technology \( i = 0 \)

poor land

\[ \alpha_{op} = 0.4 \]

\[
\max_{x_{op}} \frac{2}{\sqrt{10} \cdot 0.4} \cdot x_{op} - x_{op} \\
\]

F.O.C \[ \frac{2}{\sqrt{10} x_{op}} = 1 \Rightarrow x_{op} = 4 \]

\[ \pi_{op} = 2 \sqrt{10} \cdot 0.4 \cdot 4 - 4 = 4 \]


good land

\[ \alpha_{og} = 0.8 \]

\[
\max_{x_{og}} \frac{2}{\sqrt{10} \cdot 0.8} x_{og} - x_{og} \\
\]

F.O.C \[ \frac{2}{\sqrt{10} x_{og}} = 1 \Rightarrow x_{og} = 8 \]

\[ \pi_{og} = 2 \sqrt{10} \cdot 0.8 \cdot 8 - 8 = 8 \]

modern tech. \( i = 1 \)

poor / good land

\[ \alpha_{ip} = \alpha_{ig} = 1 \]

\[
\max_{x_{ip}} \frac{2}{\sqrt{10} \cdot 1} \cdot x_{ip} - x_{ip} \\
\]

F.O.C \[ \frac{2}{\sqrt{10} x_{ip}} = \frac{1}{2} \Rightarrow x_{ip} = 10 \]

\[ \pi_{ip} = \pi_{ig} = 2 \sqrt{10} \cdot 1 \cdot 10 - 10 = 10 \]

conclusions.

(a) traditional tech. \( i = 0 \)

poor land \[ x_{op} = 4, \pi_{op} = 4 \]

good land \[ x_{og} = 8, \pi_{og} = 8 \]

modern tech. \( i = 1 \)

poor land \[ x_{ip} = 10, \pi_{ip} = 10 \]

good land \[ x_{ig} = 10, \pi_{ig} = 10 \]

(b) given there is a fixed cost for the modern technology

- traditional tech. \( i = 0 \)
  - poor land \[ \pi_{up} = 4 \]
  - good land \[ \pi_{up} = 8 \]

- modern tech. \( i = 1 \)
  - poor land \[ \pi_{ip} = 10 - 40 = -30 \]
  - good land \[ \pi_{ig} = 10 - 40 = -30 \]

  No adoption

(c) traditional tech. \( i = 0 \)

poor land \[ \alpha_{op} = 0.4 \]

\[ 1 - \alpha_{op} = 0.6 \]

good land \[ \alpha_{og} = 0.8 \]

\[ 1 - \alpha_{og} = 0.2 \]
{ poor land, \[ \text{max} \ 2\sqrt{10.08} x_{op} - x_{op} - 5(1-x_{op})x_{op} \] 
\[ \text{TIOC} \ \frac{2}{\sqrt{x_{op}}} = 4 \Rightarrow x_{op} = \frac{1}{4} \] 
\[ T_{op} = 2\sqrt{10.08 \cdot \frac{1}{4}} - \frac{1}{4} - 5 \cdot 0.6 \cdot \frac{1}{4} = 1 \] 

{ good land \[ \text{max} \ 2\sqrt{10.08} x_{og} - x_{og} - 5(1-x_{og})x_{og} \] 
\[ \text{TIOC} \ \frac{2\sqrt{2}}{x_{og}} = 2 \Rightarrow x_{og} = 2 \] 
\[ T_{og} = 2\sqrt{10.08 \cdot 2} - 2 - 5 \cdot 0.2 \cdot 2 \] 
\[ = 8 - 2 - 2 = 4 \] 

Technology c = \[ \text{good/poor land} \] 
\[ x_{ip} = x_{ig} = 1 \] 
\[ 1 - x_{ip} = 1 - x_{ig} = 0 \Rightarrow \text{there is no pollution} \] 
\[ \text{Therefore} \ T_{ip} = 10 \] 
\[ T_{ig} = 10 \] 

Conclusion, \[ T_{ip} = 1 < T_{ip} = 10 \] 
\[ T_{ig} = 2 < T_{ig} = 10 \] 
\[ \Rightarrow \text{both will adopt} \]
without regulation $\Rightarrow$ external cost is not considered
open access $\Rightarrow$ no consideration of future cost
cheap technology will be chosen

Note: Since everyone has an access, if you don't
catch fish today, someone else will catch it.
Therefore, there is no need to reserve fish
for future gain.

Given open access, everyone has incentive to
catch as many fish as they can. Therefore
they will use the cheaper technology.

(iii) Une selective technology will be used.

(ii) \[ \text{MNC} = MB \]
- \[ 2 = 20 - 0.5x \]
- \[ x = \frac{18}{0.5} = 36 \]
- 72 fish will be caught, and
- only 36 are edible fish.

Note: Why MNC=2?
In this case, in order to
have one edible fish, you
have to catch two fish, and
each fish incur $1 to catch.

(iii) Net social welfare = total benefit - total cost
- \[ NSF = TB - TC \]
- \[ TB = \text{benefit from edible fish} = \int_{0}^{36} 20 - 0.5x \, dx = 396 \]
- \[ TC = TNC + TFC + TEC \]
- \[ = 36x2 + 2 \times 36 + \int_{0}^{36} 1.5x \, dx \]
- \[ = 1116 \]
- \[ NSF = 396 - 1116 = -720 \]

(b) Since the une selective technology is banned,
they will use selective technology.

- \[ \text{MNC} = MB \]
- \[ 2 + x = 20 - 0.5x \Rightarrow x = 12 \]
Net social welfare = TB - TC

TB = \( \int_0^{12} 20 - 0.5x \, dx = 204 \)

TC = \( \int_0^{12} MNC \, dx + \int_0^{12} MFC \, dx + \int_0^{12} MEC \, dx \)

= \( \int_0^{12} 2 + x \, dx + \int_0^{12} 2 \, dx + 0 \)  
   \text{Note: There is no external cost of edible fish}

= 96 + 24 = 120

NSW = 204 - 120 = 84

c. Selective technology + future cost is considered.

MNC + MFC = MB

2 + x + 2 = 20 - 0.5x  \implies x = 10.7 = 11

Net social welfare = TB - TC

TB = \( \int_0^{11} MB \, dx = \int_0^{11} 20 - 0.5x \, dx = 189.75 \)

TC = \( \int_0^{11} MNC \, dx + \int_0^{11} MFC \, dx \)

= \( \int_0^{11} 2 + x \, dx + \int_0^{11} 2 \, dx \)

= 82.5 + 22 = 104.5

NSW = 189.75 - 104.5 = 85.25

Conclusions:

<table>
<thead>
<tr>
<th>Policy</th>
<th># of fish caught</th>
<th># of edible</th>
<th>Social welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) No regulation + open access</td>
<td>72</td>
<td>36</td>
<td>-720</td>
</tr>
<tr>
<td>(b) Ban unselective tech.</td>
<td>12</td>
<td>12</td>
<td>84</td>
</tr>
<tr>
<td>(c) Ban unselective tech + future cost</td>
<td>11</td>
<td>11</td>
<td>85.25</td>
</tr>
</tbody>
</table>

Note: The optimal policy is (c)
(a) The higher the interest rate, the more extraction today. The higher the interest rate, the lower the present value of future benefit of non-renewable resources. Therefore people will mine more stock today. For example, if we assume two-period game, the future benefit which is the opportunity cost of today's extraction, is given by \( \frac{MB - MC}{1+R} \). If interest rate, \( R \), goes up, the opportunity cost goes down and, thus, people extract more stock today.

(b) Is OPEC bad for the environment? 
Not necessary.

OPEC which is formed by oil producers, is a cartel, and OPEC acts as a monopoly. From the externality discussion, monopoly tends to produce less and sometimes achieve (or close) to the socially optimal outcome.

(c) Can aquaculture help environment? 
Yes, it can. But not always.

Without aquaculture, the equilibrium is represented by A. That is, consumers consume \( x_0 \) units of fish at price \( P_0 \). All these fish are wild fish.
With aquaculture.

Case 1: The marginal cost is given at $p_i$, so $p_i > p_0$.
In this case, the presence of aquaculture will not affect the equilibrium. $x_i$ units of wild fish will be caught.

Case 2: The marginal cost is $p_2$.
Then consumers will consume $x_i$ units of fish. Among these fish, only $x_o$ units are wild fish, and $(x_i - x_o)$ units fish are from aquaculture. Then less wild fish is captured since $x_o < x_0$. Therefore aquaculture helps environment.

A) Groundwater may be either a renewable or nonrenewable resource. Explain.

Groundwater can be either a renewable or non-renewable resource, depending on how it is used.

1. If it is used in a consumptive way for industry, agriculture, or environmental purposes, it can be interpreted as a non-renewable resource.

2. If it is used for fishing, hydroelectric use, or recreational purposes, it would be a renewable resource.

It also depends on the extraction rate and recharge rate ($E_r$ and $R_r$). If $E_r > R_r$, it is a non-renewable resource since it will be used up. If $E_r < R_r$, it is a renewable resource.
(e) derive the optimal rotation of trees

In forestry economics, we need to decide when to cut down the entire stock, i.e., the optimal length of rotation of stock. Assuming that it is a single rotation, the maximization problem is given as follows:

$$\max_t (p-c) G(t) e^{-rt}$$

F.O.C. $$(p-c) G'(t) e^{-rt} + (p-c) G(t) e^{-rt} = 0$$

$$\frac{G'(t)}{G(t)} = r$$

$$\downarrow$$

$$G'(t) = rG(t)$$

$$\downarrow$$

$$(p-c) G'(t) = (p-c) G(t) r$$

Note: a crop is planted at time $$t=0$$, and grows to a value to $$(p-c) G(t)$$ and harvests cost $$r$$.

Where $$p$$ is price and $$c$$ is harvest cost.

(f) Why do people oppose clear cutting of trees?

"Clear cutting" of trees is a low-cost harvesting of wood. It entails significant cost of the following:

(a) destruction of non-targeted species of wood
(b) damage to dependent plants and wildlife
(c) increased likelihood of soil erosion
(d) endogenous populations of forest communities