Economics of Renewable Resources: Forestry

Lecture 5

1. Renewable Resources

- Renewables
  - Trees
  - Fish, Wildlife
  - Wine, Cheese, etc.

- Efficient use over time
  - Rate of harvest
  - Bio-economic Models
  - Often Common Property Resources (Open Access)

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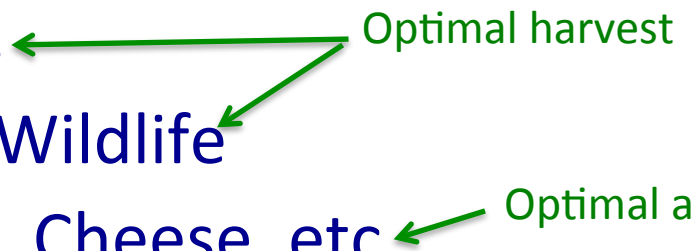

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  - Rate of harvest
  - Bio-economic Models
  - Often Common Property Resources (Open Access)

2. Forestry

- Physical Model of Growth

$$V(t) = 10t + t^2 - .01t^3$$

  - See next page
  - Other forms
  - Stochastic

$$V(t)=10t+t^2-.01t^3$$

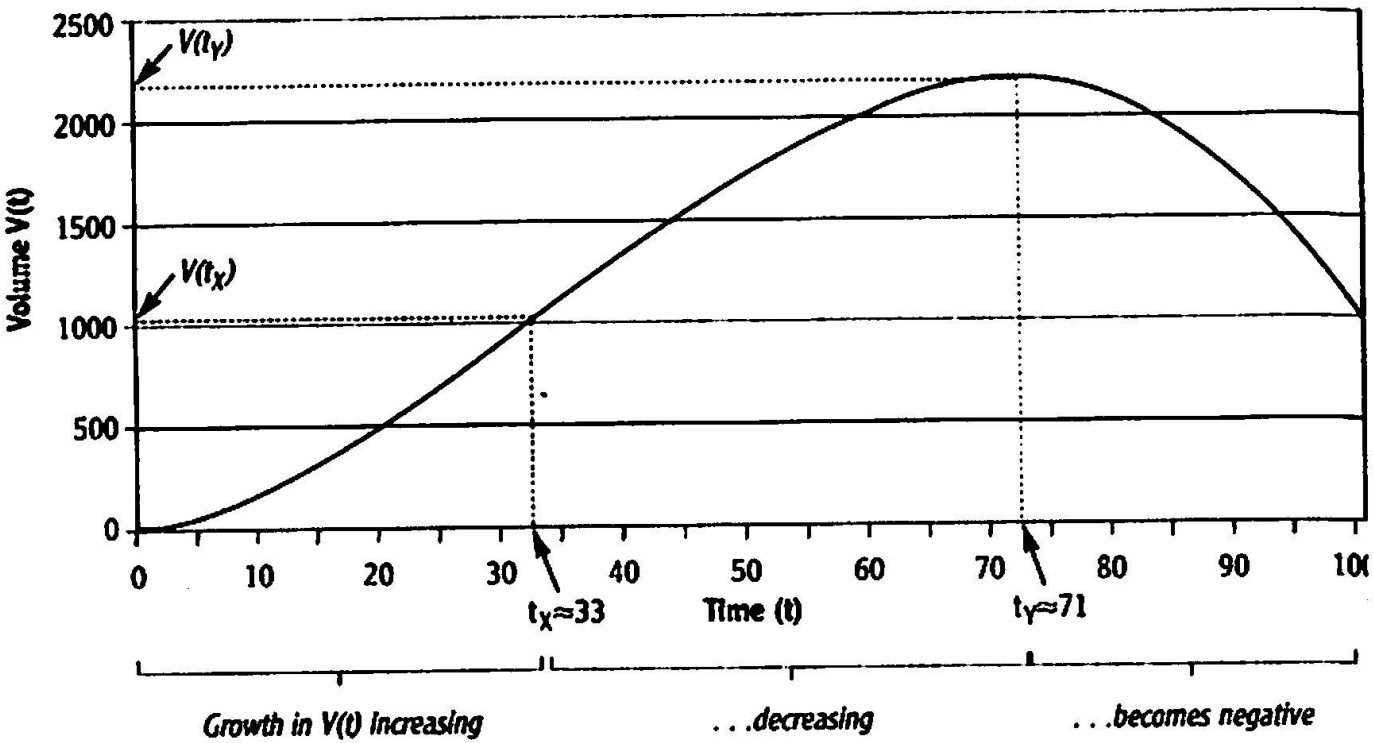
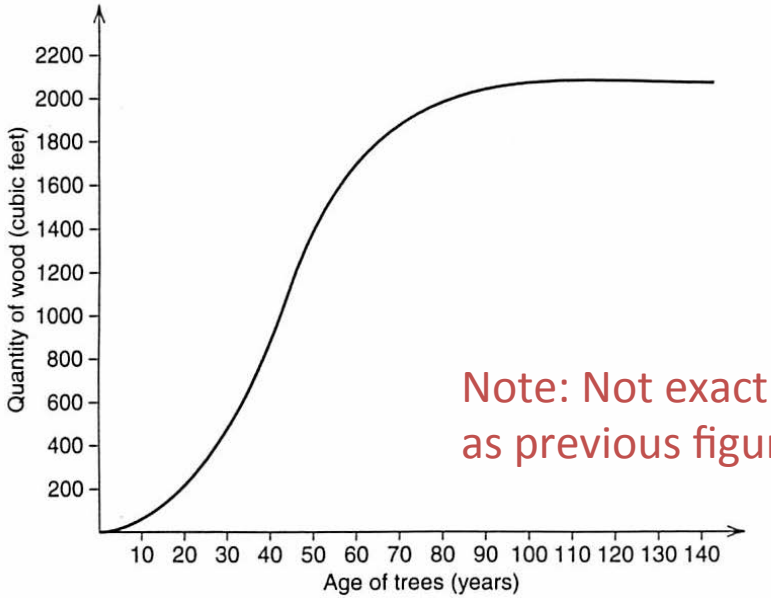


Figure 7.1 Timber volume in a forest as a function of time.

TABLE 12-1
TOTAL VOLUME, AVERAGE VOLUME, AND ANNUAL INCREASE IN VOLUME OF WOOD, BY DECADES, OF ONE ACRE OF FOREST

Age of trees (years)	Total volume of wood (cu ft)	Average volume (cu ft/age)	Annual increase in volume (cu ft/yr)
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
110	2,090	19.0	0.0
120	2,090	17.4	0.0
140	2,090	14.9	0.0



Note: Not exactly the same functional form as previous figure.

FIGURE 12-1
Total Volume of Wood by Age of Forest

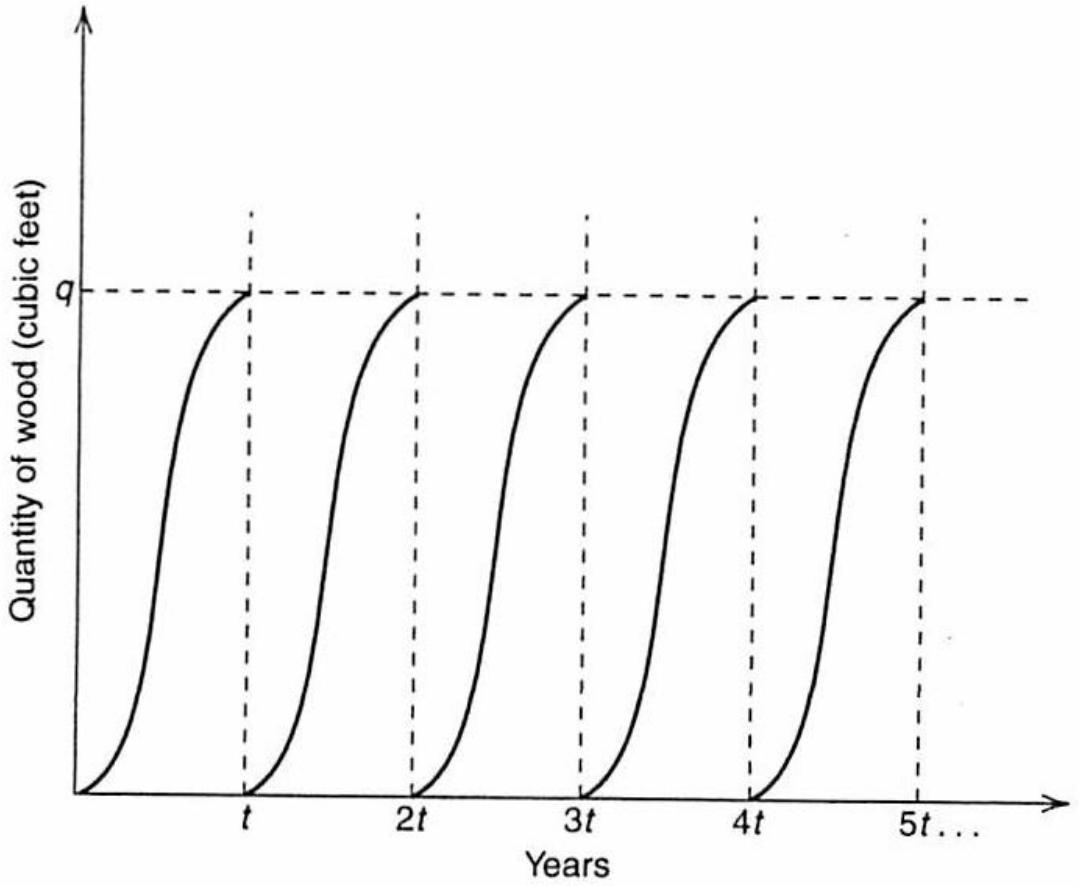


FIGURE 12-2
Typical Forest Rotation Pattern

- Bio-economic Models
  - Seek optimal rate of harvest or rotation
  - Three candidates for 'optimal'

    - Mean annual increment
      - Biologic
    - Wicksell rotation
      - Biologic + Time value of money
    - Faustmann rotation
      - Biologic + Time value of money + Site value

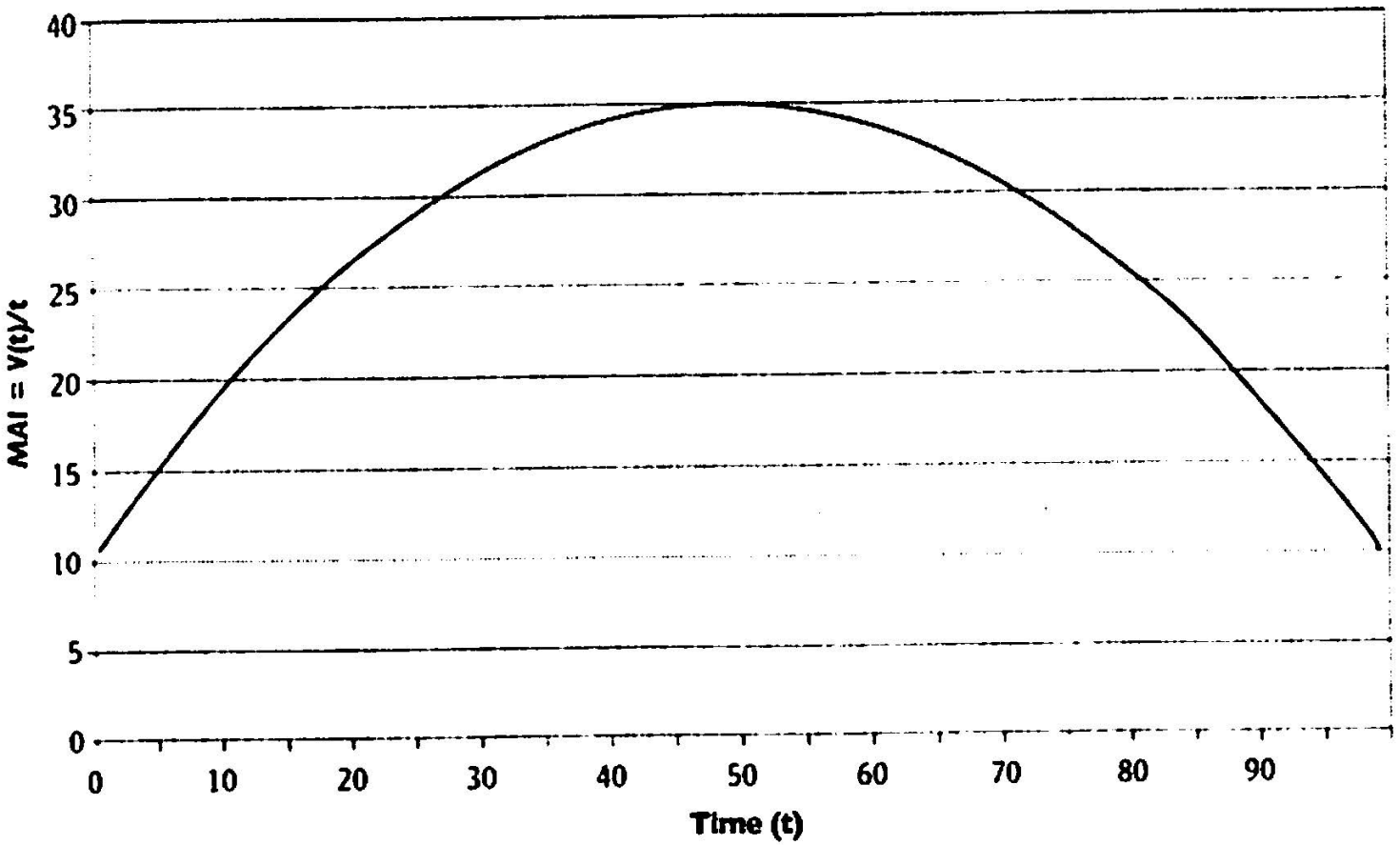


Figure 7.2 Mean annual increment ($V(t)/t$) in a forest, as a function of time.

- (1) Mean annual increment
  - Maximum sustainable harvest
  - Biological rotation
  - Maximize volume of trees (board feet) harvested over time

- (2) Wicksell rotation
  - Think of growing trees as an investment
  - Compare net returns of cutting trees today versus tomorrow.

$$(p-c)V(T_0) \qquad \frac{(p-c)V(T_1)}{1+r}$$

Value if harvested today

Value if harvested tomorrow

$p =$ price of timber

$c =$ unit cost of harvesting

$V(T_0) =$ stand volume in T_0 (today)

$V(T_1) =$ stand volume in T_1 (tomorrow)

$r =$ discount rate

- Wicksell rule
  - Cut later ….

$$(p-c)V(T_0) < \frac{(p-c)V(T_1)}{1+r}$$

  - Cut sooner ….

$$(p-c)V(T_0) > \frac{(p-c)V(T_1)}{1+r}$$

  - Efficient …

$$(p-c)V(T_0) = \frac{(p-c)V(T_1)}{1+r}$$

- Rearrange terms and simplify

$$r = \frac{V(T_1) - V(T_0)}{V(T_0)} = \frac{\Delta T}{V(T_0)}$$

  - It is efficient to harvest the stand when the rate of growth in timber volume, the rate of return to our captial asset (standing trees), is equal to the interest rate.

- Like Hotelling
  - Can you make more money by holding? If so, you do. If not, you cut.
- Wicksell rotation is inversely related to discount rate
- Wicksell is shorter than MAI

- (3) Faustmann
  - Add site value and replanting costs to model
  - Site value (S)
    - Site value is the value of a forested piece of land assuming that the landowner will implement efficient forest rotation in perpetuity; or – if forestry is not the most profitable use of that land at any point in the future – convert the land to its most profitable use.
  - Replanting costs (D)
    - Cost of replanting trees after harvest

- New conditions for optimal harvest

$$(p-c)V(T_0)-D+S=\frac{\{(p-c)V(T_1)\}-D+S}{1+r}$$

  - S is sale value or opportunity cost of holding land

- Rearranging and simplifying equation ….

$$\Delta V = r\{V(T_0) - D\} + rS$$

Marginal Benefit of harvesting next period

Marginal Cost of harvesting next period. Records forgone timber value for one year and delay in sale of land for one year.

- Or …

$$r = \frac{\Delta V}{V(T_0) - D + S}$$

Landowner should time harvest so that the rate of return on forest harvest is equal to the prevailing rate of interest

$r\{V(T_0)-D\}+rS$ = marginal cost of waiting to harvest next period

ΔV = marginal value of harvest in next period

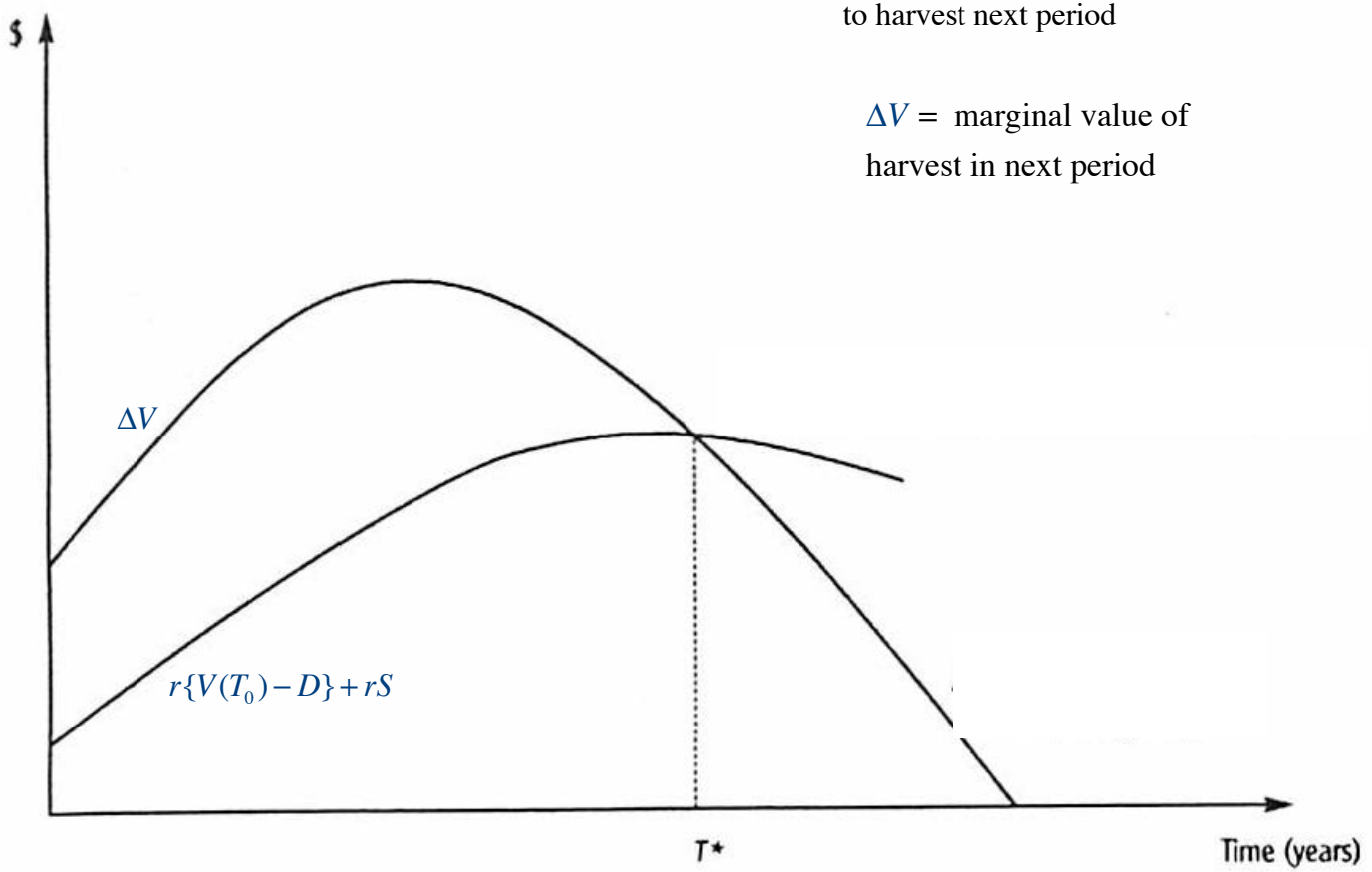


Figure 7.3 Efficient (Faustmann) forest rotation. The efficient rotation length, T^*, equates the marginal benefit of harvesting and the marginal cost.

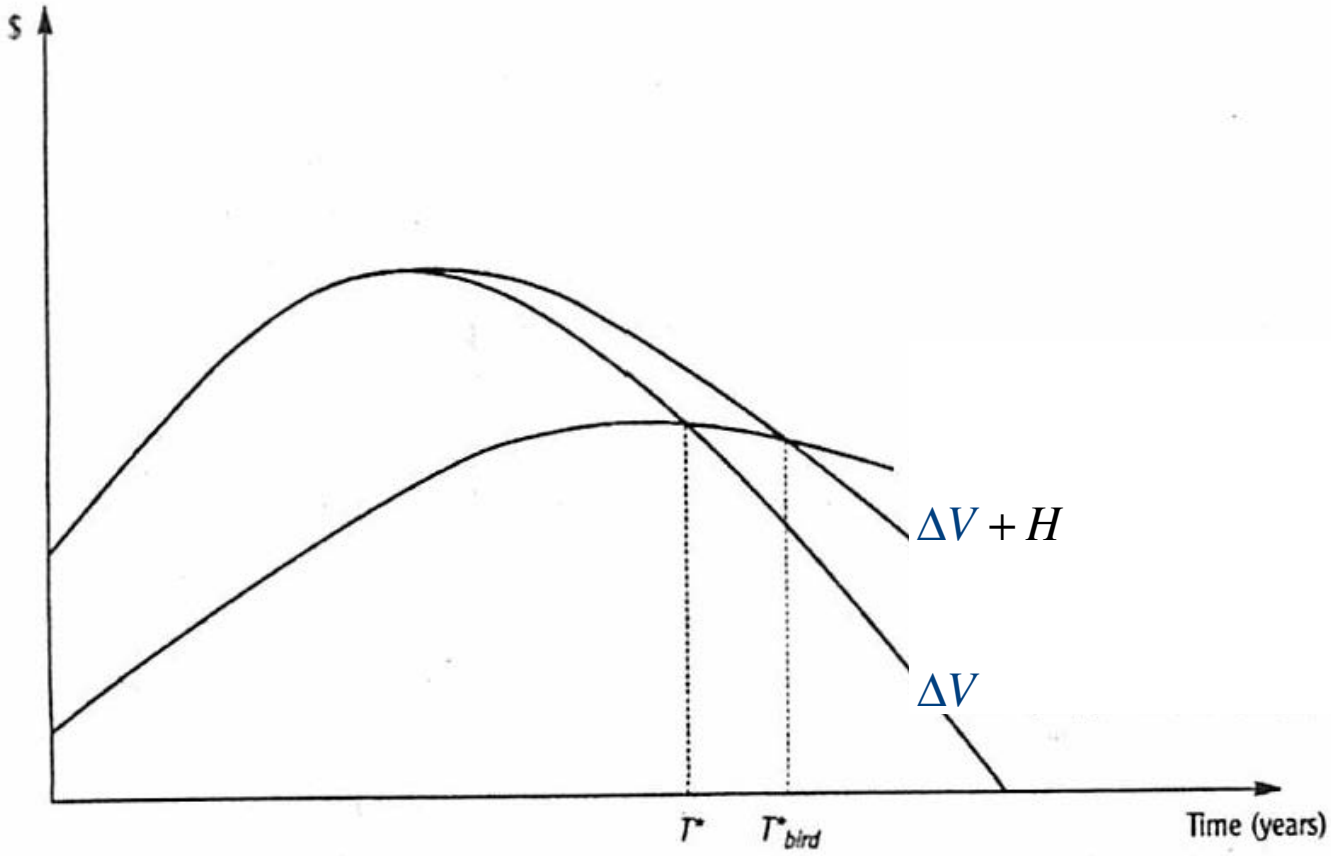


Figure 7.4 The effect of non-timber benefits on the Faustmann rotation. The value of bird habitat provided by old-growth forest represents an additional cost of harvesting timber. As a result, the efficient rotation length increases in this case, from T^* to T^*_{bird}.

- MUI, Wicksell, and Faustmann
  - Rotation period: MUI > Wicksell > Faustmann

- Factors affecting efficient rotation
  - Harvest costs
  - Externalities
  - Interest rate
  - Price of timber

- Public Goods, Property Rights, and Deforestation
  - When privately held we expect something like Faustmann rotation and efficient use
    - Think of farmers caring for land
    - It is essentially a crop

- Market failures in two realms vis-à-vis trees:
  - Externalities
    - Endangered species
    - Watershed protection
    - Carbon sequestration
  - Often not privately held (unlike most nonrenewables)
    - Tragedy of the commons
    - Common in developing countries (80% not privately held)
    - Especially difficult to capture returns due to long optimal rotations and large numbers of interested users
      - » Add political instability
      - » Uncertainty of private property rights
      - » Land title and social experiments
  - Where nontimber benefits dominate → may want (need) a publically managed resource

– Consider this cycle in typical developing country:

- Because of population pressure, the average harvest of fuel wood begins to exceed the average rate of wood production
- Farmers begin to use straw and dung for fuel; thus, less of these are available for maintaining soil fertility
- Almost all tree cover is removed, all dung is sold for cash, and wheat yields begin a serious decline
- Soil erosion becomes dramatic because of reduced tree cover and declining fertility
- There is total collapse of fertility; farmers abandon their land, swelling urban populations

– Why does this happen?

- Open access, lack of property rights, use-it-or-lose-it.
- Solutions?
  - Individual or small group property rights
  - Legal institutions

- General Model
  - The present value of net revenues from an infinite series of rotations all of length T

Choose T to $Max(\pi)$ where

$$\pi = \left[(p-c)V(T) - D\right]e^{-\delta T}(1 + e^{-\delta T} + e^{-2\delta T} + e^{-3\delta T} + \ldots)$$

$$\pi = \frac{\left[(p-c)V(T) - D\right]}{e^{\delta T} - 1}$$

  - T that solves above is the Faustmann rotation

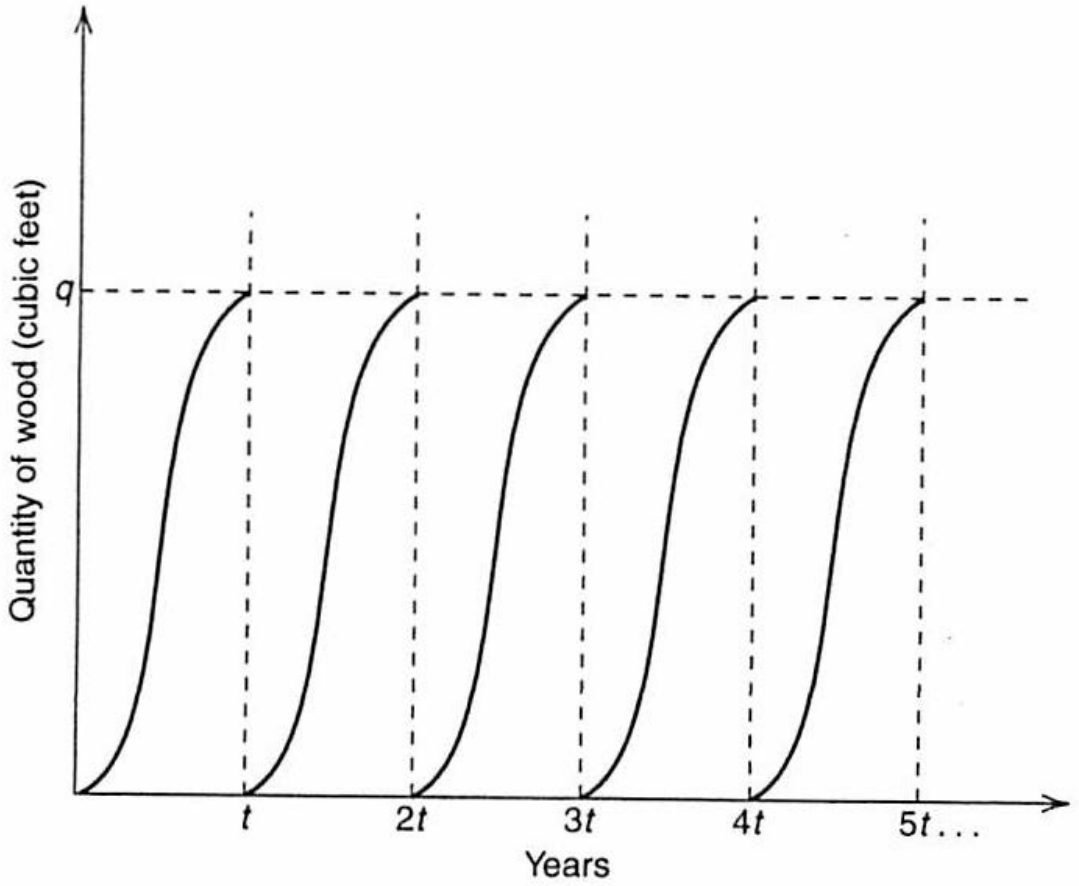


FIGURE 12-2
Typical Forest Rotation Pattern

– First order conditions imply …

$$(p-c)V'(T)=\delta\left[(p-c)V(T)-D\right]+(p-c)V'(T)e^{-\delta T}$$

– Turns out that the second term on the right hand side is

$$(p-c)V'(T)e^{-\delta T}=\delta\pi$$

– So …

$$(p-c)V'(T)=\delta\left[(p-c)V(T)-D\right]+\delta\pi$$

$$(p-c)V'(T) = \delta\left[(p-c)V(T) - D\right] + \delta\pi$$

Same as what see saw before. Another interpretation:
the cost of incrementally delaying all future stands.

Read Conrad (p. 138) for nice discussion of interpreting results.