Economics of Land Use

Deforestation

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Motivating Data - Annual Deforestation

Region	Area	80s mn ha	80s %	90s mn ha	90s %
Africa	2,236.1	4.10	0.7	4.81	0.8
Asia and Pac.	903	3.90	1.2	2.55	0.7
Lat America	1,652.3	7.41	0.8	4.41	0.5

Rates of Loss during 1980s and 1990s

1. Over 15 million hectares of tropical forest cleared annually (0.8% per year)
2. Latin America lost 7.4 million ha, almost as much as Asia and Africa combined
3. South America lost 6.2 million ha annually
4. Country with highest rate of loss was Mexico
5. Within Africa, most loss was in Central and Tropical South Africa
6. Within Asia, highest amounts and rates were in Southeast Asia
7. The following decade loss slowed slightly to 12 million hectares lost / year (0.6 % of forests)

Sources of Deforestation

1. Large scale agriculture is main source of deforestation (32% of total forest cover change)
2. Small scale agriculture represents 26% of total forest cover change
3. Shifting agricultural areas and intensification represents 10% of change

Regional Differences

1. Within Africa 60% of forest cover change is from small scale farming
2. Within Latin America and Asia large scale agriculture is the major problem (48% and 30%)

Forest Harvest Decisions

1. The basic question: *When to cut a tree*?
2. First, let us ignore non-timber values (wildlife, carbon sequestration, etc.)
3. When a community harvests an acre, it immediately replants.
4. The answer to our question involves both biology and economics.

Biological Growth of Trees

Volume of wood (cubic feet and cubit feet per year) from Fields (2008)

Age of trees	Total vol.	Average vol.	Annual increase
0	0	0.0	0.0
10	80	8.0	8.0
20	200	10.0	12.0
30	400	13.3	20.0
40	720	18.0	32.0
50	1,360	27.2	44.0
60	1,660	27.7	30.0
70	1,840	26.3	18.0
80	1,960	24.5	12.0
90	2,040	22.7	8.0
100	2,090	20.9	5.0
120	2,090	19.0	0.0
130	2,090	17.4	0.0
140	2,090	14.9	0.0

Biological Growth of Trees

Volume of wood (cubic feet and cubit feet per year) from Fields (2008)

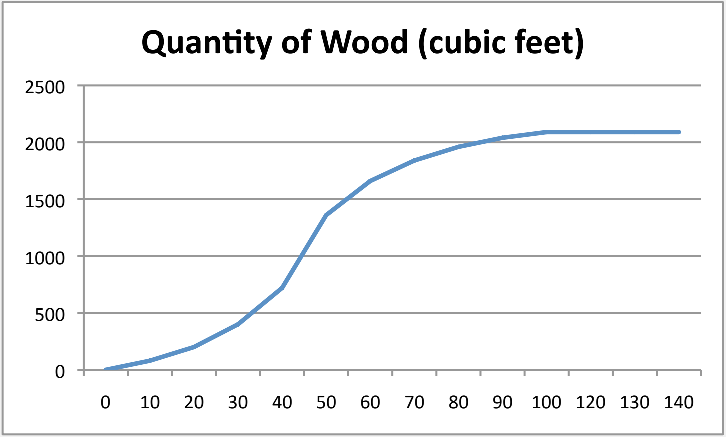


Figure: When should one cut?

When to cut?

1. When done growing, saying after 100 years?
2. But then we have to wait a long time to get the wood
3. When average available volume is highest, 60 years?
4. If 100 years – over 1,000 years we would get 2,090 x 10 = 20,900 cubit feet
5. If 60 years – over 1,000 years we would get 1,660 x 16.6 = 27,666
6. In fact, cutting when average average yield is highest gives *maximum sustainable yield (MSY)*.
7. But does this give the highest economic benefit?

Why harvesting at MSY in not the answer

1. Assume trees with be replanted after harvest, into the indefinite future
2. Then question becomes, “What is optimal timber harvest rotation?”
3. The sooner we cut the trees, the sooner we can replant and grow more wood.

Multiple rotation

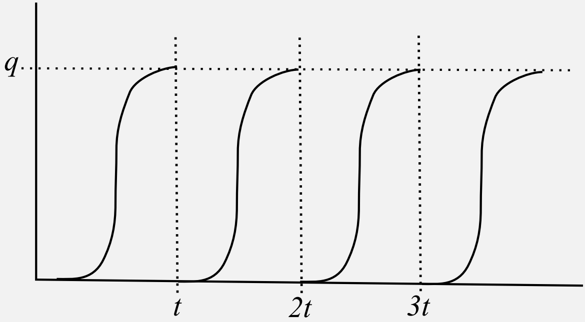


Figure: Cutting every t years

Now the frame is..

1. It is now the present, we have a forest full of trees that are growing.
2. Should be cut them this year or wait?
3. If we wait, next year we have the same decision.. Should we cut or wait?
4. We are faced with a sequence of cost-benefit analyses.
5. We must balance the benefits of cutting this year with the costs – not having the trees to cut next year.
6. Early on, the cost of waiting is presumably low (the trees are growing rapidly) but towards the end, the costs are relative high (waiting doesn't add additional wood).
7. There should, therefore, be a switching point s.t. Benefits = Costs.

Mathematical Model

- V_0 : monetary value of the wood if forests cleared this year
- V_1 : monetary value if harvest delayed a year
- $\Delta = V_1 - V_0$: value of 1-year growth increment
- C : harvest cost
- r : discount rate
- S : present value of the vacant site after trees have been harvested – this could be anything, but for now it is the value of using it for trees forever, thus the present value of the infinite future stream of payments

Mathematical Model (cont)

- If harvested this year, revenue is $(V_0 - C) + S$
- If sold next year, $(V_0 + \Delta V - C + S)/(1 + r)$
- When the forest is young, we would expect $(V_0 + \Delta V - C + S)/(1 + r) > (V_0 - C) + S$
- As forest grows older. ΔV falls and eventually $(V_0 + \Delta V - C + S)/(1 + r) = (V_0 - C) + S$
- or $\Delta V = (V_0 - C)r + Sr$

Optimal cutting

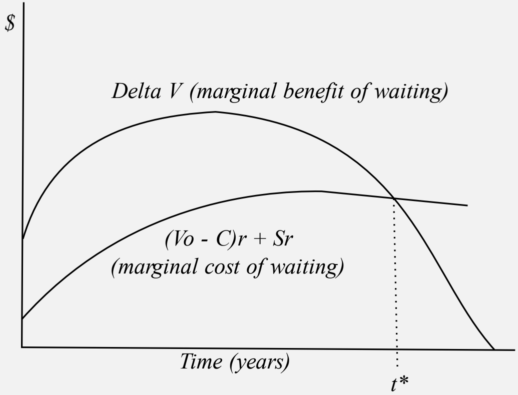


Figure: Optimal time to cut is t*

Portfolio Choice

This could also be a portfolio choice problem. Should an entrepreneur invest in cutting. We can solve for

$$r = \frac{\Delta V}{S + (V_0 - C}$$

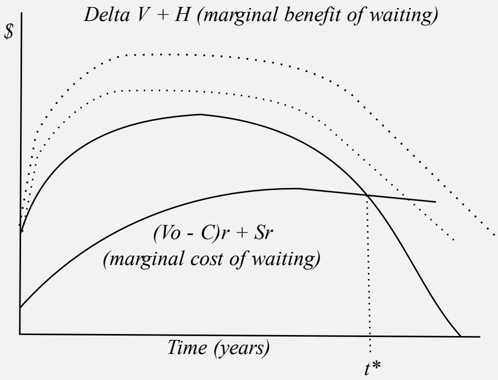
Do not cut the trees as long as the rate of return exceeds the rate of return on other assets. *Note what this implies for development*.

Factors Affecting Efficient Rotation

1. Harvesting costs change (**increase:** taxes, logging mill closes. **decrease:** new roads, new technology, cheaper land).
2. Externalities, e.g., soil erosion
3. Interest rate
4. Price of timber changes – higher prices increase ΔV, V_0, and S, though not necessarily in the same proportion. So intersection of marginal benefit and cost could shift to either the right or left.

Impacts of Nontimber Forest Values

Forest may have nontimber value *H* for: species habitat, watershed protection, carbon sequestration, ...



Home Depot Forest

In 2002, Home Depot teamed with Reforest the Tropic to balancing greenhouse gas emissions with producing wood on farms in tropics - In the Atlantic Zone of Costa Rica on Las Delicias Farm.

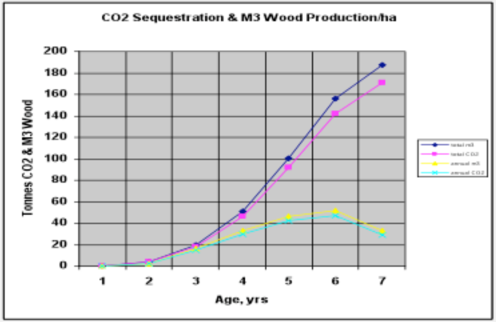
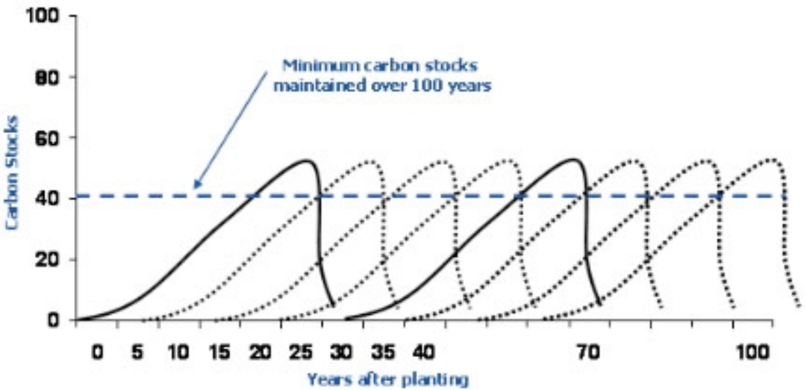


Figure: Upper lines are total sequestration, Lower lines current annual sequestration

Home Depot Results

1. The current (March 2009) annual sequestered carbon 29.4 tonnes
2. During past 6.6 years, 170.9 tonnes of carbon were sequestered
3. Current and total production of wood are 33 and 188 cubic meters, respectively
4. The forest belongs to the farmer, while the rights to CO_2 sequestered belong to Home Depot

Sequestering and Rotating Forests



Complications

1. Complicated to measure when multiple other uses, all with own time scale
2. If trees are cut and stored permanently (buildings), carbon is sequestered until they decay
3. In this case, if rate of decay is slower, then harvesting for building increases amount of sequestered carbon
4. It seems that buildings actually decay rapidly

Econometric Model of Deforestation

Setup

1. N_t^* : open access amount of land cleared
2. N_t^* : amount of land cleared under institutional constraint
3. $D_t = N_t - N_{t-1}$: deforestation
4. We will test whether institutional constraints are binding.

$$D_t^I = N_t^I - N_{t-1} = \delta(N_t^* - N_{t-1}) = \delta D_t^*$$

5. If $\delta = 0$, institutions completely stop deforestation
6. if $\delta = 1$, institutions are worthless

Reconciling Graphical Methods

– Compare two graphing methods –

Econometric Model

Assume

$$N_t^* = \beta_0 + \beta_1 P_t + \beta_2 w_t + ..$$

Rearranging

$$N_t^l - N_{t-1} = \delta N_t^* - \delta N_{t-1}$$

$$N_t^l = \delta N_t^* + N_{t-1} - \delta N_{t-1}$$

$$N_t^l = \delta N_t^* + (1 - \delta) N_{t-1}$$

Gives

$$N_t^* = \delta(\beta_0 + \beta_1 P_t + \beta_2 w_t + ..) + \lambda N_{t-1} + \epsilon_t$$

where $\lambda = 1 - \delta$

Case Study
pre-NAFTA Mexico

- NAFTA - North American Free Trade Agreement (1994). Intent was to remove trade barriers between Canada, US, and Mexico
- 1917 Mexican Constitution established *ejido* – communal land ownership.
- Community could award private use of the land, but these rights could not be rented or sold
- 1991: 29,251 ejidos representing about 55 percent of land area and most of Mexico's forests. 49.6 million hectares
- Forests ownership: 70 percent by ejidos, 25 percent by individuals, 5 percent by native communitie
- 1992: pre-NAFTA land reforms to land tenure
- Some evidence that ejidos have slowed deforestation in Mexico
- Would NAFTA lead to more or less deforestation?

Results: pre-NAFTA Mexico

Table 6.1 in Barbier

Case Study

Shrimp farm expansion and mangrove loss in Thailand

- Shrimp farming is big business in Thailand, $1.6 billion per yer
- But, also destroys coastline – 2,815 km of total coastline (1,878 Gulf of Thialand, 937 Indian Ocean)
- Mangrove deforestation about 3,000 ha/year
- Boom in shrimp prices in 1985 to about $100 / kg
- 1981 - 1985 : 15,000 metric tons annually (15 KMT)
- 1991 : 162 KMT
- 1994 : 264 KMT

Case Study

Shrimp farm expansion and mangrove loss in Thailand, cont.

- Shrimp farm area exanded from 31,900 ha (1983) to 66,000 ha (1996)
- From 3,779 farms to 21,917 farms
- Intensive farming -¿ poor water quality -¿ abandon farms in 5-6 years
- 50-65 % of Thailand's mangroves have been lost to shrimp farm conversion since 1975
- Loss is irreversible without manually replanting
- Government gives some incentive to farmers to register farms in order to gain subsidies on inputs - shrimp larvae, chemicals, machinery

Econometric Model for Thailand Mangrove Loss

Define

$$r_t = M_{t-1} - M_t = N_t - N_{t-1}$$

Change in mangroves equals the inverse of land cleared

$$N_t = N_{t-1} + r_t$$

Look at

$$\frac{M_{t-1} - M_t}{M_{t-1}} = \frac{N_t}{M_{t-1}}$$

If $N_{t-1}/M_{t-1} = 0$

Results: Thailand Mangrove Loss

Tables 6.2 and 6.3 in Barbier