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Economic analysis of exploitation and regeneration in plantations with problematic site productivity☆

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ABSTRACT

Although intensive managed plantations clearly increase the growth and yield of forests several papers refer to declining forest productivity. Therefore in this paper we study the impact of declining forest productivity on the land expectation value and the optimal rotation length. We start from the research by Lu and Chang (1996) and try to fill the gap between the stable site productivity ("best") and the site mining ("worst") cases. For that we extend the classical Faustmann model by availability of different recovering technologies. In general the model allows the analysis of the two plantation groups: "mining the site by high productive plantation followed by management of degraded areas" and "high productive plantation and regeneration cycling" with the same comparative static. The model, analysis and comparison with the two extreme cases in Lu and Chang (1996) leads to a detailed understanding of land use management when site productivity decline is possible. Particularly the relation between declining periods with intensive land use and land use alternatives after declining periods with regeneration can be well understood. Findings are: Not ever declining process asks for regeneration. Many declining processes can be stopped at early times by high cash flows after mining periods. Shortenings of the regeneration time can boost site mining intensities.

☆ This study bases on the diploma thesis by Andreas Halbritter on coppice in short rotation plantations.

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The site productivity problem

In 2005 the total amount of forest plantation area worldwide was 187.5 million hectares. While in most developed countries in the non-tropical zones investments in industrial forest plantations are reduced, the total tropical forest plantation areas more than doubled in the period 1995–2005 (ITTO, 2009).

Although intensive managed plantations clearly increase the growth and yield of forests several papers refer to declining forest productivity (DFP): Fox (2000) explains the link between different factors affecting the productivity of plantation forests and shows how different management practices can decrease or increase the site productivity. Smith (1994) focuses on the effect on plantation management to soil fertility. He mainly deals with tree removals and harvest machinery effects in relation to different soil types. Corbeels et al. (2005) examine long-term changes in productivity of eucalyptus plantations under different harvest residues and nitrogen management practices with help of a modelling analysis. They show that the productivity in such short-rotation plantations over multiple rotations can be problematic. Theirs simulations suggest that retention of harvest residues is helpful for maintaining forest productivity, but that applications of nitrogen fertiliser will be necessary to maintain current levels of productivity in the long run.

Nevertheless DFP may also play an important role in boreal forests (e.g. MacLellan and Carleton, 2003) and in temperate zone forests (Fiedler, 1990). Moreover, a similar declining productivity is observed in agriculture plantations with perennials such as sugarcane (Keertipala and Dharmawardene, 2000).

Fortunately in the last two decades extensive empirical research on site management led to detailed and better understanding of sustained productivity in tropical and subtropical plantation forests (e.g. Nambiar, 2008; Nambiar et al., 2004). Nambiar and Kallio (2008) pointed out that no major risks to soils were identified which cannot be managed by scientifically based practices.

Commonly used technologies of forest plantation management to reduce or to prevent DFP are retention of tree residues (Corbeels et al., 2005; Vitousek and Matson, 1985; Tiarks et al., 2004; Yamada et al., 2004), site preparations (Gresham, 2002; Vitousek and Matson, 1985; Shaohui et al., 2000), fertilization (Corbeels et al., 2005; Yamada et al., 2004; Fox, 2000) and irrigation (Stape et al., 2010).

Many of the described technologies for preventing DFP reduce the land expectation value (LEV) owing to the raise of cost or lower revenues. Therefore different researchers and scientists assume that management practices with DFP are rational actions of forest owners in respect to the level of interest rates (e.g. MacLellan and Carleton, 2003) according to the numerical example of the farmer, miner and forester in the famous Interest Theory by Irving Fisher (1930, p. 133 and sqq.). For this reason MacLellan and Carleton (2003) plot out so called "productivity investment frontiers" to show under which discount rate the forest owner moves from a constant site productivity concept to a concept including DFP.

However between constant and declining site management practices a lot of intermediate concepts are worth considering to reduce or to neutralize DFP. One example is to start with declining forest management in a high productivity class and change in a more extensive land management after some declining (e.g. Makeschin et al., 2008). Another land use similar to shifting cultivation and improved fallows as in agroforestry (Nair, 1993) is conceivable. Also "crop rotation" as a change of two forest types A and B, in which A represents a high productivity but also a high DFP rate and B stands for a low productive forest type however with a soil regeneration potential is worthy of mentioning.

All these intermediate concepts are not very common in forest plantation management however they are well known in agriculture since a long time. By the way agriculture traditionally has long experiences with "short-rotation" over multiple rotations.

Therefore it is useful at this point to recall that forest short-rotation plantations move closer to agriculture then to the traditional long-term forestry. In intensive managed plantations rotation ages between 5 years (eucalyptus) (Diaz-Balteiro and Rodriguez, 2006) and 25 years (pine) are common (ITTO, 2009). Tiarks et al. (2004) refer rotation ages between 6 (*Eucalyptus urophylla*, Guangdong, China; *Acacia mangium*, Riau, Indonesia) and 30 years (*Pinus elliottii* × *P. caribaea*, Queensland, Austalia). Sedjo (1999, p. 19) reckons that future rotations in US fiber farms will be shorter than 5 years.