an average trend, it's increasing;

Note to examiners: *Do not credit similar trends/patterns explicitly associated with other continents.*
Do not credit overall decrease in Asia (see last MP).

(b) Outline **two** possible human causes for the change in frequency of flash droughts between 1981–2000 and 2001–2020, as shown in **Figure 4(a)** and **Figure 4(b)**. **[2]**

a. (Human-induced) climate change may lead to more drought by shifting weather patterns, making some regions drier/precipitation more irregular / by increasing temperatures, which increases evaporation / due to increased frequency/incidence of heatwaves / due to less snow in mountaintops during winter;
b. (Human-induced) climate change may have increased regional monsoons (e.g. India) leading to less flash droughts (more rain/clouds/less evaporation);
c. Rapid drying of soil due to unsustainable farming practices/erosion;
d. Increased water extraction/diversion for agriculture/industry/urbanization increases drought possibility;
e. Increased deforestation/land degradation (for fuel/agriculture/building) decreases evapotranspiration/infiltration/interception/disrupts water cycle making soil/(local and global) climate drier;
f. Increased reforestation/sustainable land management mitigates drought conditions (increasing evapotranspiration/soil infiltration);

Note to examiners: *No need to state "increase" or "decrease" of drought frequency, but this should be (unequivocally) implied (as in MPs c & f).*
Accept other valid anthropogenic causes.

(c) Identify the continent with the highest net flash drought frequency, shown in **Figure 4(c)**. **[1]**

Africa

(d) Outline **two** ways in which governance can mitigate the impacts of flash droughts. **[2]**

a. Increase financial support for local farmers for water conservation efforts (e.g. drip-irrigation);
b. Bans on watering lawns in dry spells;
c. Regulations/incentives/taxes/education reducing household water usage/wasting;
d. International agreements over fair water rights;
e. Develop early warning systems to allow more time for preparation;
f. Invest in desalination systems;
g. Establish aquifer recharge systems replenishing groundwater (e.g. directing treated wastewater, runoff into injection wells, infiltration basins);
h. Fund restoration of salinized soils;
i. Regulate/restrict/tax water extraction by industries/agriculture;
j. Promote/fund ecological urban planning to increase rain infiltration/decrease run-off/ increase water storage/increase humidity (e.g. less impermeable surfaces, more green areas, artificial ponds, green roofs, etc.).
k. Fund construction of water reservoirs/dams;
l. Promote application of drought resistant crops;

Note to examiners: *Do not credit strategies mitigating the causes of flash droughts (as mentioned in Q4b: climate change, unsustainable farming, urbanization, industrialization, deforestation, agricultural expansion).*

(e) Explain how the changes in net frequency of flash droughts shown in **Figure 4(c)** can influence environmental migration and political stability. **[3]**

Increased frequency of flash droughts/ can lead to increased environmental migration due to*:*
a. Lack of drinking water may lead to death;
b. Water shortages leading to poor hygiene/worse living conditions;
c. Poor harvests/food shortages;
d. Loss of income of farmers/herders;

Increased frequency of flash droughts can influence political stability due to*:*
e. Failure of government to address food/water shortage leading to loss of trust to the government/resentment/down-voting/riot;
f. Disease outbreak/hygiene issues (due to water /food shortage) may lead to tensions in hospitals/super-markets;
g. Lack of drinkable water/food/health may be felt more by marginalized groups leading to violent anti-government actions/accusation of ethnic cleansing;
h. Environmental/climatic refugees may increase tensions within urban areas as living space is limited/more people forced into slums / increased political tensions with other countries as migrants seek shelter/employment at cost to government/taxpayer;
i. (Prolonged drought/poor governance) may lead to economic recession / restrict economic development, as most funds should go towards fighting the drought's impacts;

Note to examiners: *Credit opposing impacts linked to decreased frequency of flash droughts and linked to emigration toward the less affected regions and/or political stability.*
Do not credit converse MPs twice (e.g. credit MPc or MPd and then also "regions with less droughts experience increased food production/higher income").
Allow ***[2max]*** *if influences only on migration or political stability are mentioned.*
Do not credit migration of non-human species.

Section B

5. (a) Outline why the hydrological cycle is considered a closed system. **[4]**

a. No water (in any physical state: ice, liquid, vapor) may enter or leave the Earth / no water added in the global hydrological cycle and no water lost to space / hydrological cycle (exchanges energy but) does not exchange matter with other systems;
b. There may be minor losses, when UV breaks apart water molecules allowing hydrogen to escape / or minor gains through icy comets/meteors;
c. The amount of water in the Earth-atmosphere system/hydrological cycle is stable in a geological time scale;
d. Water is continuously being recycled within the Earth-atmosphere system/between the abiotic (atmosphere, hydrosphere, lithosphere) and biotic (producers, consumers, decomposers) stores of the Earth;
e. There is continuous input and output (exchange) of energy (with outer Space);
f. Solar energy enters leading to water evaporation / ice melting/sublimation;
g. (Latent) heat is continuously exchanged during condensation/freezing/deposition;

Note to examiners: *For full credit there needs to be reference to both energy and matter; otherwise* ***[3max]****.*

(b) Explain how the chemical and physical properties of water help to support and maintain living organisms. **[7]**

a. Water is a polar molecule able to form hydrogen bonds between adjacent water molecules / a property responsible for many of its life-supporting properties, e.g. adhesion/cohesion/capillary action/surface tension/solvent capacity/high boiling point (100°C);
b. High cohesion / water molecules stick together, make water liquid (in room/usual temperature), thus is a suitable habitat/drinkable;
c. Ice less dense than water, thus ice floats on liquid water/lakes don't freeze from bottom (lake stratification) / thus fish survive under-water during winter (in lakes) / offers habitat for polar bears/walruses;
d. High adhesion / water molecules stick with other (non-water) molecules/surfaces allows capillary action/upward movement of sap in roots/xylem of plants / responsible for provision of nutrients to leaves from roots;
e. Strong surface tension (cohesion), thus, insects may walk/hunt on water (and use it as habitat);
f. Strong surface tension (cohesion) maintains shape of cells/turgidity;
g. High (specific) heat capacity/may absorb high amounts of heat without warming much/absorbs heat slowly and emits slowly entails less extreme temperature changes in water bodies (compared to surrounding air), allowing survival (serve as less extreme habitat);
h. As a universal solvent offers a medium for biochemical processes / is major constituent of organisms' body;
i. As a universal solvent, nutrients dissolved in (soil) water for plant growth/root uptake/transport;
j. Transparency allows photosynthesis as deep as 200m in clear waters;
k. Transparency allows aquatic animals to see through water to hunt/mate/avoid predators;
l. Water is soluble to gases such as oxygen which is essential for most aquatic species survival;
m. Water is able to absorb carbon dioxide which is required by aquatic plants for photosynthesis;
n. does not dissolve lipids, thus is responsible for hydrophobic bonds / maintains structure of cell membranes;
o. As a liquid exerts pressure to all objects within it/offers buoyancy, thus many organisms may float / fish waste less energy to move in water;
p. (As a solvent) has various levels of abiotic factors: pH/salinity which determine its suitability as a habitat (e.g. freshwater vs marine species / plant growth dependent on soil pH/salinity / while high acidity/salinity kills most organisms);
q. High (specific) heat capacity allows thermoregulation in organisms;
r. Ability to pass from one phase to another (evaporation, freezing, etc.) via absorption or release of heat is responsible for Earth's climate/energy transfers within the atmosphere / thermoregulation (homeostasis) in organisms (e.g. via sweating);
s. Low viscosity allows movement of fish / movement through thin capillaries / infiltrate/percolate in soil;
t. Thermohaline circulation/lake stratification (and associated movement of nutrients/upwelling/downwelling/ocean conveyor belt) due to warmer water being less dense than colder water (down to 4°C)/and differences in salinity;

Note to examiners: *Credit any statement that states a chemical or physical property of water and correctly links it to a mechanism supporting/maintaining life, (notice the minor exception in MPa). Other combinations than the ones shown in MPs may be valid, too.*

(c) To what extent could mitigation strategies be successful in bringing freshwater use back within the planetary boundary? **[9]**

- **Understanding concepts and terminology** crossing planetary boundary; stability/resilience of Earth system; blue water; green water; water footprint/scarcity/stress/security; hydrological cycle; limited store; over-extraction; deforestation; damming and water diversion; unsustainable water management; climate change; urbanization; EIAs; natural capital/income; sustainable use; renewable by recurring processes; freshwater habitats/ecosystems; doughnut economics; global collaboration; environmental law; local/national/international level; transboundary issue; environmental accounting; tragedy of commons; ecological economics; instrumental value; unequal distribution; environmental justice; Anthropocene; tipping points; Sustainable Development Goal 6;
- **Breadth in addressing and linking** a range of mitigation strategies (local to global scale) and how they could bring freshwater use back within an acceptable safe operating space, respecting the Earth's ecological limits, aiming at reducing the risk of irreversible environmental damage;
- **Examples** of mitigation/water conservation strategies at the local, national and /or international level, ranging from simple individual actions, local small projects, to national regulations and transboundary/international agreements combatting the causes of water scarcity/stress.
- **Balanced analysis** of how humans have crossed the planetary boundary of freshwater use and evaluate the ability of named mitigation strategies in achieving sustainable water management and use, and avoiding catastrophic tipping points;
- **A conclusion that is consistent with and supported by analysis and examples given,** e.g. "Due to its uneven distribution, sustainably managing freshwater storages requires a combination of changes in attitude, technological innovation, transboundary agreements and fair governance granting access to water for all. Then, there is hope of reversing the trend of crossing the planetary boundary of "freshwater use".

Note to examiners*: water quality/pollution is addressed by different planetary boundaries: "biogeochemical flows" (nitrates/phosphates) and "novel entities" (plastics/chemicals). No penalty to refer to these two PBs, but they should not constitute the main component of the essay, because, then, we should reduce descriptor of "link to context", not-so-relevant examples, unbalanced analysis and limited support of final conclusion. Such examples would contribute marks, only if explicitly stated that lower quality of water leads to reduced availability.*

Please see markbands on page 25.

6. (a) Outline the difference between carrying capacity and biocapacity, and the factors that influence both. **[4]**

Difference:

a. Carrying capacity is the maximum number of individuals of a species that a habitat/area can (sustainably) support;
b. Biocapacity is the capacity of an ecosystem to renew biomass or to provide resources and to absorb its resulting wastes / for any given region, it measures the amount of productive land available (which may be smaller or larger than the actual size of this region);

*Influencing factors **[3max]**:*

c. (High) resource availability (water/food/space) will directly increase (both) carrying capacity / biocapacity of an ecosystem;
d. The number of other species can influence the carrying capacity for a species due to predation/competition/mutualism/parasitism;
e. Urbanization/deforestation/resource use/ecosystem instability negatively impacting habitats can reduce (both) carrying capacity / biocapacity;
f. Sustainable management of production systems/technological innovations increasing efficiency may increase (both) local human cc / biocapacity;
g. Importing goods/exporting waste increases (both) local human cc / biocapacity;
h. Density-independent factors (weather, natural disasters) may change (both) carrying capacity / biocapacity / e.g. a natural wildfire or human deforestation will reduce both / higher rainfall or irrigation may increase both;
i. by increasing productivity (via technological advancements in agriculture or waste management) can increase (both) carrying capacity / biocapacity;
j. Increased human population and population density can decrease biocapacity (not cc) by increasing demand for resources...;
k. ...and increasing production of waste materials / waste accumulation also decreases carrying capacity;
l. Human carrying capacity also depends on lifestyle of population inhabiting the area / high consumption rate decreases cc;

***Note to examiners:** Allow **[3max]** if only carrying capacity or only biocapacity is discussed.*

(b) Discuss how government policies can increase or decrease human population growth. **[7]**

[General guideline: Each policy should be linked, at least implicitly, to a demographic factor leading to increased or decreased growth (e.g. birth, fertility, death rates, family size, etc.). The minimum requirement would be that the context clarifies that the policy stated is pro- or anti-natalist]

Policies that decrease human population growth: ***[4max]***

a. Anti-natalist policies directly lowering birth rate through legislation and punishments / e.g. by forbidding couples/families from having more than 1 or 2 children, like China's "one child" policy;
b. ...which can cause gender imbalance and ageing populations / leading to reduced fertility and higher adult mortality;
c. By introducing taxes/economic disincentives to families having more children, indirectly reducing birth rate / forcing their decision for a smaller family;
d. By bringing in pension schemes / achieving economic development entails less reliance on needing children for support later in life / reduces urge for many children to care for their elderly/sick parents;
e. Family planning policies increasing access to birth control/contraception / else couples may not be able to avoid pregnancy, even if they wanted to;
f. Administering/funding vaccination programs for children can reduce child mortality rates / reduces the need to "replace" the dead child/or pro-actively give birth to more (to have a few survive);
g. By emancipating women through (sex) education might reduce fertility rates / as women might want less children/would know better how to keep their children healthy (decrease infant mortality);
h. By providing more working positions/chances for career to women leading less women to stay at home / reducing fertility rate/want for more children;
i. Advertising/campaigns promoting a more secular way of thinking/materialistic way of living/later marriages would lead to smaller families/lower birth rate;
j. Policies leading to poor/uncertain economic conditions/high unemployment may force younger people out of the country (emigration) reducing reproductive potential;

Policies that increase human population growth: ***[4max]***

k. Providing financial incentives / e.g. tax reductions/bonus payments could encourage people to have more children;
l. Providing social benefits / e.g. free childcare and/or free/cheap schooling/subsidized housing can encourage people to have more children;
m. Offering work benefits / like better job opportunities/large paid maternity/paternity leave for parents with 3 or more children would increase birth rates.
n. Policies on health screening and medical intervention/improved public health can reduce CDR/increase lifespan;
o. Providing jobs to immigrants may increase population of a country / allowing also their families would increase birth rate, too.
p. Public education/media advertising the advantages of larger families / promoting pro-natal religious worldview would increase family size;
q. Banning abortions/limit access to contraceptives would increase birth rates;
r. Increased birth rates would decrease the (old-age) dependency ratio in a country (although may initially increase the young-age dependency ratio);

Note to examiners: *No credit for general socio-economic impacts of policies without clear link to population growth. Allow* ***2 max*** *for policies linked to immigration/emigration* ***[1each]****.*
No credit for evaluation of policies.

*Allow **[1max]** for a valid conclusion that doesn't just repeat previous points (usually at the end of response) / e.g. a policy may fail to succeed it's intended purpose due to lack of funding / disobedience of people for cultural reasons / conflicting with other policies/factors (advertise large families but high prices of houses).*

(c) To what extent is a technocentric approach the most effective way of increasing the biocapacity of a given area? **[9]**

The following guide for using the markbands suggests certain features that may be offered in responses. The five headings coincide with the criteria in each of the markbands (although ESS terminology has been conflated with "understanding concepts"). This guide simply provides some possible inclusions and should not be seen as requisite or comprehensive. It outlines the kind of elements to look for when deciding on the appropriate markband and the specific mark within that band.

Answers may include:

- **Understanding concepts and terminology** of biocapacity; regenerate natural resources; waste absorption; productive land available; measure of sustainability; technocentrism; technological advancement/innovation; increased efficiency; current/mainstream environmental economics; "green" economic development; nature serving human needs; instrumental use value; (sustainable) resource management; EF; ecological deficit/surplus; ecosystem stability; depletion of natural capital; economic growth; ecological economics;
- **Breadth in addressing and linking** how a technocentric approach would manage to sustainably produce natural resources in an area and absorb resulting waste.
- **Examples** of technological "fixes" and/or policies prioritizing economic growth that would lead to sustainable and effective resource & waste management, also habitat restoration and/or reduction of habitat damage; or fail to do so. Increasing biocapacity implies an increase in productivity of land and/or waste absorption capacity and/or increase of its regenerative capacity (ecosystem resilience/integrity).
- **Balanced analysis** of whether the strategies outlined succeeded in increasing biocapacity on a (long-term) sustainable way, or short-term (unsustainably) or not at all or decrease it (evaluation); contrasting to other EVSs and/or comparing with EF would be an asset, but not required.
- **A conclusion that is consistent with and supported by analysis and examples given,** "Technocentric approaches are usually very efficient in increasing land productivity (biocapacity), but require funding and expertise, which may not be available to all societies (e.g.LEDCs). Sustainability of the method is not guaranteed, as they prioritize economic growth over the environment (and they may disregard some habitat damage)."

***Note to examiners:** contrasting to strategies linked to other EVSs, although an asset, should not constitute the major part of the response.*

Please see markbands on page 25.

7. (a) Identify **four** possible impacts of urban sprawl on the surrounding terrestrial ecosystems. **[4]**

a. Reduce soil fertility / destroy soil structure / change nutrient cycling patterns due to urban run off/concreting surfaces;
b. Habitat fragmentation/degradation/reducing habitat diversity from construction of roads/expanding residential areas/materials used for construction...;
c. ...Leading to loss of species/reduction in species diversity (due to loss of habitat/habitat degradation from construction);
d. Increase edge effect on species from habitat fragmentation / road construction / land reclamation / noise pollution;
e. Disrupt wildlife corridors / change dispersal patterns / hindering animal migration due to road construction/fencing;
f. Reduce resources (nesting, food, etc.) (leading to population reduction) from loss of green space/concreting surfaces;
g. Reduced genetic diversity / reduced reproductive potential of species populations / leading to extinction vortex due to habitat fragmentation from roads;
h. Change to foraging/hunting/mating behavioral patterns from light/noise pollution/fencing/land reclamation;
i. Harm the health/reduction in number of sensitive species due to air/water pollution;
j. Water pollution due to construction reduces amount/quality of water available ;
k. Urban heat island effect due to more concrete/glass constructions;
l. Deforestation leads to less evapotranspiration/rain interception altering local climate/reducing rainfall/causing droughts;
m. Via gardening/opening roads/causing edge effect may introduce invasive species outcompeting native ones / create ideal urban environment for pests / urban exploiters/adapters;

Note to examiners: *Allow [1max] for positive impacts.*
No credit for socio-economic impacts.
Credit should be gained for a theoretical statement or example linking any urban sprawl element (Construction of roads / covering soil by impermeable structures (e.g. concrete/tarmac) / land reclamation for expanding residential/commercial areas / increased air/light/noise pollution / fencing / loss of green areas) to a relevant impact, as exemplified in MPs (more combinations with urban sprawl elements possible). Link could be implicit depending on context.
No credit for listing impacts without linking to an urban sprawl element, e.g. "urban sprawl would lead to reduction of genetic, species and habitat diversity" is TV and should not gain any mark.

(b) Using named examples for both, explain how the reintroduction of apex predators and keystone species can impact biodiversity. **[7]**

*Definition **[1max]**:*

a. APs are found at the top of a food chain/ have no natural predators (at least in the specific community);

Reintroducing an apex predator can increase biodiversity...

b. ...as they consume herbivores/reduce herbivore populations limiting overgrazing/may increase plant species/diversity;
c. ...and allowing vegetation recovery/increase plant growth/diversity / increase in shelters/habitats/niches attracting a higher variety of other species;
d. Presence of AP causes herbivores to hide/move away from open areas allowing plant species to recover (increasing biodiversity);
e. APs reduce populations of species at lower trophic levels in the food web, decreasing competition that allow other species to increase in population / may prevent one species from becoming dominant.

Reintroducing an apex predator can reduce biodiversity (leading to extinction of already present species) ...

f. ...by causing imbalance in established predator-prey oscillations/relationships...;
g. (In small/isolated/island/degraded habitats) AP can cause population declines preying on/consuming native species;
h. ...or overexploit resources for competitive predators (increase competition for food/habitat);

[4max] for Apex predator impact on biodiversity.

Keystone species: relevant examples would include (apex and non-apex) predators (e.g. purple see star, orca), ecosystem engineers (e.g. beaver, elephant) or mutualists (e.g. honeybee, mycorrhizal fungi).

*Definition **[1max]**:*

i. KSs have a disproportionately significant impact on community structure/sustainability of ecosystems / their removal may lead to ecosystem/food web collapse;

Reintroducing Keystone species may increase biodiversity...

j. ...by preventing the dominance of a single species monopolizing an ecosystem;
k. ...by maintaining structural integrity of their ecosystem/food web community/ support ecosystem interactions (e.g. sea otters in kelp forests)...;
l. ...or by alleviating competition (e.g. non-apex starfish keeping mussels in check);
m. ...or by creating habitat (e.g. African elephants expanding savanna = habitat diversity/beavers and ponds)...;
n. ...allowing colonization by more species /acting as catalyzers of succession (e.g. nitrogen fixing plants or free-living bacteria);
o. ...or by restoring ecosystems (e.g. willow recovery by introducing beavers in Scotland);
p. ...or contributing to soil/humus formation (e.g. earthworms, termites);
q. ...or adding to soil fertility (e.g. soil mixing by pocket gophers / prairie dog adding dung);

Reintroduced Keystone species may decrease biodiversity...

r. ... if it functions as invasive (non-apex predator) species, e.g. outcompeting rare native species (as in the case of sea otters locally extirpating abalones)...;

s. ...or it explodes in population lacking natural control mechanisms (like introducing water buffalo in Ermakov island of Danube river);
t. ... if it leads to unintended consequences causing population crash/extinction (e.g. introducing dingoes in fenced conservation areas in Australia may have led to reduction of bettongs instead of helping them recover as expected);

[4max] *for Keystone impact on biodiversity.*

Note to examiners: *Allow* ***[6max]*** *if no named example given (no need for two named examples, as many APs may also be considered KSs, like Yellowstone wolf). For the same reason avoid crediting the same impacts twice, once linked to an AP, and again to a KSs. Obviously, allow MPs linked to different named species.*
Apex/top predators: accept any carnivore/omnivore, as they may function as apex predators in degraded food webs where highest trophic level is missing, but do not accept herbivores, which, however, could be example of keystone species.

(c) To what extent do *ex situ* strategies play a more successful role in conserving biodiversity compared to *in situ* strategies? **[9]**

The following guide for using the markbands suggests certain features that may be offered in responses. The five headings coincide with the criteria in each of the markbands (although ESS terminology has been conflated with "understanding concepts"). This guide simply provides some possible inclusions and should not be seen as requisite or comprehensive. It outlines the kind of elements to look for when deciding on the appropriate markband and the specific mark within that band.

Answers may include:

- **Understanding concepts and terminology** *in situ* vs *ex situ*; habitat based (all in situ); national parks or reserves; sanctuaries; biosphere reserve; Key Biodiversity Areas (KBAs); species based; CITES; botanical garden; zoo; seed banks; breeding centers; flagship/keystone/charismatic species; mixed approach; Convention on Biological Diversity (CBD); captive breeding and reintroduction; active management of wild areas; conservation area design; EVSs; international organizations; GOs; NGOs; citizen science; volunteers; parabiologists; factors influencing success: media, speed of response, diplomatic constraints, financial resources, political influence; environmental law; environmental justice; biodiversity planetary boundary; IUCN; conservation status;
- **Breadth in addressing and linking** how both *ex situ* and *in situ* strategies can be used to conserve biodiversity while evaluating their advantages and limitations.
- **Examples** at local or regional level; habitat based *in situ*; Serengeti National Park; UNESCO biosphere reserves; sanctuaries; species based (usually, but not always *ex situ*); CITES; botanical garden; zoo; seed banks; Chengdu Research Base for Giant Panda breeding (*in situ*); Svalbard seed bank in Norway; Royal Botanic Gardens in Kew; mixed approach (usually combines *in* and *ex situ*, but can be exclusively *ex situ*); Durrell Wildlife Conservation Trust; Nagoya Protocol;
- **Balanced analysis** evaluating advantages and limitations of both *ex situ* and *in situ* conservation strategies and contrasting them in terms of their success, e.g. if they go as planned, if they are well received by communities impacted, if they increase biodiversity, if they protect endangered species, etc.;
- **A conclusion that is consistent with and supported by analysis and examples given,** "*Ex situ* strategies may be the only viable option for critically endangered species, however, the long-term survival of a species is inadvertently dependent on the preservation of a healthy intact habitat (*in situ* strategy). A mixed approach that integrates both strategies may be more successful than prioritizing one over the other;

Please see markbands on page 25.

Section B, part (c) markbands

Marks	Level descriptor
0	The response does not reach a standard described by the descriptors below and is not relevant to the question.
1–3	The response contains: • minimal evidence of knowledge and understanding of ESS issues, concepts or HL lenses content • fragmented knowledge statements poorly linked to the context of the question • some appropriate use of ESS terminology • no examples where required, or examples with insufficient explanation/relevance • superficial analysis that amounts to no more than a list of facts/ideas • judgments/conclusions that are vague or not supported by evidence/argument.
4–6	The response contains: • some evidence of sound knowledge and understanding of ESS issues, concepts and HL lenses content • knowledge statements effectively linked to the context of the question • largely appropriate use of ESS terminology • some use of relevant examples where required, but with limited explanation • clear analysis that shows a degree of balance • some clear judgments/conclusions, supported by limited evidence/arguments.
7–9	The response contains: • substantial evidence of sound knowledge and understanding of ESS issues, concepts and HL lenses content • a wide breadth of knowledge statements effectively linked with each other, and to the context of the question • consistently appropriate and precise use of ESS terminology • effective use of pertinent, well-explained examples, where required, showing some originality • thorough, well-balanced, insightful analysis • explicit judgments/conclusions that are well-supported by evidence/arguments and that include some critical reflection.