Unit 4: Valuation and Non-Energy Resources

Econ 3535

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Reading for This Lecture

- Chapter 3, pages 46-63

Lecture 27

- Valuation overview
- Cost/benefit analysis
- Efficiency

Valuation overview

Natural resources are special because they are valuable, but they originate without ownership

- Most goods are allocated by markets. Willingness to pay and willingness to accept manifest through prices

Government, as the representative of collective interest, sets the rules by which natural resources are allocated for use or preservation

- When goods are valuable but not privately owned, we need a non-market definition of value

Valuation - why?

Most of the effort we put into valuation is intended to inform policy decisions

- Otherwise it's just subjective; e.g. "this will create jobs" vs "this will destroy the environment"

Goal of environmental economics is to introduce some cold objectivity into otherwise emotional policy debates

- All valuation methods are inherently limited by uncertainty
- Hopefully nobody tries to pass off a valuation result as definitive fact
- For important decisions, we should use many different approaches

Positive vs normative analysis

Positive: measures objective effects of a policy action

Normative: evaluates policy along inherently subjective criteria

Normative analysis is essential for decision making

Broadly speaking, there are two different scenarios where we do normative policy analysis

1. Decide if a pre-defined project is "worth it"
2. Find the optimal policy among all possible choices

Cost-benefit analysis

CBA is a common approach for situations where the policy action is well-defined; do the benefits outweigh the costs?

- If PV(TB) > PV(TC), we do the project
- Present Value from Topic 1

Even though this may seem objective, it still uses subjective assumptions

- Benefits/Costs to any person are worth the same
- Do we value benefits equally for all people? (Old vs young, rich vs poor, EJ issues, etc.)

Costs are usually easier to measure than benefits

- Often times we spend money to preserve something. Costs easy to measure; value of preserving hard to measure
- More on this later

Example Cost-Benefit Analysis

Example of calculating the net benefits of the Clean Air Act:

TABLE 3.3 Summary Comparison of Benefits and Costs from the Clean Air Act-1990–2020 (Estimates in Million 2006$)

	Annual Estimates			Present Value Estimate
	2000	2010	2020	1990–2020
Monetized Direct Costs:				
Low[1]				
Central	$20,000	$53,000	$65,000	$380,000
High[1]				
Monetized Direct Benefits:				
Low[2]	$90,000	$160,000	$250,000	$1,400,000
Central	$770,000	$1,300,000	$2,000,000	$12,000,000
High[2]	$2,300,000	$3,800,000	$5,700,000	$35,000,000
Net Benefits:				
Low	$70,000	$110,000	$190,000	$1,000,000
Central	$750,000	$1,200,000	$1,900,000	$12,000,000
High	$2,300,000	$3,700,000	$5,600,000	$35,000,000
Benefit/Cost Ratio:				
Low[3]	5/1	3/1	4/1	4/1
Central	39/1	25/1	31/1	32/1
High[3]	115/1	72/1	88/1	92/1

Pareto optimality

An allocation is "Pareto optimal" if you can’t help anyone without hurting someone else

- I get a dollar, you get a dollar, we throw a third dollar away - not Pareto optimal
- I get a dollar, you get two dollars - Pareto optimal

This concept is helpful because it removes unjustifiable allocations

Corollary: Any Pareto optimal allocation is theoretically justifiable according to some set of subjective values (or a social welfare function)

First Equimarginal Principle

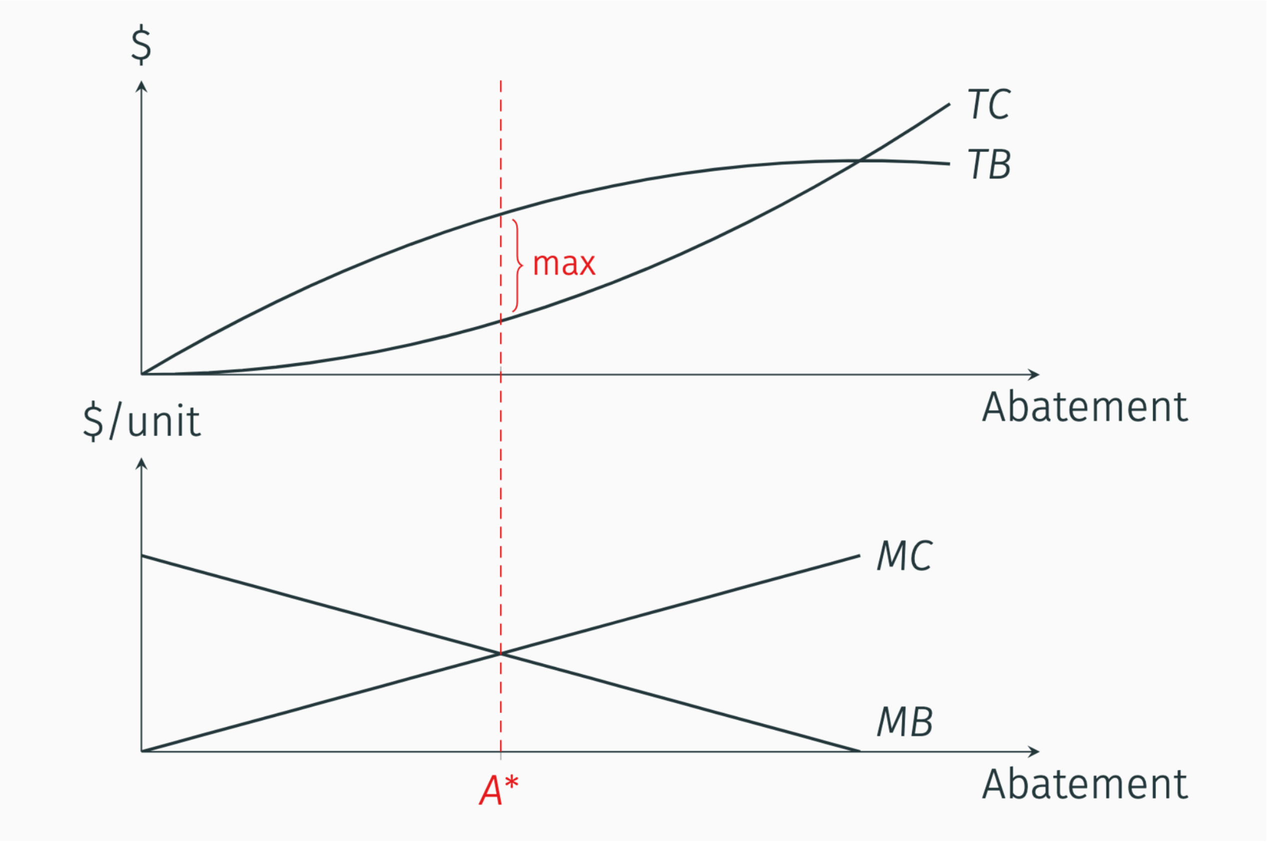
> **First Equimarginal Principle**
>
> Social net benefits are maximized when the social marginal benefits from an allocation equal the social marginal cost

Translation: When a decision can be described along a single axis (i.e. how many dollars should be spent), keep increasing until the next unit costs more than it creates in benefit

Same idea as in markets with externalities

- Socially optimal Q is where $SMC = SMB$

First Equimarginal Principle



CBA limitations

Study based on Army Corps of Engineers water projects

- About half of the projects had costs estimates that were off by 20+%
- Sometimes the decision looks wrong in hindsight

Who gets the benefits and who gets the costs?

- CBA is solid if we only care about total amounts

"Social welfare functions" adjust for distribution of outcomes

- 1. weight outcomes differently across different groups of people
    - e.g. taking money from a low-income individual is worse than from a high-income individual
- 1. weight each marginal dollar received differently
    - e.g. 10 people get $1 vs. 1 person gets $10; need not be equally desirable outcomes

Cost-effectiveness analysis

The major alternative to CBA is **cost-effectiveness analysis**

- Pick a policy goal, find the least-cost method of getting there
- Useful for when costs and benefits are harder to justify in direct comparison

Montreal Protocol is an example of this

- Instead of asking "What is the optimal tradeoff between skin cancer and refrigerator prices?"
- They ask "Which ozone-depleting chemicals are in the top 1% most valuable, and how do we most cheaply phase out the rest?"

Second Equimarginal Principle

> **Second Equimarginal Principle**
>
> The least-cost way of meeting a goal will be when the marginal costs of all possible methods are equal

Translation: Don’t use expensive methods until we have exhausted all of the cheapest options

Same idea as in cap and trade

- Remember, $MAC_1 = MAC_2$ is a condition for optimality

Static efficiency

This second area of normative analysis tries to identify the best policy among all possible versions

- All other values of Q produce same outcome, but cost more
- Parallel in regular markets - the "best" Q is where supply = demand

An allocation of resources satisfies the "static efficiency" criterion if it maximizes total economic surplus for one point in time

- Dynamic efficiency requires a sequence of allocations across users and time periods
    - Will discuss this in forestry and fishery models later

Conclusions

What we have seen so far

- Broad criteria for normative analysis and decision making
- How do we decide if this policy is worth it?
- How do we decide what the best version of this policy is?

Next time

- Methods for valuation
- How do we place value on natural resources without markets?
- How do we know what society is willing to trade for another polar bear?

Reading for Next Time

- Chapter 4. Next couple of lectures comes from Chapter 4

Lecture 28

- Different types of value
- Stated preference methods and biases

Recap

Last time, we talked about the philosophy of valuation

- How do we decide if this policy is worth it?
- How do we decide what the best version of this policy is?

Environmental economics is used to support policy decisions

- Educated guesses about important numbers
- Always other important considerations

Should humans place economic value on the environment?

Philosopher Arne Naess made the argument that the environment has intrinsic value, unrelated to human interests [debate 4.1 in the book]

- Why value the human economic perspective over any other?
- How much is a human worth to a monkey?

Economics is necessarily human-centric

Best environmentalist argument in favor of putting a value on environmental goods

- If we don’t make environmental value tangible, it often defaults to a value of zero

Types of value

1. Use value
    - The main one - value we get by directly using resources
    - Wood from the forest, air quality, scenic beauty
2. Option value
    - Value from potential to use the resource in the future
    - You may never go to Yellowstone, but you might value the option to go
3. Non-use value
    - Bequest value, cultural, religious, artistic, symbolic value

> "There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains, even though they would be appalled by the prospect of being exposed to it" (Rosenthal and Nelson, 1992)

Preferences are secret

The sum of use, option, and non-use value to everyone in society represents the "benefit" side of the equation

- If you could read minds, this would not be a problem

As I mentioned last time, benefits are usually harder to determine than costs

- Costs are often just dollar projections of contract work

- Benefits are internal, subjective, and complicated to describe

Many practical challenges in determining the true benefits of a policy

Methods for measuring value

1. Stated preference
   - Experimental and survey methods, usually hypothetical
   - Contingent valuation, choice experiments, ranking exercises
2. Revealed preference
   - Methods that use data to infer things about people’s preferences
   - Market prices, hedonic models, expenditure-based models

Stated preference methods

Contingent valuation surveys

- Ask people how they would behave in a hypothetical market
- "What is your willingness to pay (WTP) for a policy that does X?"

The answers you get in a survey are likely to be biased in several different ways

- Very cool intersection of psychology and economics

Survey methods like this depend on if you can trick respondents in to telling the truth

- This makes for some odd conference discussions

Stated preference methods

Example: Northern Spotted Owl

Endangered species in the Pacific Northwest (Example 4.2 in the textbook)

Government ran a mail survey to 1000 households to determine the value that households place on this species

Responses indicated that value placed on this one species justified the preservation of a designated "habitat conservation area"

- Benefit-cost ratio was somewhere from 3-1 to 43-1

Valuation hinged on the "non-use" value of the species

1. Strategic bias

Survey answers can influence actual outcomes, so people exaggerate willingness to pay

- "Sure, I would pay $10,000 to preserve that stretch of river, I go there all the time"

2. Information bias

Respondents have highly variable responses when they don't have much information about the question being asked

- Ex: Canadians apparently value polar bears at $6.3 billion per year based on survey responses (about $500 per household per year)
  - https://www.nextnature.net/2013/11/how-much-is-a-polar-bear-worth/
  - From tourism and hunting, the use-value is about $9 million per year

3. Starting point bias

The way the question is framed will influence what people see as a reasonable answer

- Survey designs sometimes often trade off this bias with information bias

Is the height of the tallest redwood tree more or less than _ feet? vs. What is your best guess as to the height of the tallest redwood tree?

- Responses to the second question were greatly impacted by the number given in the first

4. Hypothetical bias

Respondents answer differently if they know they will not be held to their answer

- Real economic decisions are made with scarce resources, surveys are not
- Starting point of 1,200 – 844 was the average guess
- Starting point of 180 – 282 was the average guess

5. Difference between WTP and WTA (status quo bias)

WTP is a payment for improvement from the status quo

WTA is the compensation you would demand for enduring the opposite

- Empirically, WTA tends to be much greater than WTP
- I would be willing to contribute 50 dollars towards a park near my house, but removing an existing park would feel more like 200 dollars of lost value to me

A thorough survey would ask for both numbers

- WTP is the lower bound, WTA is the upper bound

Lecture 29

- Revealed preference methods

Recap: valuation of environmental goods

Challenge of properly allocating scarce resources without the use of market prices

Stated preference (SP) methods

- Surveys and experiments try to simulate market prices for environmental goods
- Answers can often be systematically biased

Revealed preference (RP) methods

- Today!

Revealed preference

Revealed preference methods make use of observational data, rather than survey or experimental data

- Sometimes valuation of an environmental good is baked into other market or observable outcomes

Because of this, RP can really only be used for "use value"

SP methods can be used to estimate all three value categories

- Use, option, and non-use

Travel cost method

Most useful for recreational resources, where travel cost is a large component of the decision making process

- Fishing spots, national parks, beaches, hiking trails

Travel costs: time, effort, gasoline, vehicle maintenance, plane tickets, etc.

Example: BP oil spill in 2010 (Deepwater Horizon)

Travel cost methods were used to estimate the value lost by tourists

- Part of the analysis that led to ~$60 billion in fines paid by BP

Travel cost method - example

1. Ask visitors at Yellowstone where they traveled from
2. Estimate the implied travel cost
   - Usually distance is the biggest variable
3. This number forms a lower bound for the willingness to pay (WTP) for the use value of the environmental good
   - True WTP is higher - we know this because they decided to go
   - Difference between WTP and costs is consumer surplus

Hedonic methods

Break down a good into components, and use a large market dataset to estimate the effect each component has on the final price

- Strategy used in lots of areas, especially labor and real estate
- Home prices and wages are "prices" determined in the market

Most useful when the market good is multi-faceted and common. A lot of factors make for a good job or for a good house

- Finding two jobs that are similar in all ways except 1 allows to see how much wage people would be willing to give up for that one feature
- Finding two homes that are similar in all ways except 1 allows to see how much people value that one amenity

Hedonic example - real estate

Three houses are identical except for the following two traits:

	House A	House B	House C
Near a park?	yes	yes	no
Central A/C?	yes	no	yes
Market price	\$450,000	\$420,000	\$400,000

Comparing A and B: central A/C is worth an extra \$30,000

Comparing A and C: being near a park is worth an extra \$50,000

Base value of the house with neither amenity would be \$370,000

- \$450,000 - \$30,000 - \$50,000 = \$370,000

Compensating differentials

Components of a job that affect market wage are called **compensating differentials**

The desirability of a job comes down to much more than just the hourly wage

- Safety, flexibility, choice of hours, personal appeal

Roof workers are usually paid more than landscapers. Why?

- Wage differences can explain how people trade off income with other job components, including health impacts from environmental hazards

Value of a statistical life

Is Life Priceless?

Value of a statistical life (VSL)

- The marginal rate of substitution between mortality risk and money (or anything else)

In other words, how much are we willing to accept for a small increase in risk of death?

VSL example

Air pollution policy reduces probability of death from 1:100,000 to 1:150,000

- Across a population of 1 million people, expected number of deaths fall from 10 to 6.67

If the average WTP for this policy is $5 per person, then $5 million = 3.33 statistical lives

- VSL = $1.5 million

Governments use VSL instead of asking millions of people strange questions

- Policy costs $2 million, expected to save 3.33 lives
- If VSL = $1.5 million, policy is worth it

VSL Real-life Example

Bishop, Kuminoff, Mathes, and Murphy

> "The annual implicit cost of a 0.1 percentage-point reduction in mortality risk among older Americans and find that this figure is both relatively low and decreasing in age, from $1,346 for a 67 year old to $246 for an 87 year old."

Value of a statistical life

100% chance of killing one person vs 1% chance of killing each of 100 people?

- VSL works better when the marginal risks are very small and spread out
    - "statistical life" rather than "life"

Young vs old

- Same mortality risk $\rightarrow$ very different impact on life years

Wealthier people end up having a higher VSL (yikes)

- US: ~$5-8 million
- Sierra Leone: ~$577,000
- e.g. higher-income countries have a higher WTP (ability to pay?) for environmental regulation

Lecture 30

- Ecosystem services

Ecosystem services

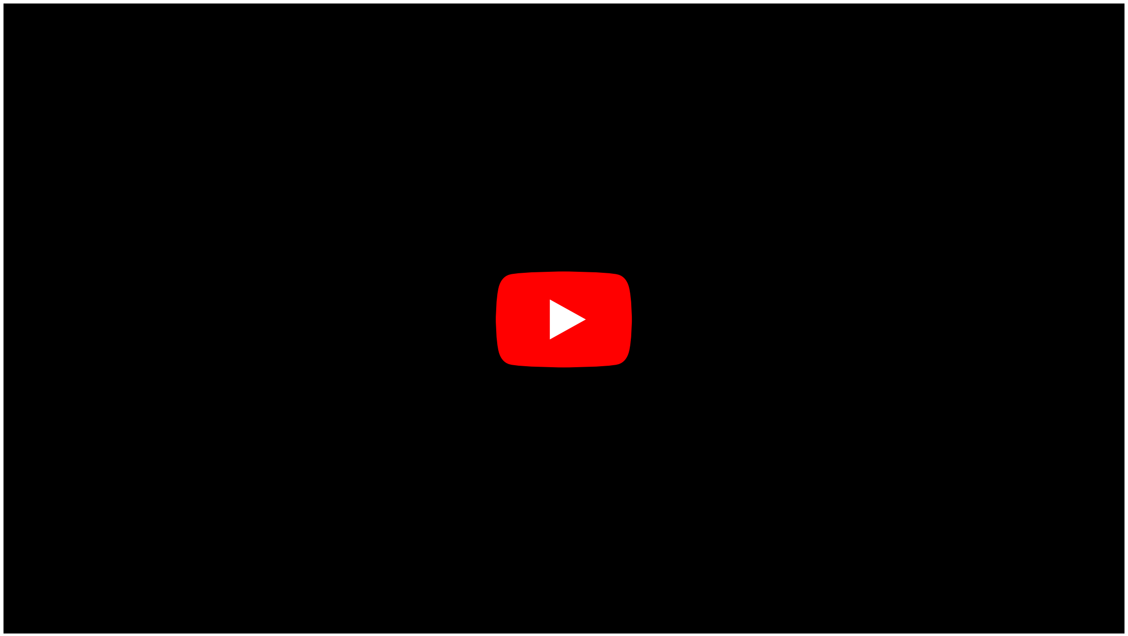
Ecosystem services are the benefits that humans gain from well-functioning ecosystems

- Ecosystems as natural capital; a renewable, long-run source of value

Example: mangrove swamps

- Tropical, coastal vegetation
- Helps prevent large waves from eroding the coastline
- Provide a direct ecosystem service through cost reduction of coastal maintenance

Mangrove swamp demonstration



https://www.youtube.com/embed/cNE56Wua7bA

Categories

The UN Millennium Ecosystem Report defines four categories of value produced by ecosystems

1. Supporting services
    - Nutrient cycling, pollination, habitat provision
2. Provisioning services
    - Food, raw materials, energy, genetic diversity
3. Regulating services
    - Carbon sequestration, predation, disease control
4. Cultural services
    - Recreation, education, spiritual/historical/cultural significance

Case study #1: Coral Reefs

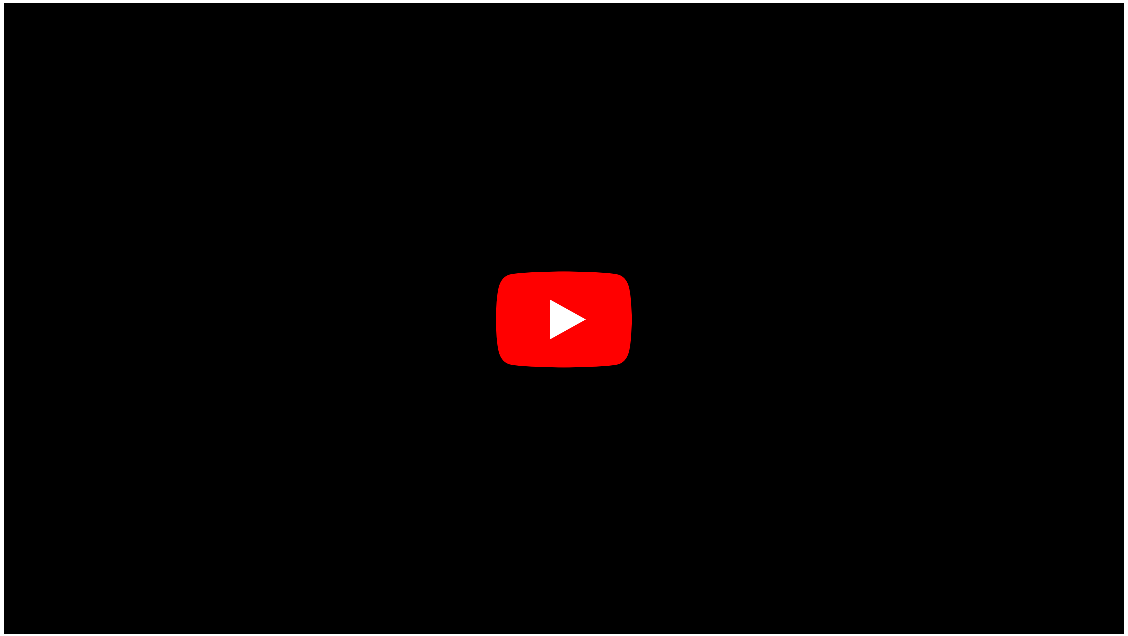
Ecosystem services

- Coastal protection, biodiversity support, fisheries support, tourism, non-use value

Threats

- Damage from overfishing, pollution
- Bleaching from higher water temperatures - more fragile, less able to combat disease
- Ocean acidification from CO2 absorption

Estimates



https://www.youtube.com/embed/3kb0bz-3lWc

Sources of "Natural Capital"

Food and research value

- Directly measured from market data - same as with energy resources

Tourism/aesthetic amenity

- Revealed preference methods (primarily travel cost)

Regulating services

- Extrapolated from the cost of achieving the same results with man-made structures
- OR from estimated damage reduction from extreme weather events

Maintenance of genetic diversity

- Stated preference methods

Case study #2: Bees

Domesticated beekeeping is a textbook example of a positive externality

- The more honey I produce, the more my neighbor's crops improve

Pollination services are also sold directly - revenue of ~$656 million per year

- https://www.vox.com/2015/7/6/8900605/bees-pollination-ecosystem-services

Wild bees

Direct value added from crop pollination is ~$15 billion per year in the US

- (Crop revenue with pollination) minus (Crop revenue without pollination)

Pollination also has non-market sources of value

- Supports genetic diversity, ecosystem resilience, and nutrient cycling

Apparently only 12.6% of wild bees actively pollinate agricultural crops

- The rest pollinate other plants which are not sold in markets

Valuation based only on marketable crops is easier, but ultimately an incomplete picture of the value

Source: https://obamawhitehouse.archives.gov/blog/2015/05/19/announcing-new-steps-promote-pollinator-health

Wild bees

Ecosystem services for non-market plants are harder to evaluate

Option value

- Species that currently do not provide market value could be insurance against pollination losses from climate change
- Challenging to predict exact value, many variables at play

Non-use value

- Support native plant species, ecosystem resilience, and biodiversity

Colony collapse disorder

~33% of colonies died in the winter of 2010

CGE models estimate that the decline in pollinator services amounts to a $334 billion annual economic loss globally

- Most of the loss is not from crops but rather in secondary markets

Shortage of worker bees within a bee community causes hive imbalance

- Cause is uncertain, but human activity is a likely contributor

White House policy in 2015

- Aim to set aside 7 million acres of pollinator-friendly habitat
- However, did little to prevent harmful pesticide use

Reading for next time

- Video: The economic, social and icon value of the Great Barrier Reef
- What Is The Real Value Of The Great Barrier Reef? (online version)
- What bees can teach us about the real value of protecting nature (online version).

Lecture 31

- Bioeconomic systems
- Static fisheries

Recap

Early in this class we studied the two-period model of mineral extraction

- Scarcity
- Optimal conservation of resource
- Role of technology, extraction costs, demand

Value of the conserved resource falls to zero in the long run

- Use economic models to find the best resource allocation

Bioeconomic systems

Bieconomic systems have a feeback between the environment and economic value:

The value, quantity, and quality of the resource affects economic activity, and vice versa

- Fisheries, livestock, forestry
- Sustainability
- Inputs and outputs

Contrast with energy resources and non-renewable resources

- Gold doesn't grow more gold if you wait til next year to mine it

Bioeconomic systems are more like a bank account

- Depositing more money creates more interest payments in the future

Fisheries

Fishery is the broad term for any bioeconomic fish system

- Can be private, public, or in between

Biological model - Shaefer (1957)

Assumptions

- We work with average, long run growth
- Ignore interaction with other species, population age, other environmental effects

Biological model of fish growth

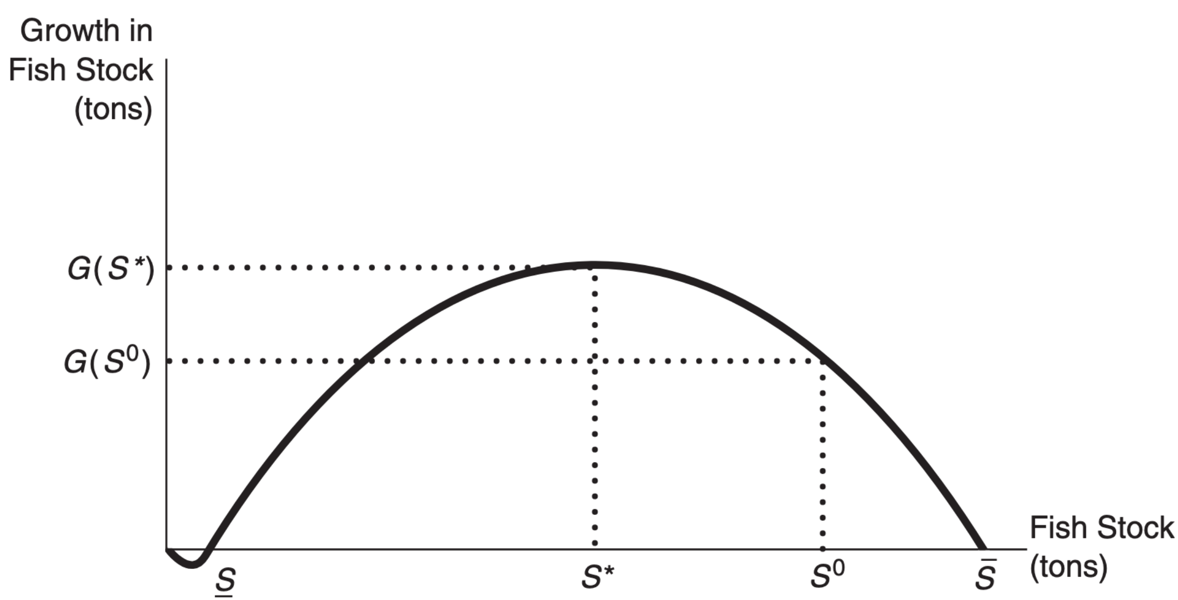
Vertical axis

- Population change per period
- Birth/death cycle only, not fishing

Horizontal axis

- Number of fish presently in the fishery

FIGURE 13.1 Relationship between the Fish Population (Stock) and Growth



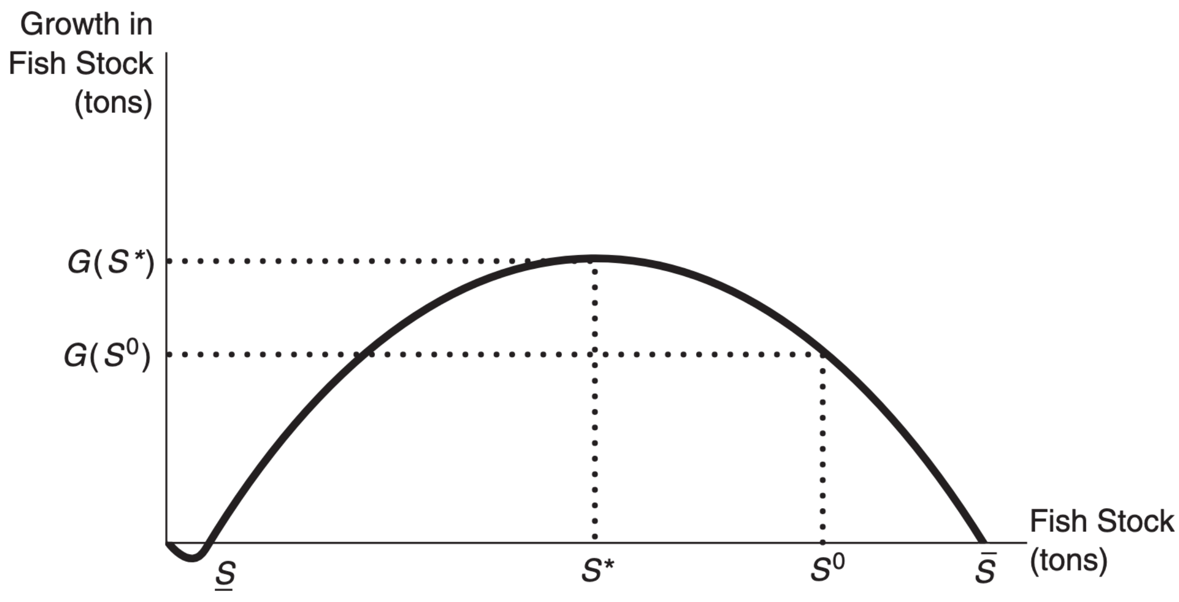
Biological model of fish growth

$\underline{S}$ is not zero; it is the point at which the death rate > birth rate

$\bar{S}$ on the far right is the carrying capacity

- Resources of the fishery limit population growth

FIGURE 13.1 Relationship between the Fish Population (Stock) and Growth



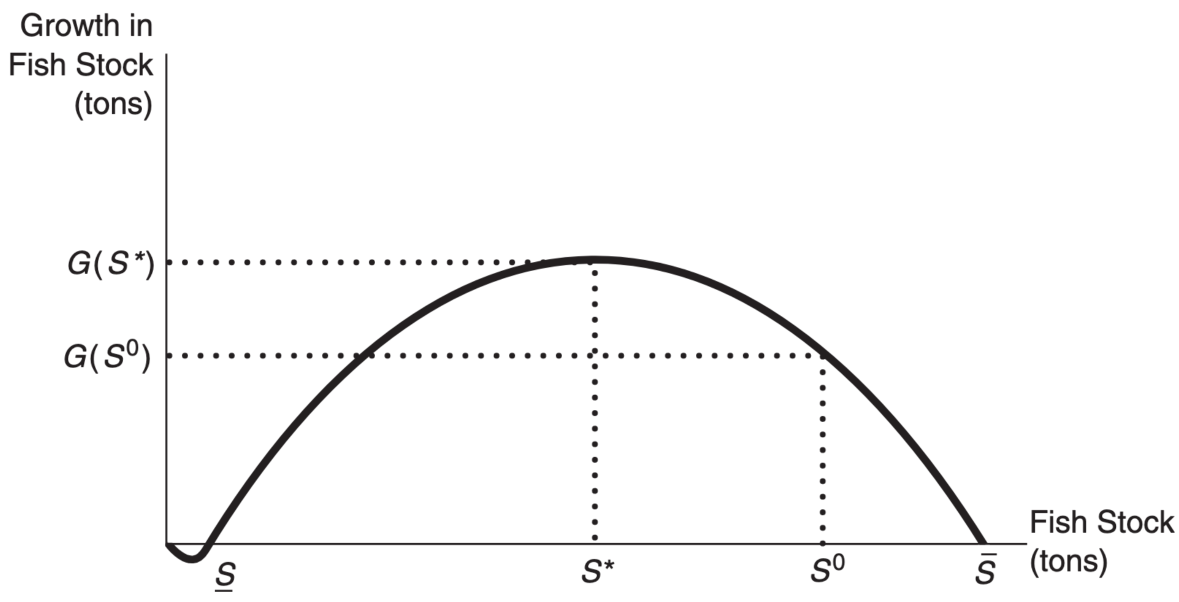
Sustainable yields

In general at a level S, we can harvest $G(S)$ fish every year and the stock will remain at S (sustainable yield)

S^* is the stock with the "Maximum sustainable yield"

- Population level that enables the fastest growth rate, $G(S^*)$

FIGURE 13.1 Relationship between the Fish Population (Stock) and Growth



Bioeconomic model

Sustainable (in this context): we face an identical situation every period

The biological model is the basis for sustainability

- We can sustainably fish at a rate less than or equal to the growth rate
- Licenses in public fisheries are based on this principle

However, we need an economic model if we want efficiency also

Efficient sustainable yield

- Harvest maximizes (total revenue) – (total costs)
- While only fishing $G(S^{\text{efficient}})$

Bioeconomic model

Gordon-Schaefer bioeconomic model of fisheries

- Choice variable is the level of "fishing effort"

Assumptions

- Constant price of fish, constant marginal cost of effort
- Quantity caught is proportional to stock
- Discount rate of $r = 0\%$

Remember, maximum sustainable yield (MSY) gives us the maximum benefit, not the maximum NET benefit

Bioeconomic model

For now, this is the static model because $r = 0\%$

- Only looking at sustainable outcomes

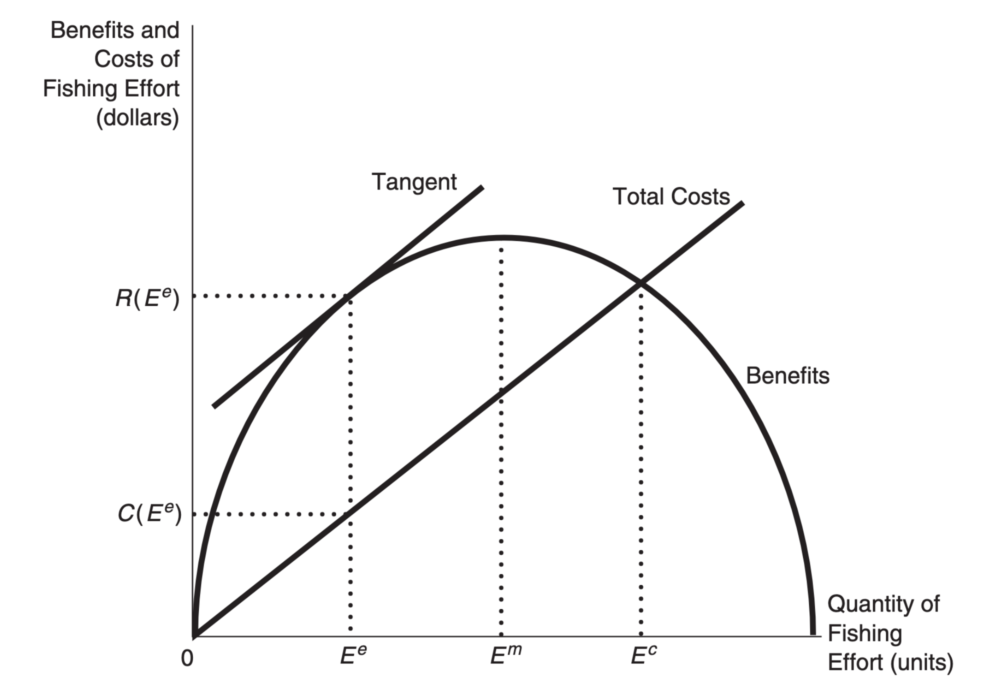
Level of effort fishing $\rightarrow$ fish stock $S \rightarrow$ growth rate $G(S)$

- Growth rate = number of fish we can take each period

Benefit curve is the mirror image of the growth curve from before

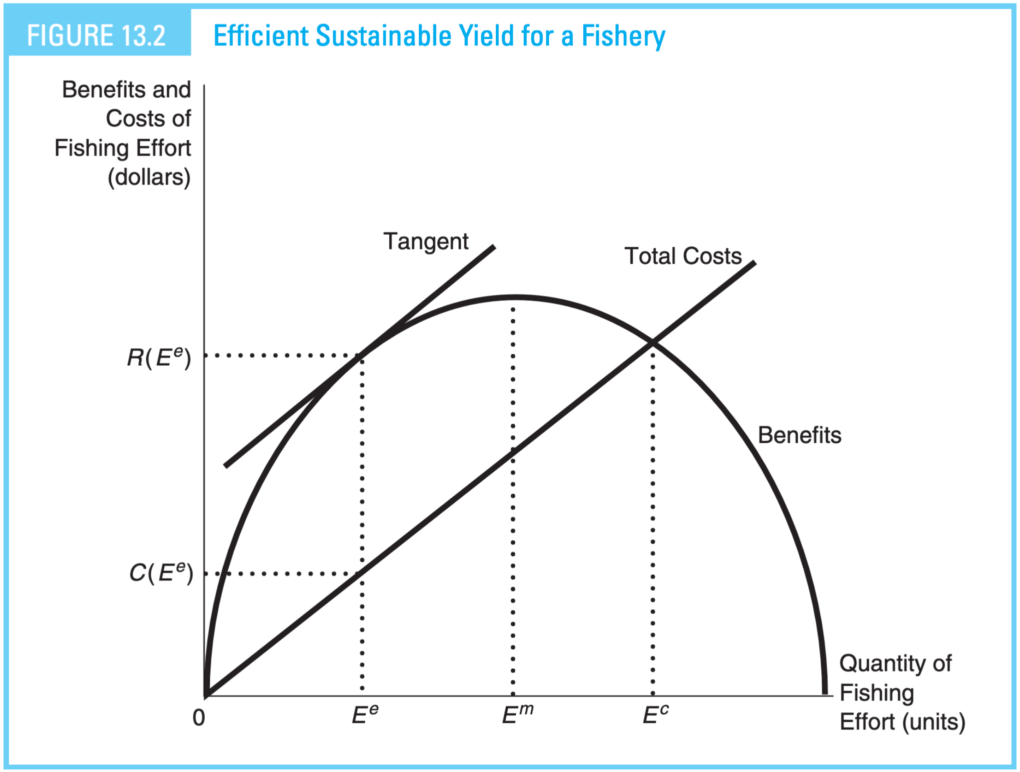
- Large effort $\longrightarrow$ small population $\longrightarrow$ low growth rate
- Small effort $\longrightarrow$ large population $\longrightarrow$ low growth rate
- Medium effort $\longrightarrow$ medium population $\longrightarrow$ high growth rate

FIGURE 13.2 Efficient Sustainable Yield for a Fishery



Total cost curve

- Constant MC of effort $\rightarrow$ increasing total cost of effort
- Marginal cost = slope of the Total cost curve



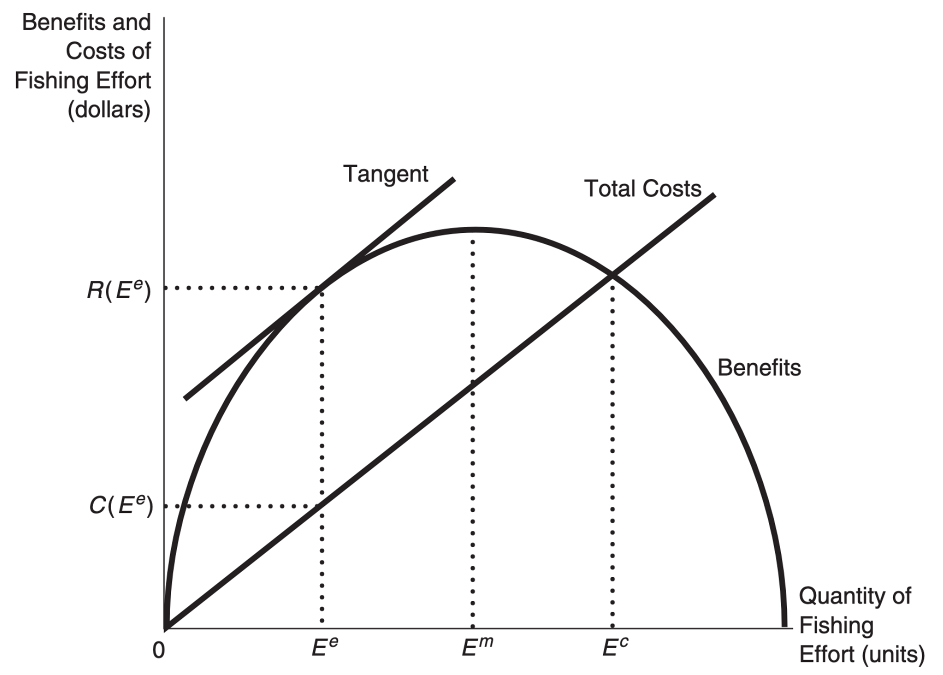
At the effort level E^C, the total cost of effort is equal to the total benefit

- Zero profit

At E^M, the level of effort results in maximum benefits per period

- Not maximum profit

FIGURE 13.2 Efficient Sustainable Yield for a Fishery



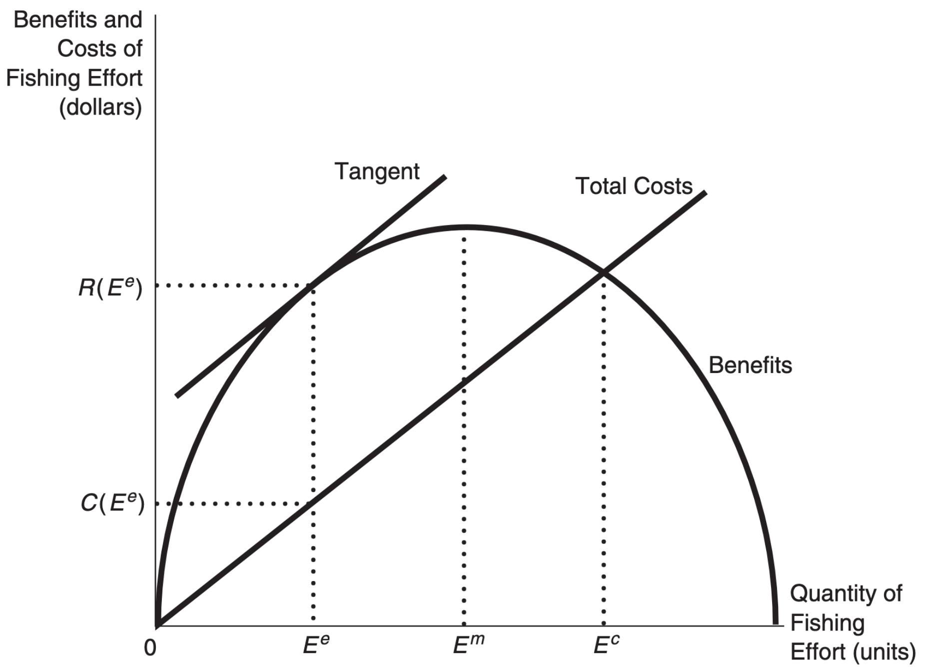
Bioeconomic model

E^E is the effort level corresponding to the "Efficient Sustainable Yield" (when $MC = MB$)

$R(E^E)$ is the value of the ESY

$C(E^E)$ is the cost of obtaining the ESY

FIGURE 13.2 Efficient Sustainable Yield for a Fishery



Bioeconomic model

$R(E^E)$ - $C(E^E)$ is the profit we get when the fishing rate = the ESY

Why is the maximum profit? Two ways to think about it:

1. Max distance (vertical) between TB and TC

2. Point at which MB = MC (slope of TB = slope of TC)

Fundamental Tradeoff of Fisheries

The fundamental tradeoff is:

By fishing one more fish today, I can not fish 1 tomorrow **AND** I change tomorrow's growth rate

Lecture 32

- Dynamic fisheries
- Open access fisheries

Conclusions/Recap

Sustainable fishing $\rightarrow$ actions lead to constant population size at the end of each period

1. Biological model gives us Maximum Sustainable Yield, which maximizes benefits across all sustainable levels of fishing

2. Bioeconomic model gives us ESY, which maximizes net benefits across all sustainable levels of fishing effort

    - Maximum Sustainable Yield is not efficient because it does not consider any costs

Dynamic model

The dynamic model expands on the static model

- Allows for non-sustainable outcomes that may be more efficient if we explicitly value the present over the future
- Discount rate of zero turns this back into the static model

For this section, we will focus on intuition and not the math

- The math in this section of the book uses differential equations (fancy calculus)

Open access fisheries

Everything before now has been from the perspective of a single decision-maker who captures the benefit of conservation

- Think of inland fish farms or privately owned lakes

How do things change when we introduce other people to the mix?

- Most fisheries are open-access; common resources

- Oceans, coastlines, rivers, lakes

When we treat fish as a rival but non-excludable good, there are two main sources of inefficiency

1. Static inefficiency

In the static ESY scenario, fish profitably in every period

- Under open access, profit opportunity brings additional fisherman

More fisherman $\rightarrow$ higher total effort $\rightarrow$ smaller stock of fish

- Even under sustainable fishing levels, this is inefficient
- In the long run, more competitors (fisherman) will enter until industry profit goes to zero

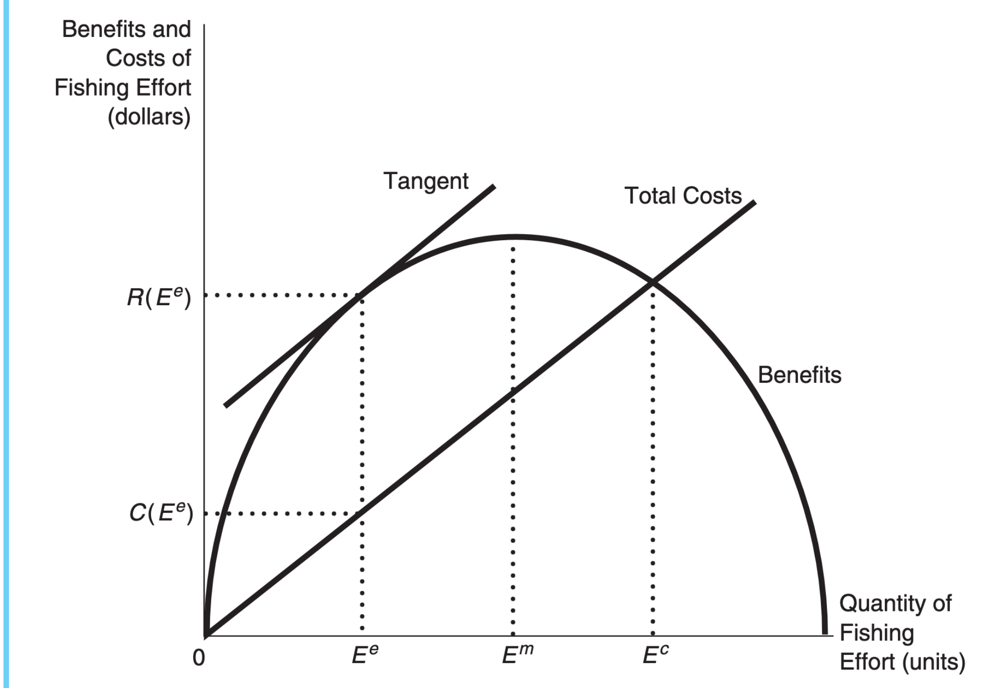
1. Static inefficiency

Recall from before, E^E is the level of effort corresponding to the ESY

With open access, participants enter until there is no more profit opportunity, and total effort is at E^C

- In this picture, they have about the same sustainable catch, but profits are zero now!

FIGURE 13.2 Efficient Sustainable Yield for a Fishery



2. Dynamic inefficiency

In open access fisheries, individual decision-makers do not benefit as much from leaving fish in the water

- All of the incentives of the dynamic model plus a lower benefit in the future

This often leads to overfishing

- Textbook example of tragedy of the commons

Reading for next time

- Forestry Chapter 12, pages 293-299

Lecture 33

- Forestry

Forests

Forests cover 33% of the land in the US, about 31% globally

Bioeconomic system

- Value of the resource over time depends on economic interaction

Forests are open-access, but usually not as open as fisheries

- Probably easier to regulate logging companies and farms than individuals who fish

Age

- Key feature for fisheries model - growth rate of the population
- Key feature for forest model - growth rate of individual trees

Recently, trees have become a key component in "net-zero emissions"

Deforestation

Biggest cause of deforestation is land use conversion

- Clearing forest land for agricultural and livestock land
- Subsistence farming is a big part of this - is afforestation/reforestation regressive?

Aggravates the problem of climate change through lowered GHG sequestration capacity

- Afforestation/reforestation has a positive externality $\rightarrow$ under-produced common resource

Loss of ecosystem services

- Biodiversity, soil erosion and desertification
- Coastal protection - mangrove swamps

Deforestation/Afforestation

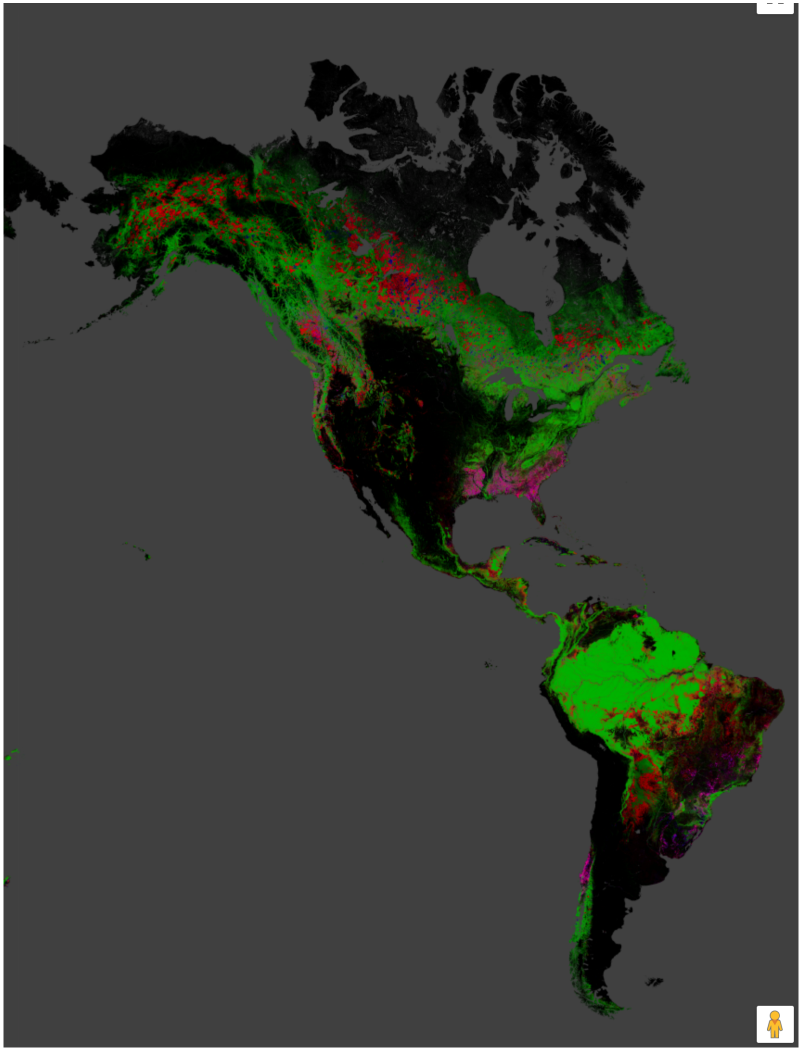
Green: forest cover

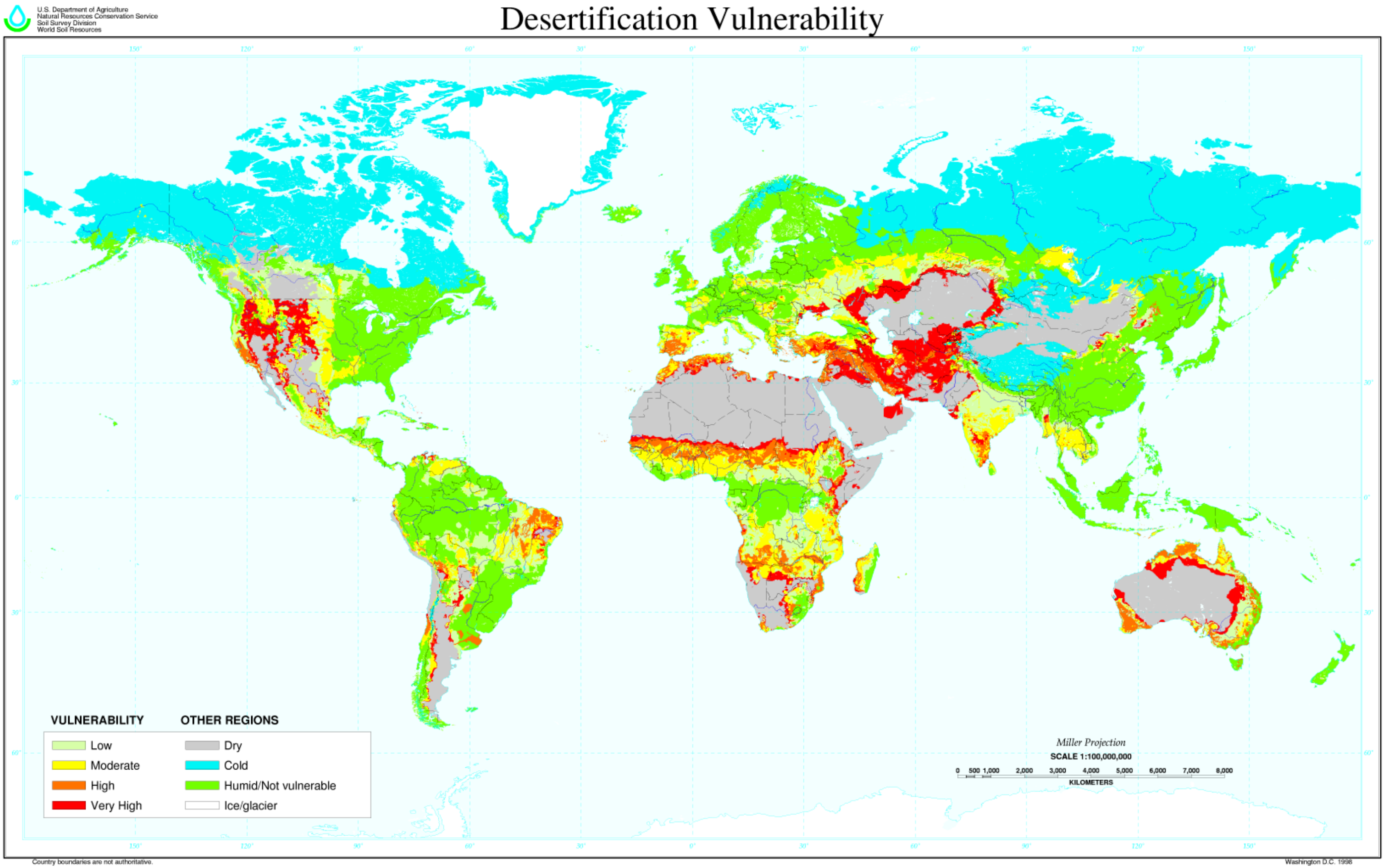
Red: loss (2000-2016)

Blue: gain (2000-2012)

Purple: gain and loss

Source

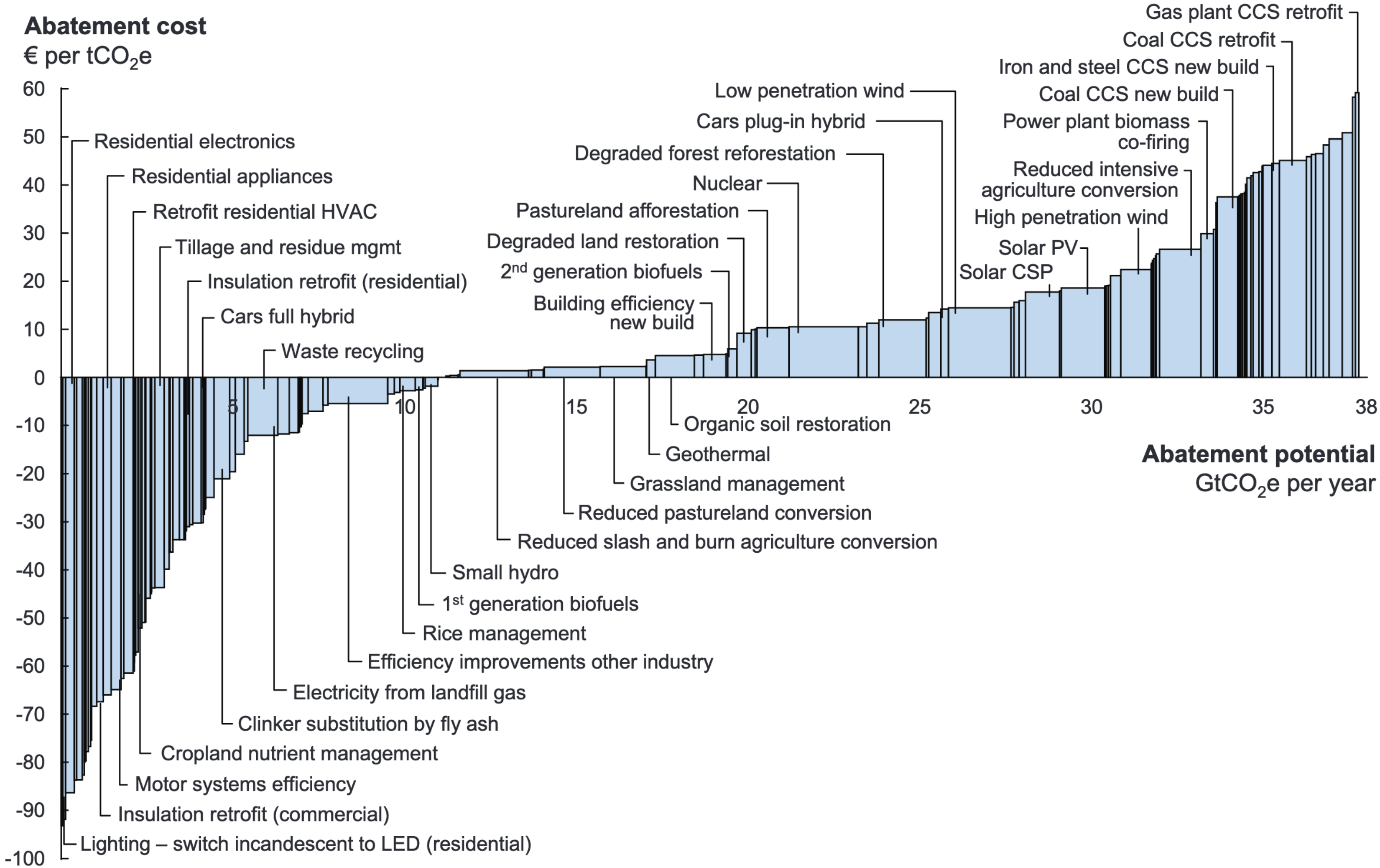




U.S. Department of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources
Desertification Vulnerability
VULNERABILITY
Low
Moderate
High
Very High
OTHER REGIONS
Dry
Cold
Humid/Not vulnerable
Ice/glacier
Miller Projection
SCALE 1:100,000,000
KILOMETERS
Country boundaries are not authoritative.
Washington D.C. 1998

Exhibit 1

Global GHG abatement cost curve beyond business-as-usual – 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

Harvest of forests

Macro perspective - land use management

- Different land uses have different value to society, optimal balance
- Problems related to open access and tragedy of the commons

Micro perspective - optimal timing of harvest decision

- Today: model of plantation forestry
- Single owner, profit maximization problem

Commercial uses of forest harvest

- Wood fuel, building material, paper products, carbon credits, etc.

Comparison with fisheries

Both resources: slower growth rate or higher discount rate incentivizes overuse

Compared to fisheries, forests:

- Grow more slowly but last longer
- Have more well-defined property rights (private good)
- Are a crucial input into climate change models

Biological model of growth (Clawson, 1977)

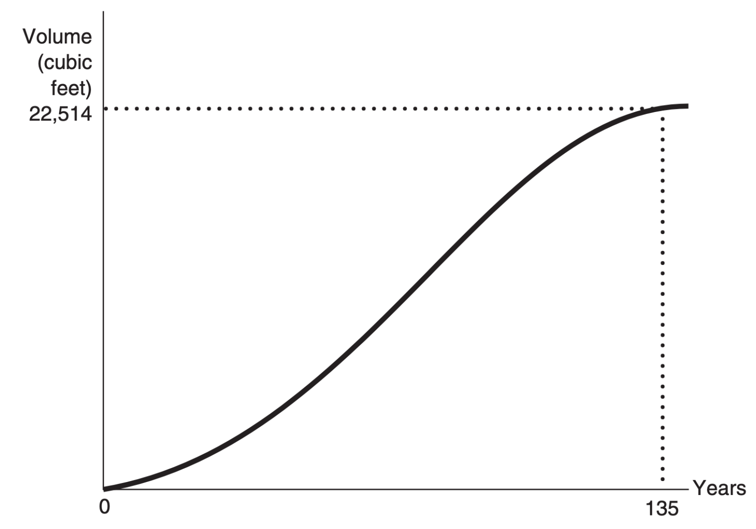
Growth is in volume of wood per acre, per year

- Average growth rate of all trees in the forest

Trees do not affect growth rate of other trees

Number of trees does not change

FIGURE 12.1 Model of Tree Growth in a Stand of Douglas Fir.



Single-rotation harvest model

Single-rotation

- No re-planting decision; model ends at harvest

Assumptions

- Fixed cost of planting one acre: $1,000
- Marginal cost of harvesting: $0.30 per cubic foot
- Price: $1 per cubic foot

Maximize PV(NB)

- PV(NB) = PV(revenue) – PV(extraction cost) – planting cost in period zero

Optimal choice will depend on the discount rate

Main ideas

Planting costs happen in current period, no discount

- Benefits and marginal cost of harvest occur in the future and they are discounted equally

Higher discount rate $\rightarrow$ harvest sooner

Cost and price do not affect optimal harvest date after the trees are planted

- Cost and price affect overall profitability
- "I wish I hadn't made this investment, but I still benefit from harvesting it"

Economic Harvesting Decision

TABLE 12.1 Economic Harvesting Decision: Douglas Fir

Age (years)	10	20	30	40	50	60	68	70	80	90	100	110	120	130	135
Volume (cubic feet)	694	1,912	3,558	5,536	7,750	10,104	12,023	12,502	14,848	17,046	19,000	20,614	21,792	22,438	22,514
Undiscounted ($r = 0.0$)															
Value of Timber ($)	694	1,912	3,558	5,536	7,750	10,104	12,023	12,502	14,848	17,046	19,000	20,614	21,792	22,438	22,514
Cost ($)	1,208	1,574	2,067	2,661	3,325	4,031	4,607	4,751	5,454	6,114	6,700	7,184	7,538	7,731	7,754
Net Benefits ($)	−514	338	1,491	2,875	4,425	6,073	7,416	7,751	9,394	10,932	12,300	13,430	14,254	14,707	14,760
Discounted ($r = 0.01$)															
Value of Timber ($)	628	1,567	2,640	3,718	4,712	5,562	6,112	6,230	6,698	6,961	7,025	6,899	6,603	6,155	5,876
Cost ($)	1,188	1,470	1,792	2,115	2,414	2,669	2,833	2,869	3,009	3,088	3,107	3,070	2,981	2,846	2,763
Net Benefits ($)	−560	97	848	1,603	2,299	2,893	3,278	3,361	3,689	3,873	3,917	3,830	3,622	3,308	3,113
Discounted ($r = 0.02$)															
Value of Timber ($)	567	1,288	1,964	2,507	2,879	3,080	3,128	3,126	3,046	2,868	2,623	2,334	2,024	1,710	1,449
Cost ($)	1,170	1,386	1,589	1,752	1,864	1,924	1,938	1,938	1,914	1,860	1,787	1,700	1,607	1,513	1,435
Net Benefits ($)	−603	−98	375	755	1,015	1,156	1,190	1,188	1,132	1,008	836	634	417	197	14
Discounted ($r = 0.04$)															
Value of Timber ($)	469	873	1,097	1,153	1,091	960	835	803	644	500	376	276	197	137	113
Cost ($)	1,141	1,262	1,329	1,346	1,327	1,288	1,251	1,241	1,193	1,150	1,113	1,083	1,059	1,041	1,034
Net Benefits ($)	−672	−389	−232	−193	−237	−328	−415	−438	−549	−650	−737	−807	−862	−904	−921

Value of timber $=$ price $\times$ volume$/(1 + r)^t$

Cost $=$ \$1,000 $+$ (\$0.30 $\times$ volume)$/(1 + r)^t$

Net benefits $=$ value of timber $-$ cost

Price $=$ \$1

Multiple-rotation harvest model

Multiple-rotation harvest creates interdependence

- Harvest early and start growing more trees vs harvest later and increase current trees' value
- Invested earnings help pay for next cycle

The punchline: later harvest dates have an additional opportunity cost compared to the single-harvest model

- Ability to re-plant results in shorter optimal harvest cycles

Complicating the model

Relaxing assumptions

- Lumber prices tend to increase over time
- Harvest technology improves over time, leading to lower MC

With a partner, how would this effect the optimal harvest timing? These effects lengthen the optimal harvest cycle, as the net benefit per unit grows over time

- Counteracts the discount rate

Forestry and Carbon Offset Credits

For a lot of firms, they can "offset" their emissions by buying carbon credits; the major source being planting of new trees

- Relatively cheap to "abate" using trees at about $12 per metric ton of carbon (source)
- Buy credits if a firm's marginal abatement cost is more expensive than marginal cost

UN has a program to mix development and carbon offsets (e.g. developing hydroplants in developing countries): https://offset.climateneutralnow.org/AllProjects

As the number of credits sold, will the cost increase?

- Using cheapest sources first

Questions about quality of permits:

- The Guardian - Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows
- Bloomberg - These Trees Are Not What They Seem
- Bloomberg - Timber

Reading for next time

Land use; Chapter 10

Lecture 34

- Land use
- Food insecurity

Land resources

Fixed location, multi-purpose resource

Land is inherently scarce because we cannot make more of it

- Allocation problem is in choosing between competing uses of land

Unrestricted markets tend to allocate land according to its highest value use

- Value determined by willingness to pay rather than net social benefits

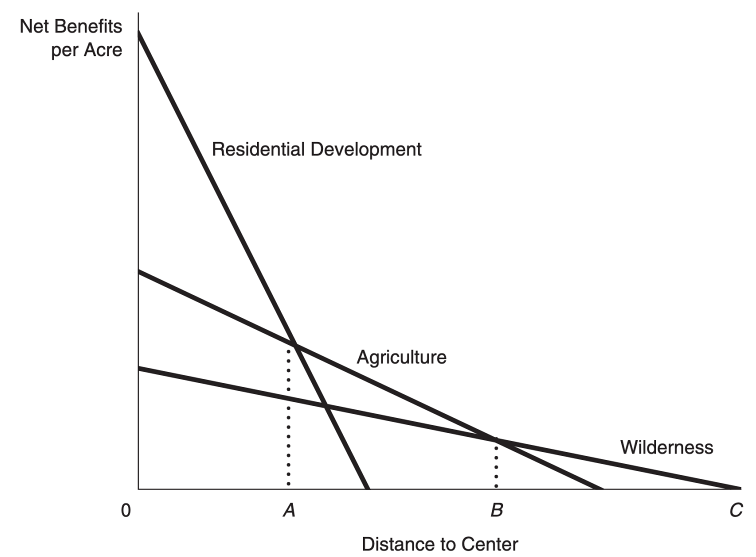
Urban planning model

Each line is called a "bid-rent" function

- Net benefit of each activity depends on how far away it is from the city center
- E.g. increasing travel costs to economic center

Everything from zero to A miles from the city center should be residential

FIGURE 10.1 The Allocation of Land



Land use conversion

Over time, these relationships can change with technology

- 1870: 50% of US population worked in agriculture
- 2008: <2% of US population worked in agriculture

In the US,

- Industrialization shifted bid rent function upward for urban uses
- Rising productivity of agricultural land, improved shipping infrastructure shifted bid rent function down for agriculture
- Entire regions specialize in agriculture or in non-agriculture

Advantages of Cities

Cities are great places due to *agglomeration forces*

- Higher density of people make people more productive (e.g. Silicon Valley for innovation)
    - Studies find that wages are higher for the same person when they move to a denser city
- Better consumptive amenities (e.g. compare food in Denver to Boulder)
- Allow for more upward mobility; more interactions with people
- Much lower carbon footprint

Terrific book: TRIUMPH OF THE CITY: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier

Zoning and Land-use Regulations

At the start of the 20th century, cities became nervous about the layout of cities

- Factories in residential neighborhoods, dilapidated apartments ("slums")
- Power lines everywhere (remember!); too narrow roads

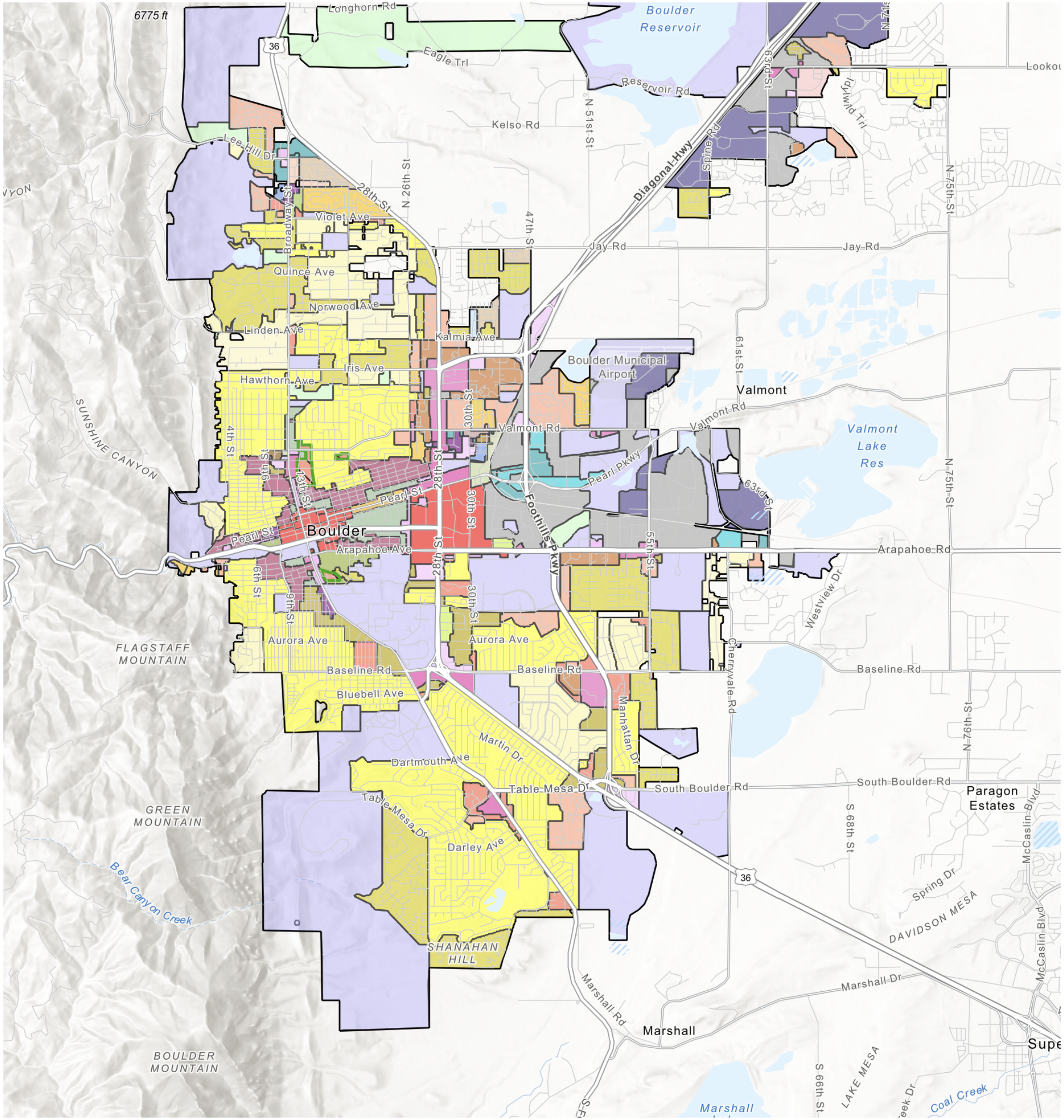
They passed *zoning laws* to control what kind of buildings can be built where

- Commercial/business districts
- What kinds of residential housing: single family homes, duplex, triplex, apartments

These exploded around 1930 outside of the big cities

- Part of the story was about race; some explicit (racial restrictions) and some implicit (dense housing)

Some zoning makes sense (e.g. keep pollutions out of city center), but towns really went hard...



Costs of Zoning

Raising Home Prices

- Limit the number of homes that can be built, raising the cost (Source)
- NIMBYism: Local homeowners vote and they don't like to vote to build more buildings (Source)

Increasing Economic Segregation

- Strict zoning keeps low-income people from moving to nice school districts and high-amenity areas (Source)
- Racial segregation too (Source)

Limiting Economic Growth

- High home prices keep people from moving to high productivity places (like SF and NYC) lowering economic growth (Source)

Costs of Zoning

Urban sprawl

- Since zoning limits density, homes build outwards (Source)
- Increases pollution from driving

Inequality

- Putting commercial districts in low-income and/or minority neighborhoods (Source)
- Highways put there too (Source)

Food insecurity

Most environmental issues are relatively new, but this one is old

WHO/FAO pillars of food insecurity

- Availability, accessibility, utilization, stability

Early economist Thomas Malthus (~1800)

- Argued there is an unsustainable relationship between growth of human population and growth of food production

This type of argument persists today, but we easily create enough food for everyone

- Technology outpaces human population growth

Food production

Modern food insecurity is more about costs and distribution across people, not total production

- Current food production capacity is essentially unlimited

Vertical Indoor Farming

- Vertical farming can reduce carbon footprint by reducing need for transportation
- Lower water use, much greater yield efficiency, conditions determined by machine learning algorithms

Global food market

Supply curve for the global food market is still up for debate

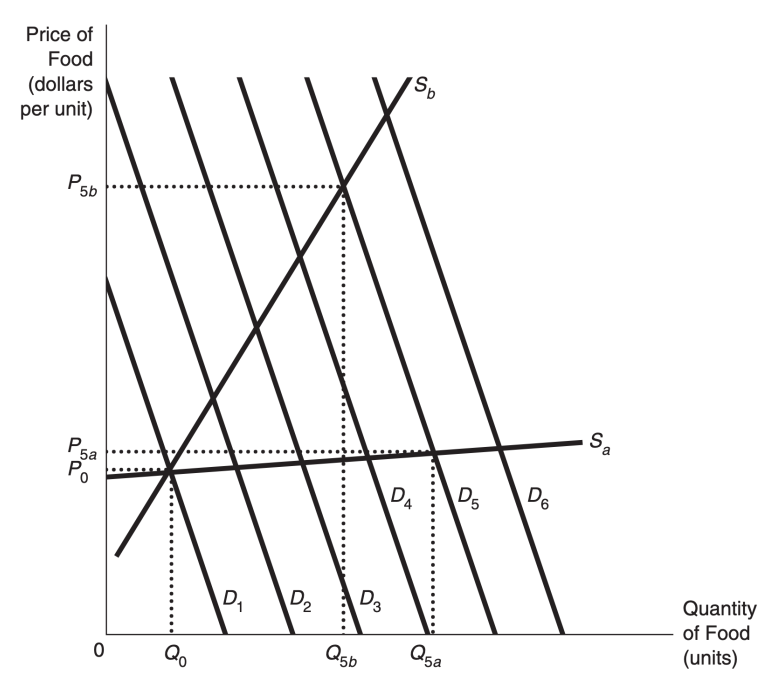
S_a : Elastic supply

S_b : Inelastic supply

$D_1 - D_6$

- Demand curves shift with population growth over time

FIGURE 11.1 The Market for Food



Global scarcity hypothesis

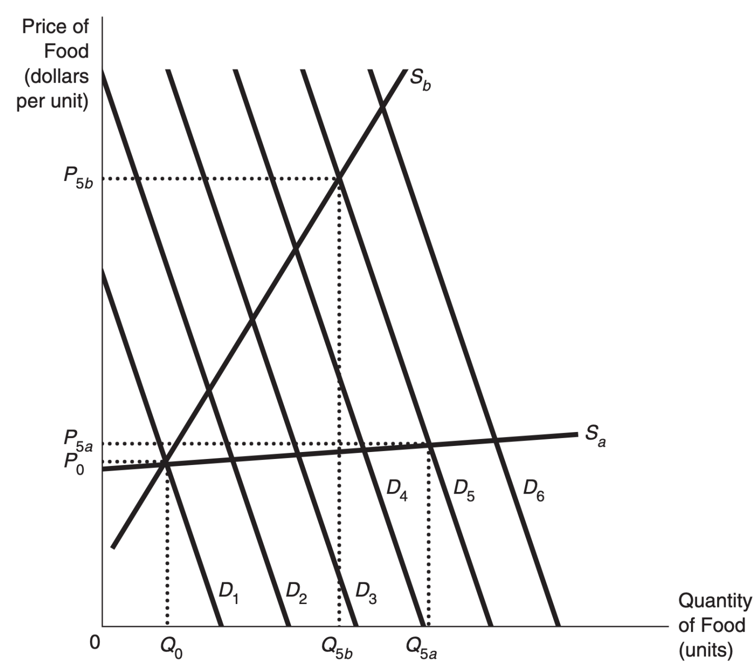
Strong form: per capita food production is declining

- $\longrightarrow$ Steep curve like S_b
- Little empirical evidence in recent past

Weak form: food prices are rising faster than other prices

- $\longrightarrow$ Not as steep as S_b but upward sloping
- A reasonable hypothesis

FIGURE 11.1 The Market for Food



Next time

- Water (Chapter 9)

Lecture 35

- Water

Water demand

US: 355 billion gallons per day (2010)

- Lower than in 2005

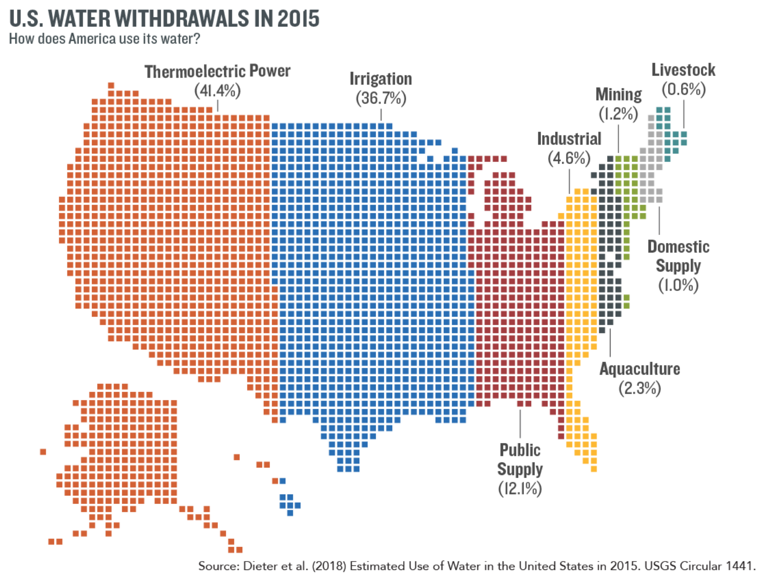
Thermoelectric power requires a lot of water for cooling

Agriculture too

- Doesn't include livestock

Public supply

- Residential and commercial uses



Water demand

Residential/commercial (~12% of total)

- Water is a utility good much like electricity
- Homes are connected for direct water use (showers, tap, sprinklers) and for waste (toilets, sink drains)

Residential water pricing

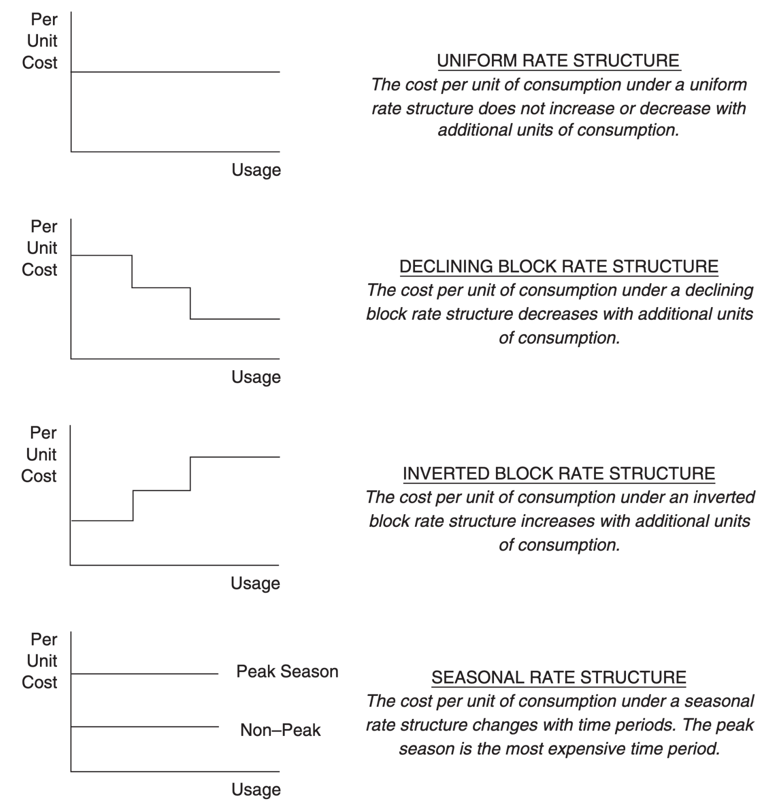
Compared to electricity, water demand is more elastic

- Easier on the margin to conserve water than electricity (when prices are high)
- However, demand response is harder

Ex. 9.5

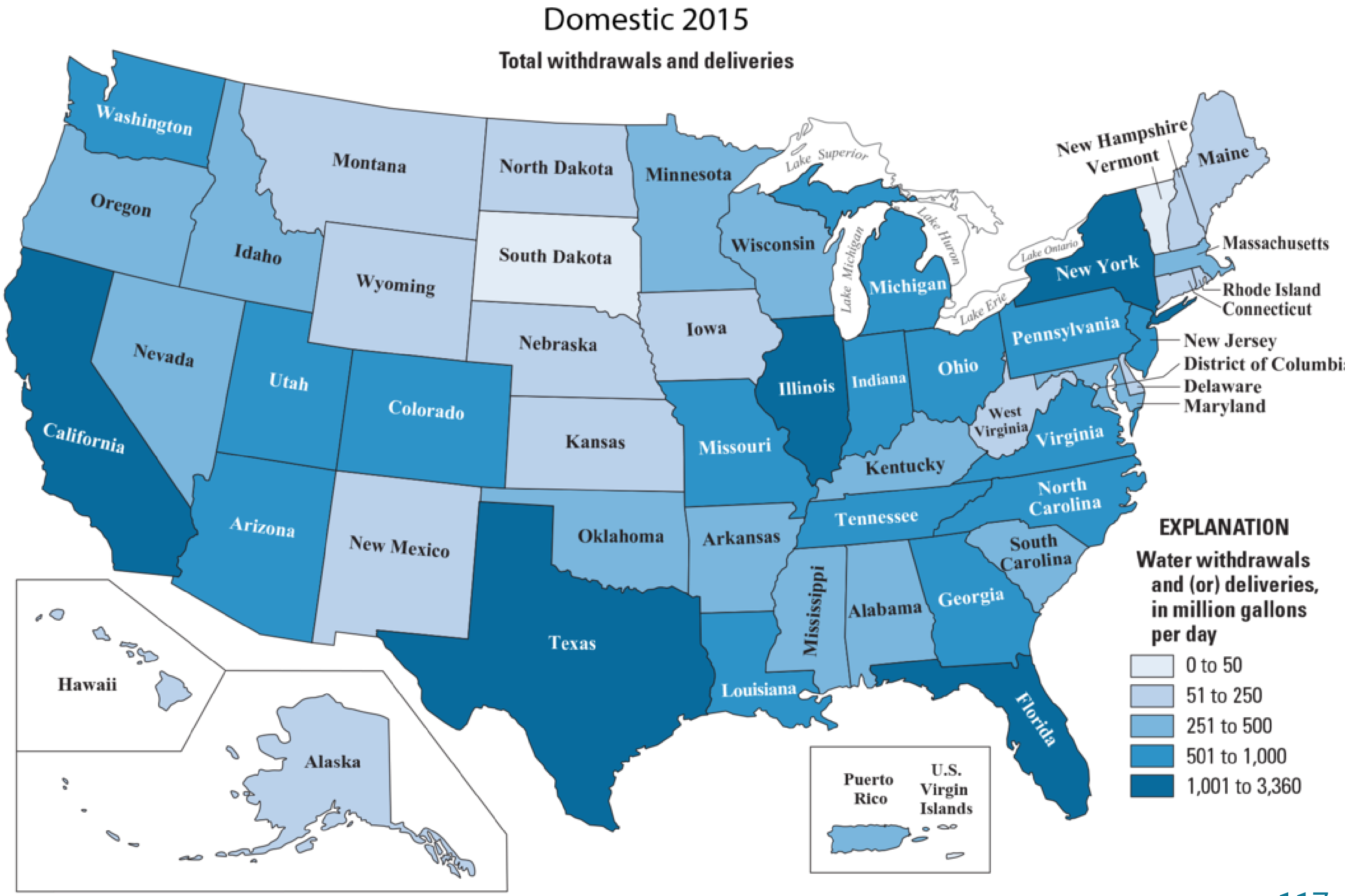
- Canadian households with water metering are better at conserving water
- Water use was 70% higher under flat rate than under inverted block rate

FIGURE 9.4 Overview of the Various Variable Charge Rate Structures



Source: Four examples of consumption charge models from WATER RATE STRUCTURES IN COLORADO: HOW COLORADO CITIES COMPARE IN USING THIS IMPORTANT WATER USE EFFICIENCY TOOL, September 2004, p. 8 by Colorado Environmental Coalition, Western Colorado Congress, and Western Resource Advocates.

Water demand



Water supply

Fresh water is plentiful overall, but it is scarce in some places

- No universal rules for water management

Surface water: renewable

Ground water in aquifers: semi-renewable

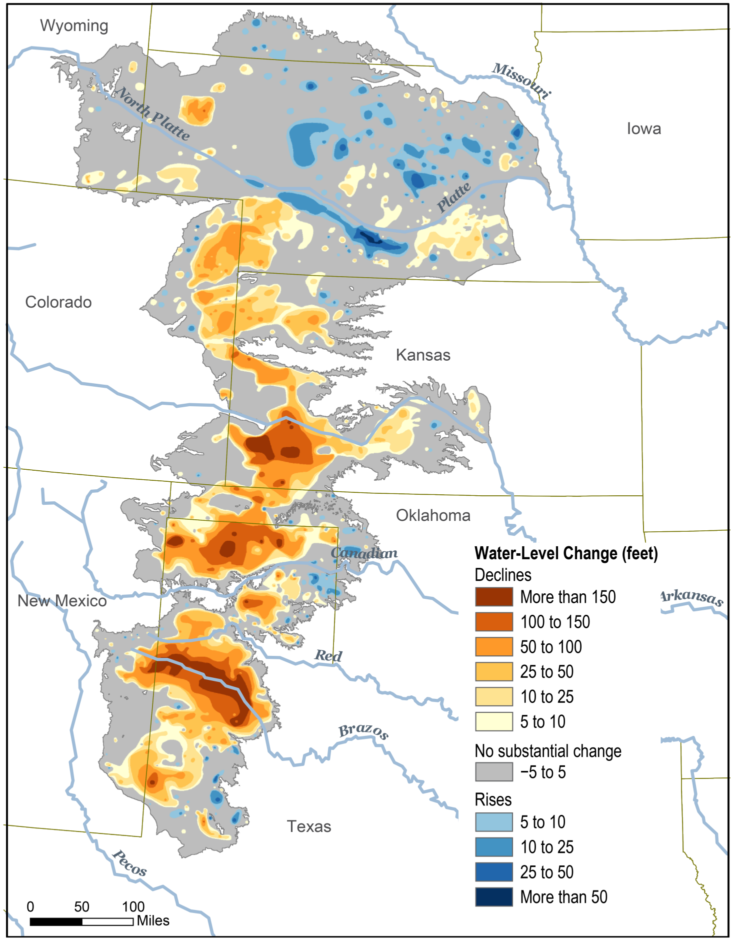
Example: Ogallala Aquifer

Huge aquifer in the middle of the US

- Ground water

Supplies water primarily for agriculture

Annual refill rate: 22mm per year; Extraction rate: 77mm per year



Water rights

Water rights are particularly challenging to assign

- Water is used and then disperses; cannot own specific water molecules
- Sources of water change dramatically over time
- Changes to water infrastructure can affect existing beneficiaries

Riparian rights

- Early American system gave water rights to owners of adjacent land
- Became less appropriate as population growth and development created scarcity

Water rights

Under the structure of riparian rights, there was no way to transfer ownership

- Transferability - one of the necessary components for complete property rights
- It became necessary to revise the rules when water became important elsewhere

Prior appropriation doctrine

- No longer tied to land ownership
- Whoever starts using the water first gets "senior" rights
- "Junior" rights distributed to the next group

Water rights

Over time, perspectives evolved until water was seen as a public good

- Owned by the state, used by citizens

Instead of a right to ownership of water, people could have "usufructuary rights"

- Allowed them access to the public good without traditional ownership rights
- Government ultimately claimed ownership/responsibility

Expanded role of federal government in water allocation

Privatization of water

Facing declining infrastructure, government can turn over control to private companies

- Hoping they can manage water more efficiently
- Attractive option for poorly funded governments

Cochabamba, Bolivia

- Privatization can go very badly - violent protest and early contract termination
- Monopoly control over an essential resource, price hikes
- Movie - Tambien la Lluvia (Even the Rain)

Surface water

Because surface water is renewable, allocation problem is across different uses within the same time period

Texas rice belt

Since around 1900, farmers in the lower floodplains of the Colorado River received water naturally

Over time, population increased dramatically

- Water authority built dams to form reservoirs and supply residential water

Rice farmers received water for a very low price because of their rights

- More socially efficient to let the price rise, force farmers to switch crops
- Issue of efficient land use conversion over time

Recent droughts put stress on the region

Reading for Next Time

- Is Recycling Worth It? (online version).

Lecture 36

- Waste and Recycling

Overview

Virgin vs recycled materials

- How do firms choose the type of inputs to use?

Trash can vs recycling bin

- How do consumers choose where to put their waste?

Total volume of trash produced

- How does society decide what trash is worthwhile?

Overview

The US generates about 254 million tons of trash per year

- Recycle or compost about 87 million tons (34.3%)

Landfills produce about 1.8% of the greenhouse gases in the US

- Mostly methane, which is a bad one

Connection to resource taxonomy concept

- Resources exist in several forms - in the ground, in landfills, and in existing products distributed throughout the economy
- Each of these enter into the "potential reserves" function - they are profitable to extract under some set of circumstances Is Recycling Worth It?

Economics of recycled materials

The value of recycled materials depends on both economic and environmental factors

- Varies according to the material, as well as economic conditions

Direct: Price of recycled material vs price of virgin material

- All else equal, profit-maximizing firms will probably choose the cheaper of the two

Indirect: Net externality of recycling vs net externality of disposal

- If this difference is important, there may be a market failure

Cost of recycling

Labor costs

- Sorting, handling, resource marketing, certifications

Transportation

- Usually requires additional steps

Energy use

- Some of the benefit is negated by the extra energy used in the process

Disposal options

Landfill/dump

- Aesthetic externality if located near population; extra energy/transportation-related externalities if not
- Methane emissions from decomposition - potential for energy conversion?
- Potentially useful resources are harder to obtain in the future

Incineration

- Essentially recycling the energy potential, but usually with low efficiency
- Emissions are hazardous - fly ash and heavy metals

Consumer recycling decision

The consumer’s choice between bins determines the recycling rate

- On the other hand, the firm’s perspective takes recycling rate as a given

Consumers mostly care about the net external impact of recycling

- Otherwise it’s just a transfer from mining company shareholders to recycling company shareholders

It’s an abstract decision with no direct feedback

- Is __ worth recycling if I have to thoroughly clean it first?
- Are they just going to toss it in the landfill if I don’t do a good enough job?

The "warm glow" effect and other social norms play a huge part in this decision

What should we recycle?

Some materials are worth it

- Aluminum - energy use 96% less than virgin aluminum
- Paper products also usually have significant net benefit

However, others are often not worth it

- Glass is often a net negative to recycle

> "Our biggest concern and our biggest challenge today is municipal solid waste and contamination in our inbound stream…roughly 15 to 20 percent of what we process ends up going back to the landfill. It's incredibly inefficient to do that."
>
> CEO of ReCommunity Recycling

Waste Reduction Model (WARM)

EPA created WARM to evaluate GHG reduction methods

Biggest sources of GHG that could be reduced via better methods

Policies

Volume pricing of trash

- Parallel to "demand response" idea in electricity - incentives are better when there is a decision to be made on the margin

Influences two different decisions

1. which bin to use?
2. how much trash to produce overall?

Downsides

- Illegal dumping of trash to save money
- Regressive?

Policies

Refundable deposits for recyclable goods

- E.g. bottles, cans, batteries, pesticide containers

Works like a conditional tax - only have to pay it if you don’t end up recycling

Probably more progressive than regressive

Policies

Taxing the non-recyclable version of a good, i.e. plastic bag taxes

- Probably motivated by littering, which is related

Ireland imposed a 0.15 euro tax on plastic bags

- $\rightarrow$ 90% decrease in use

Evidence suggests that wealthier customers tend to change their behavior, whereas poorer customers mostly absorb the tax

- Almost certainly regressive on the cost side
- Who benefits from reduced litter?