Economic Analysis of Exploitation and Regeneration in Plantations with Problematic Site Productivity

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Introduction

- Classical Faustmann model assumes constant forest productivity (CFP)
- But: also declining forest productivity is observed (e.g. MacLellan & Carleton 2003, Fiedler et al. 1990)
- Important role in short term plantations in forestry (Nambiar 2008; Blinkey 1997) and agriculture (Keerthipala & Dharmawardene 2000)
- Discussed solutions:

    fertilization (Nambiar 2008, Nambiar et al. 2004)

    crop rotation (Nair 1993)

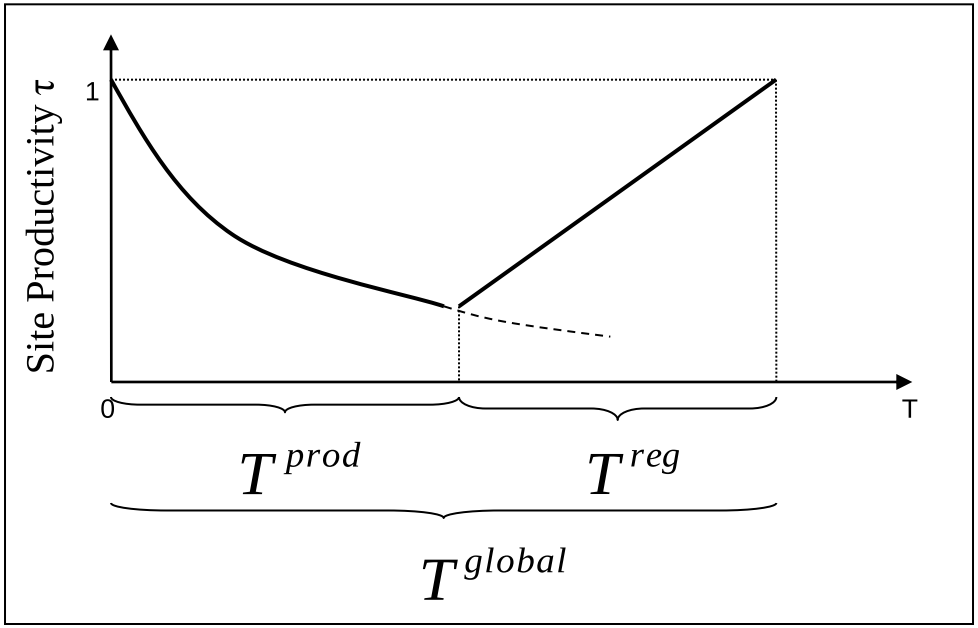
    shifting cultivation (Makeschin et al. 2008)

- Previous economic research on DFP (Routledge 1987, Lu & Chang 1996)

Model

Idea

A highly profitable but site quality consuming production period is followed by a less profitable but site quality improving regeneration period.



Model

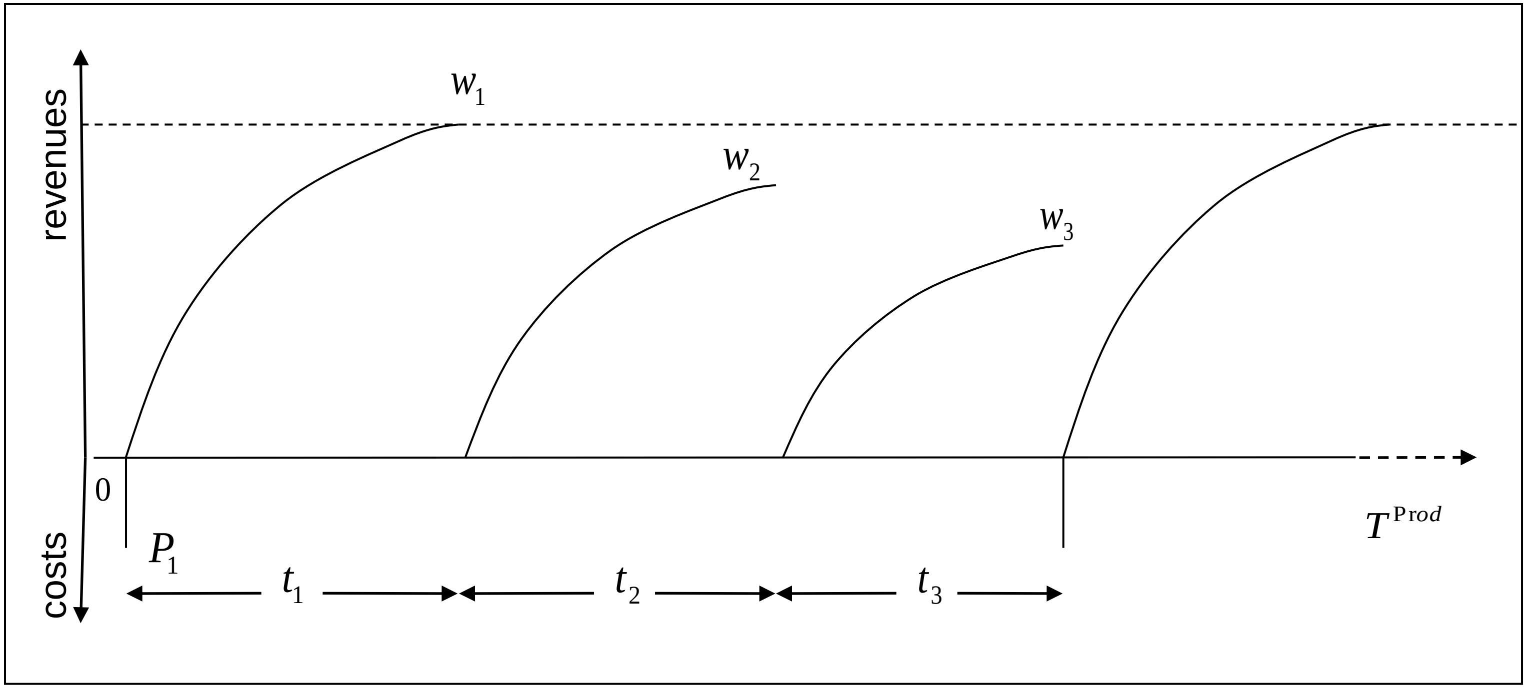
Site productivity

$$\tau(T) := \begin{cases} 1 - \int_0^T f(T)\,dT & \text{if} \quad T \le T^{prod} \\ \min\left\{ \alpha(T - T^{prod}) + \tau(T^{prod}), \ 1 \right\} & \text{if} \quad T^{prod} < T \le T^{global} \end{cases}$$

- During intensive production site productivity is a convex and declining function to time.
- During regeneration site productivity is a linear increasing function to time.
- ‚Regeneration technology' is introduced by α.

Model

Example: SRC-Model without DFP*



* Medema & Lyon (1985), Tait (1986)

Model

intensive Production: SRC-Model with DFP

$n \in \{1, 2, ..., N\}$

Volume growth: $g_n := g(t_n, S_n)$

Coppice factor: $S_n := S(k_n) > S(k_n + 1) \qquad k_n \in \{0, 1, ..., n-1\}$

Stand value: $w_n := \overline{p} g_n \tau_n$

Costs: $P_n := P(k_n) = \begin{cases} P & if \quad k_n = 0 \\ 0 & if \quad k_n > 0 \end{cases}$

Model

Exploitation-regeneration-cycle

NPV Prod:

$$NPV^{prod} := \sum_{i=1}^{N} \left(w_i - P_i e^{r t_i} \right) e^{-r T_i} \qquad T_n := \sum_{i \le n} t_i, \quad T_N := T^{prod}$$

NPV Reg:

$$NPV^{reg} := b \int_0^{T^{reg}} e^{-rx} dx - C$$

LEV:

$$LEV := \left(NPV^{prod} + e^{-rT_N} NPV^{reg} \right) \left(1 - e^{-rT^{global}} \right)^{-1} = NPV_0^{global} \left(1 - e^{-rT^{global}} \right)^{-1}$$

Analysis

Optimal rotation age

$$\max_{(t_n)_{n \in I}} LEV$$

General FOC:

$$\frac{\partial g_n}{\partial t_n}\tau_n + b\frac{f_N}{\alpha}e^{-r(T^{global}-T_n)} = r\left[v_n + NPV_n^{global}\right] + r\left(1+\frac{f_N}{\alpha}\right)LEVe^{-r(T^{global}-T_n)} + \sum_{i=n}^{N} g_i f_i e^{-r(T_i-T_n)}$$

The optimal rotation age balances the revenues and costs of a harvest delay by one time unit.

Analysis
3 sub-cases

Fertilization: $\alpha \to \infty$

$$\frac{\partial g_n}{\partial t_n}\tau_n = r\left[v_n + NPV_n^{prod}\right] + rLEV^{Fert}e^{-r(T_N - T_n)} + \sum_{i=n}^{N} g_i f_i e^{-r(T_i - T_n)}$$

Alternative land use: $\alpha \to 0$

$$\frac{\partial g_n}{\partial t_n}\tau_n = r\left[v_n + NPV_n^{global}\right] + \sum_{i=n}^{N} g_i f_i e^{-r(T_i - T_n)}$$

‚Mining': $\alpha \to 0, \quad b = 0$

$$\frac{\partial g_n}{\partial t_n}\tau_n = r\left[v_n + NPV_n^{prod}\right] + \sum_{i=n}^{N} g_i f_i e^{-r(T_i - T_n)}$$

Comparative statics

Rotation age

Does a faster regeneration technology prolong rotation ages?

$$\frac{dt_n}{d\alpha} = ?$$

Criterion: $$r < \frac{\dot{\eta}_N}{\eta_N} \Bigg/ \left(\frac{1 + \frac{f_N}{\alpha}}{1 - e^{-rT^{global}}} \right) \quad with \quad \eta_n := 1 - \tau_n$$

For relatively small interest rates faster regeneration will lead to higher rotation ages and thus to more intensive production.

Comparative statics

Rotation age

Does a more profitable regeneration lead to lower harvest ages?

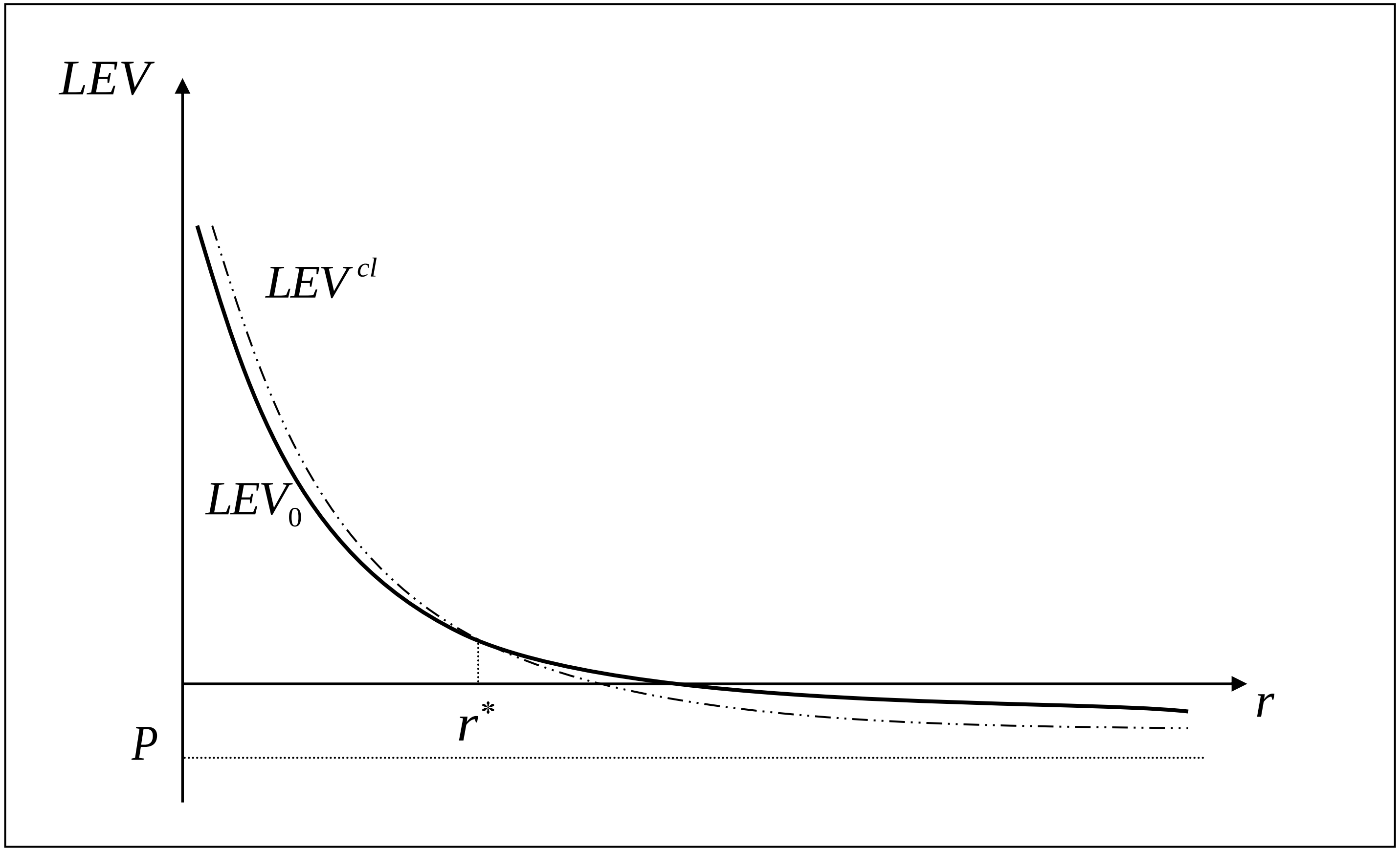
$$\frac{dt_n}{db} = ?$$

Criterion: $r \geq \frac{\dot{\eta}_N}{\eta_N}$

Only for relatively high interest rates more profitable regeneration will lead to lower rotation ages and thus to less intensive production.

Comparative statics

Interest rate and land use



Summary

- The intruduced model provides understanding of site management if DFP occurs and fills the gaps between the ‚best‘ and the ‚worst‘ case by Lu & Chang (1996)
- FOC has to take DFP into account. The relation to CFP-case is not obvious. Only for the mining-case the optimal rotation ages tend to be longer due to lower costs of prolonging a harvest.
- Faster regeneration can boost site mining activities.
- Declining regeneration cash flows can boost site mining activities.
- Interest rate has an important impact on the selected land use. For relatively high discounting costs mining might be economically optimal. Intensive Production & Regeneration is more profitable than extensive land use for high interest rates.

Thank you for your attention