Non-industrial Private Land Use and Forest Management

Landscape and Policy Perspectives

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Abstract

Demand for raw materials and food has long been rewarding intensive production oriented land uses, which has led to various environmental and social issues. Policies attempting to reconcile the interests and claims of different groups in society emerge from political process. Scientific research can support policy making by providing factual information and by generating and analyzing policy options. This thesis is an investigation of the prerequisites and a further development of methodologies and tools for scientific policy support concerning Non-industrial Private (NIP) land use and forest management in Sweden. Three characteristics of NIP (or small-scale, family) landownership are at the focus of the thesis: (i) spatial constraints (estate size) (Paper I), (ii) landowner behavior (Papers I, II and IV), and (iii) spatially explicit information on forest attributes and land use (Papers II and III).

Paper I assesses hypothetical scenarios of spatially targeted deciduous forest allocation strategies in the context of small scale forest ownership in southern Sweden. The study demonstrates that in order to avoid a priori unattainable policy goals, theoretical gains from spatial targeting need to be considered against the background of required landowners' participation. Paper II analyses agricultural land-use change in Kronoberg County during 2000's. The study shows that a significant portion of the originally reported pastures' area has been replaced by land previously reported in other categories. Furthermore, the study indicates an overall extensification of grassland utilization in the county. Paper III presents a method for improved classification and accuracy assessment of ad-hoc categorical maps based on continuous-scale remote sensing estimates of forest variables. The method is applied in mapping deciduous dominated forests from an existing spatial dataset. Paper IV deals with a mixed, qualitative-quantitative approach to forest policy scenario construction. The paper proposes facilitating inferences of forest management configurations from assumed external factors by using a structured representation of forest management "behavioral matrix". An application example from a regional case study is provided.

Keywords: land use, forest management, agriculture, policy, landscape, non-industrial private, landowner behavior, spatial information, map accuracy, scenario analysis, simulation

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Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Lindbladh, M., Felton, A., Trubins, R. & Sallnäs, O. (2011). A landscape and policy perspective on forest conversion: Long-tailed tit (Aegithalos caudatus) and the allocation of deciduous forests in southern Sweden. *European Journal of Forest Research*, pp. 861-869.

II Trubins, R. (2013). Land-use change in southern Sweden: Before and after decoupling. *Land Use Policy* 33(0), pp. 161-169.

III Trubins, R., Sallnäs O. (2014). Categorical mapping from estimates of continuous forest attributes – classification and accuracy. *Silva Fennica* vol. 48 no. 2 article ID 975. 16 p. (published in web)

IV Trubins, R., Jonsson, R., Wallin, I., Sallnäs, O., Behavioral matrix – an approach to representing forest management and linking qualitative and quantitative inferences in forest policy scenario construction. (Manuscript)

Papers I-III are reproduced with the permission of the publishers.

The contribution of R. Trubins to the papers included in this thesis was as follows:

I Trubins carried out the calculations and made certain contribution to the writing of the manuscript. The estimated overall contribution is 20 %.

II Trubins carried out the analysis and wrote the manuscript himself.

III Trubins formulated the model, carried out the calculations and basically wrote the manuscript. The idea emerged in a discussion between the authors. The estimated overall contribution is 80 %.

IV Trubins carried out the calculations and wrote the manuscript. The idea was formulated in a discussion between the authors. The estimated overall contribution is 60 %.

Abbreviations

BN	Bayesian Network
kNN	k-Nearest Neighbor
NFI	National Forest Inventory
NIP	Non-industrial Private
NIPF	Non-industrial Private Forest owners

1 Introduction

Non-industrial Private[1] (NIP) forest land constitutes about 51% of the entire forest area in Sweden. Especially in the south of the country this ownership form is dominant; in some counties it makes up to about 80% of the forest area. The weight of the NIP forests in the total wood supply is also substantial, about 43 % on the national level in the years 2007 – 2009 (Swedish Forest Agency, 2011). Many landowners own both forest and agricultural land; about 33% or 3.7 M ha of the non-industrial private forest land is included in agricultural holdings (Swedish Board of Agriculture, 2011). Collectively, NIP landowners form and preserve much of the landscapes we know. Regardless of ownership type, demand for raw materials and food has long been rewarding intensive production oriented land use, which has led to various environmental and social issues in Sweden and worldwide. Policies attempting to reconcile the interests and claims on land use held by different groups in society emerge from political process. Scientific research can support policy making by providing factual information and by generating and analyzing various policy options. However, NIP landownership possesses distinct characteristics that affect the conditions for and place specific demands on policy making and thus on the scientific research that aims to support it.

1.1 A conceptual model of land use and forest management determination

The issues of biodiversity conservation, water quality and scenery (also referred to as ecosystem services) are essentially issues of conflicting land uses; some of them could even be described as conflicts between uses and non-uses (a non-use may be attributed an intrinsic value and therefore does not need to necessarily be justified by provision of any service). The fact that one and

1. Also referred to as small-scale or family forest ownership

the same land use may produce several goods or services simultaneously, as in the concept of multiple-use forestry, does not change the issue in principle. The trade-offs still need to be made by choosing between land uses characterized by different combinations of the goods and services in question. This thesis regards forest management approaches that can be characterized by different sets of objectives as distinct "land uses"; therefore, in the following discussion "land use", is interchangeable with "forest use" or "forest management with a specific set of objectives".

Furthermore, this thesis regards the issues mentioned above as political and social rather than technological. Even though the technological level is one of the factors affecting the political process as it determines trade-off possibilities between the uses, no technological development can remove any of the issues completely, unless the alternative uses are altogether decoupled from each other, which is not quite realistic in most cases. Moreover, a hypothetical possibility for a trade-off-free joint land-based production of all demanded goods and services in the future does not ease much the issues today.

For example, everyone agrees that, in general, conserving biodiversity is a good thing. However, there is no agreement about how much values associated with other uses can or should be sacrificed and by whom. We speak, for example, of conflicts between "agriculture and biodiversity conservation" (Henle *et al.*, 2008), between "forest biodiversity conservation and other human interests" (Niemelä *et al.*, 2005) and at last, between "human activities and biodiversity conservation" (Young *et al.*, 2005). In these conflicts the stances of involved people are affected by their values and beliefs. The beliefs tell people what is true and the values tell them what is just. None of the two necessarily remains constant. Thus, there is no solution that will make everyone happy. The "win-win solutions" with regard to nature conservation and economic outcomes have been strongly questioned as an adequate descriptor of the outcomes that actually occur in conservation projects in developing countries (McShane *et al.*, 2011; Robinson, 2011). Nevertheless, solutions obtained in a democratic process usually are accepted, at least temporarily, for the merits of the democratic process itself, if not for the factual outcome.

Fig. 1 is a conceptual model of the system determining land use. Here the concept of land use is understood as one implying composition from a multitude of distinct uses and their corresponding areas with reference to location. The system boundary could, of course, be chosen differently but now the model focuses on the elements relevant for the present discussion. The model is presented as a structural scheme in which the components take inputs and produce outputs which might be information or direct influence by actions.

Political process affects land use in two ways – directly through legal regulation and indirectly through intended as well as unintended incentives for landowners. Together, these two types of influence constitute policy. The policy in the sense of this model can consist of a set of multiple policies in the everyday sense. How and at which levels the political process happens, who are the involved actors and their distribution of power does not matter for the argument here. The process is affected by the values ascribed by the involved actors to the different land uses and by the actors' beliefs regarding technological possibilities. The boundary of this element is permeable to anything that can affect the perceived values of the different land uses and the beliefs regarding technological options. Of course, a correlation can be expected to obtain, for example, between perceived values of timber-oriented forest use and timber market prices. A similar abstraction of the political process is made in the analytical framework used by Hellström (2001). A special mention should be made of the information on the land-base and the forest characteristics. Such information, even if objective in a statistical sense, is not necessarily interpreted in the same way by all actors.

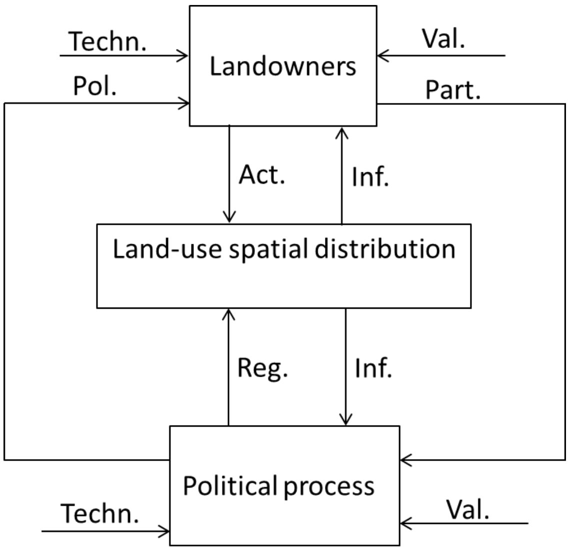

Figure 1. Conceptual model of land-use determination. Notations: Tech. – technology i.e. information affecting the actors' beliefs regarding production possibilities and trade-offs; Val. – values i.e. any type of information or experiences that affect the actors subjective values associated with different land-uses, Inf. – inventory i.e. information on the actual land-use and provision of goods and services; Act. – allocation i.e. landowners choices of land-use; Pol. – policies i.e. any intended or unintended outcomes of the political process that affect the landowners subjective values associated with different land-uses; Reg. – regulations i.e. direct compulsory prescription of land-use; Part. - all forms of landowners participation in the political process as citizens and as a specific interest-group.

Landowners act within the legal regulations set by the political process but for the rest, they too weigh the subjective values they ascribe to the different land uses given the perceived possibilities for technological trade-offs. Thus, anything that affects these values and beliefs affects decisions regarding land use. Essentially, this can be seen as a utility maximization problem. The deliberate incentives created by the political process are part of those influences. Landowners themselves, of course, participate, directly or through representation, in the political process.

The presented model highlights the respective roles of political process and landowners' decisions in the formation of land use. Political process including various actors with different beliefs and values, rather than "society's objectives" or "society's influence", is defined as a partial determinant of land use. This helps in avoiding the illusion that the "society" has the full freedom and the power of imposing whatever regulations on private land use. Furthermore, such representation helps to realize the linkages between this process and the analytic activities (often undertaken by researchers) intended to help in "solving" the biodiversity conservation- or other land use issues. Defining landowners' decisions explicitly as a partial but dominant determinant of the land-use is important for understanding the specific policy and research challenges posed by non-industrial private land-use and forest management.

The political process is in part influenced by and in part sets the research agenda. For example, Head (2010) notes that "the topics and formats are usually influenced by funders' priorities". Therefore, questions like "what are the conditions necessary for preventing or reducing biodiversity loss?" and "what are the options for maximum realization of land-based production potentials?" often stand, apparently unaffected by the contradiction, side by side on the research agenda. Sometimes, some sort of balance is defined but more often claimed without defining (see, for example, McShane *et al.* (2011) on the "win-win" rhetoric in nature conservation). In fact, these questions are the instances of the same class of research. Such research aims to generate and analyze policy options and it can take both normative and anticipatory forms. More basic, "fact-finding" research deals with establishing facts pertinent to the issues in question rather than analyzing policy options; however, that does not mean that the foci of studies are therefore unaffected by the politics and the personal beliefs and values of the researchers. A parallel can be drawn with the "time sensitive request for information" and the support for "longer-term strategy and policy development" distinguished by Shaxson (2005). A bit aside stands the research that assumes a meta-perspective on the political process and focuses on studying the politics rather than forest or land use issues as such. All these types of research can affect and normally are hoped to affect the political process. However, quantifying the impact of research on policy is very difficult (Ryan & Garrett, 2004). Finally, there is the research that focuses on technological development, on finding methods for increasing the productivity or the efficiency of different land-uses that can include production of timber as well as "production" of biodiversity or water or scenery and that may or may not entail a change in the trade-offs.

This thesis includes both "fact finding" and "policy options" research in relation to such properties of NIP landownership that most saliently distinguish it from industrial or public landownership. The focus is not on estate level challenges in land-use allocation, forest management or agriculture that an individual landowner might face but rather on the land use and forest management as a whole in a given territory.

1.2 Properties of non-industrial private land-use and forest management

Certain properties of NIP land ownership have important implications for policy making and hence for research. In a NIP dominated area, policies required for achieving same land use goals will be different than in a large single industrial or public ownership area. This section is built around three such properties of NIP landownership namely (i) spatial constraints, (ii) landowner behavior, and (iii) spatial information on forest and land-cover. Exhaustiveness is claimed neither for the set of "challenging" properties nor for the descriptions of challenges that they pose.

1.2.1 Spatial constraints

NIP landownership is characterized by relatively small estates. Estates of less than 50 ha make up about one third of the total NIP productive forest area in Sweden; estates of less than 100 ha – about a half of the total area (Swedish Forest Agency, 2011). This places a constraint on the possibilities for spatial organization of land use at landscape-level. A spatial organization can be motivated by a possibility to better exploit the existing variation in some land or land-cover characteristics for an overall more efficient provision of goods and services. For example, a spatially targeted conservation strategy might be seen as a more cost-efficient way of achieving certain conservation benefits and hence perhaps the only feasible way. However, it is impossible to require landscape level coordination from an individual landowner but rather the policy itself needs to be spatially targeted and supported by a suitable institutional arrangement, for example, to implement a compensation mechanism. However, institutional arrangements usually mean costs that may or may not be acceptable. Furthermore, the current forest policy paradigm in Sweden, “freedom under responsibility”, presupposes reliance primarily on voluntary conservation commitments by landowners rather than on regulative instruments. Basically the same applies to conservation of biologically or culturally valuable agricultural land.

1.2.2 Landowner behavior

NIP landowners, unlike firms, are not subject to the goal of profit generation as their raison d’être. The individuals possess different beliefs and values; they find themselves in different occupation and income categories, in different live stages and in different environments (Hugosson & Ingemarson, 2004; Lönnstedt & Tornqvist, 1990). They manage their land or their forest differently and they respond differently to different information and incentives (Appelstrand, 2007). Therefore, it is in most cases difficult to foresee landowners’ response to one or another policy or their actions with no new policies when other factors change (the two are instances of the same problem). This should be seen in comparison to industrial owners, firms whose motives are generally more uniform and stable over time. However, this is not at all to say that industrial ownership is, thanks to its “predictability”, in some ways “better” with regard to the pending forest and land-use issues. Even though it might make finding such policies that suit all landowners more demanding a task, the diversity of NIP landowners in general is an opportunity for higher variation and diversity of forest practices and hence forest structures (e.g. Kurttila, 2001), not even mentioning the socio-economic and cultural values of NIP landownership.

1.2.3 Spatial information on forest and land-cover

Not all Non-industrial Private Forest owners (NIPF) in Sweden buy an inventory of their forests and obtain forest management plans. Thus there is no complete landscape coverage by traditional stand-wise forest inventory data. Those owners that do have fresh-inventory data are not obliged to share it. In the latter aspect, the industrial forest owners might be the same; however, their data covers large areas which would enable them to conduct specific landscape-level analyses and planning if they were motivated to do so. It should be noted that the statistical National Forest Inventory (NFI) of Sweden provides various data at regional level. However, the NFI data is aspatial at a sub-regional level. Currently available spatially explicit data on landscape level for NIP regions is based on remote sensing methods. This data widens the opportunities for spatial landscape analyses but it still has some rather serious limitations.

The problem of spatially explicit data exists also with respect to agricultural land although to a lesser extent. Current system of collecting agricultural land-use statistics is combined with the administration of applications for the support payments. Those landowners that choose not to apply for any payments also do not report on the state of the agricultural land on their property. This often coincides with termination of agricultural activity and is likely to involve semi-natural pasture land which is in general less productive than arable land. However, this land often hosts rare species which risk disappearing if forest is allowed to take over. Thus, it is likely that there are biodiversity values at risk in the “grey zone” of the agricultural land-use datasets.

In any case, the lack of spatial information can obscure certain aspects relevant to assessments of ecosystem services and, perhaps, prevent spatially targeted policies from being designed and implemented. Some technical and scientific aspects with regard to the currently available spatially explicit data on forests, and more generally on land-cover and land-use, will be discussed more thoroughly below.

1.3 Related research

The challenges that actors meet in addressing the land use issues in NIP dominated areas are reflected in scientific research. The classification into “fact-finding” and “policy options” is used in structuring the overview of the scientific research pertaining to each of the three properties of NIP landownership presented in the previous section: (i) spatial constraints, (ii) landowner behavior, and (iii) spatial information on forest and land-cover. Table 1 correlates the discussed NIP properties with the two admitted types of research. Further exposition follows the numeration in the table. The objective of the exposition is mainly to present the current research agenda in rather general terms. It should be therefore seen as exemplifying the research in the respective areas rather than as a comprehensive review.

Table 1. *Research areas related to NIP land use or forest management. The numbers in brackets indicate the papers included in this thesis. (See the description of the research areas in the text)*

NIP landownership property	“Fact finding” research	“Policy options” research
Spatial constraints	1	2 (I)
Landowner behavior	3	4 (II, IV)
Spatial information	5 (II, III)	6

1. "Fact finding" research on spatial constraints

"Fact-finding" research in relation to spatial constraints investigates spatial variation in some land or land-cover characteristics within and between estates. Carlsson et al. (1998) studied the relationship between habitat size, shape and abundance and the variation of habitat occurrence between estates. The study included a simulation and an empirical investigation of four estates in different parts of Sweden. The empirical study found differences in the variation of the occurrence of different habitat types confirming the conclusions based on simulations. To my knowledge, to date this is the only investigation of this type carried out in Sweden.

2. "Policy options" research on spatial constraints

"Policy options generating" research with a focus on spatial constraints examines the possibilities for reducing inoptimality caused by the spatial constraint of estate size on landscape level planning of forest-use. Fries et al. (1998) proposed a procedure for landscape level ecological planning in NIP forestry named "The Stream Model". The strategy focuses primarily on creating uncut buffer zones along streams. The study involved elaboration of an actual landscape plan with participation of 41 forest owners in an area in northern Sweden. The plan was based on voluntary setting-aside of forest areas by owners; the efficiency of the approach was not analyzed. Ask (2002) compared reserve selection strategies using estate- alternatively landscape-level objectives in two study areas in southern Sweden. The comparison shows potential benefits of landscape level coordination in reserve selection. Furthermore, Ask & Carlsson (2000) compared forest stands actually set-aside by forest owners with a random selection of stands in three study landscapes in southern Sweden. The study found that the forest stands actually selected by the landowners had a higher spatial nature conservation value, i.e. due to location in the landscape, than the mean value obtained in the Monte Carlo simulation of stand selection.

This research area seems to receive greater attention in Finland. Pukkala *et al.* (1997) state that "a completely new planning approach, including practices of information sharing and group decision making is needed […]". Kurttila (2001), discussing different spatial forest planning approaches, reemphasizes the potential benefits of supra-estate regional forest planning but also notes that the practical applicability can be problematic since spatial objectives for large area might not be perceived as relevant by forest owners. Kurttila *et al.* (2002) studied the effects of two conflicting goals, improvement of old-forest pattern and equal participation of forest owners using a goal programming planning model in a multi-holding study area. The study found that the two goals were difficult to achieve simultaneously. Considerable differences in the economic impacts on the individual forest-holding persisted in all generated plans. In a similar study, Jumppanen *et al.* (2003) found more promising results when using the empirically based forest management strategies from Pesonen (1995) as a base case. In another study, Kurttila & Pukkala (2003) addressing a planning problem that involved holding-level goals and a landscape spatial goal of clustering the habitats for flying squirrel (*Pteromus Volans*) found that the spatial habitat structure could be improved with only minor losses in holding-level objectives. The authors suggest that in this case, the holding-level targets are only rarely compromised because the variation in the objectives of the owners is efficiently taken into account. Nousiainen *et el.* (1998) presented a case study in which an approach to cross-border planning involving afforestation of former agricultural land was tested. Visual characteristics of the landscape were among the considered variables. Out of the six farms in the case study area, only three were willing to participate.

In Norway, Eid *et al.* (2001) investigated the impact of different level of environmental restriction on timber production on NIP forest estates simulating individual and cooperative management strategies in a study area consisting of eight properties. The results of the study indicated that the impact of the restrictions can vary considerably due to the heterogeneity in the initial forest state among the properties. Cooperative management turned out to be only slightly more efficient so that the authors doubt whether the gains would outweigh the transaction costs. Hoen *et al.* (2006) investigated the potential efficiency gains of cooperation based on a larger study area consisting of 48 properties. The addressed planning problems involved different target level for old forest coverage and maximization of NPV value. The study found that increase in the size of management units allows for higher targets of old-forest coverage. The gains in terms of NPV were found to be small also in this study.

In the US, where the south-east is dominated by NIP landowners, the landscape scale inefficiencies of ownership-centered forest management have also been addressed. Schulte *et al.* (2008) investigated the potential economic and ecological benefits of cross-boundary coordination in three landscapes in Wisconsin, USA. In line with Eid *et al.* (2001), the study found that the economic gains of coordination, as a sum across estates, would be rather small and the overall landscape-scale structure cannot be much affected within time-horizons relevant for planning since the landscapes are already highly fragmented. However, ecological benefits can be expected at a patch scale. While in Europe the focus has been mainly on determining and demonstrating the potential landscape level efficiency gains (ecological and economic) and estate level trade-offs of multi-holding cross-border management coordination, in the US more research seem to have focused on studying the conditions necessary to actually bring about such cooperation. For example, Amacher *et al.* (2003) proposed investigating empirical possibilities for NIPF cooperation as one of new and fruitful directions for empirical research of NIPF landowners. Gass *et al.* (2009) explored hypothetical alternatives by which cross-border coordination of forest management might occur based on interviews of 51 NIP landowners in Wisconsin, USA. The study concluded that the social relationships are a major factor contributing to landowner's willingness to participate. Furthermore, the results of the study indicated that forestry professionals can fulfil a bridging function between the landowners. Finley *et al.* (2006) conducted a mail survey to elicit the NIP landowners' attitudes toward cross-boundary cooperation in forest management in Massachusetts, USA. The study found that about one-quarter of the respondents were completely disinterested in any form of cooperation while about one-fifth of the respondents indicated their interest for cooperative wildlife conservation activities.

In summary, the reviewed studies indicate a considerable potential for ecological benefits from multi-estate cross-boundary coordination of forest management, however, associated with varying degrees of conflict with holding level economic goals. At the same time, the potential for purely economic gains from coordinated management is found to be low. Almost all cited authors emphasize that the principal challenge for practical application of the coordinated management participation of forest owners. As an important condition is mentioned equitable sharing of the costs of the landscape level ecological benefits among the participating forest owners as some estates might be constrained by the coordination more than the others. Furthermore, it is pointed out that even a few forest owners willing to assume higher conservation costs might considerably improve the achievement of spatial objectives at landscape level hence the need to identify such forest owners in all actual planning situations.

3. "Fact finding" research on landowner behavior

The most studied aspect of NIPF management behavior is harvest decision. The two most important theoretical frameworks for economic modelling of harvest decisions are the optimal rotation model and the household production model. It is probably fair to say that theoretical harvest models are prone to same type of criticism as much of theoretical economics in general: they are too seldom confronted with empirical data (Kuuluvainen, 2009). Household production models are common also for modelling land use allocation involving agricultural land uses (e.g. Balkhausen *et al.*, 2008). Empirical studies focus on how forest management decisions (mostly harvest decisions) area affected by forest the owner's and property characteristics. Examples of econometric studies on Swedish NIPF behavior are: a quantitative study of harvest decisions by Carlén (1990); qualitative studies by Lönnstedt (1989), Lönnstedt (1997), Lönnstedt & Törnqvist (1990); a study of aggregate supply by Hultkrantz and Aronsson (1989); a more recent quantitative study by Eriksson (2008); a study of the effects of risk preferences by Andersson & Gong (2010). These and other studies such as Favada *et al.* (2009), Dennis (1989), and Hyberg & Holthausen (1989) found that harvest decisions are affected by owners characteristics. Furthermore, Favada *et al.* (2009), Karppinen (1998) and Kuuluvainen *et al.* (1996) confirmed that harvest decisions are affected by forest owners' objectives. As the focus of the quantitative empirical studies is usually harvest decision; they tell little about how an estate as a whole is managed over time. In contrast, such perspective can be found in the qualitative study by Lönnstedt & Törnqvist (1990). They look at forest estate as an enterprise going through different phases of ownership from bequest to bequest. Another line of research deals with eliciting forest owners' objectives and forming typologies; in Sweden, Ingemarsson *et al.* (2006) determined five types of NIPF based on their objectives.

4. "Policy options" research on landowner behavior

Analyzing policies from an anticipatory perspective implies the need to consider landowners' behavior. If the forest management decisions are successfully modelled in econometric studies it seems reasonable to expect that some of the models could be used for predictive purposes. However, the low numbers of instances of such applications suggest that the issue is not that simple. The use of aggregate econometric timber supply models is a relatively well established practice of this kind. A classic example is the TAMM model (Adams & Haynes, 1980) and the Southern Timber Supply Study. The aggregate supply from all forest in Sweden has been analyzed by Brännlund *et al.* (1985) and for NIP forests by Hultkrantz & Aronsson (1989) . In contrast, the use of individual harvest choice models in predictive fashion seems to be a rather unproven terrain. Few examples in which aggregate supply is estimated from individual harvest choices are Polyakov *et al.* (2010), Butler (2005), and Prestemon & Wear (2000).

Other approaches to at least roughly consider the observed forest owner behavior, as opposed to theoretic, use qualitative information and/or rely on an expert's judgment. For example, Butler *et al.* (2010) estimates social as opposed to biophysical availability of wood in the Northern United States by imposing a number of restrictions including "ownership attitude"; the strength of the restrictions was set judgmentally. A Swedish study that could be brought up for comparison is "Calculating non-industrial private forest owners' cuttings" by Lönnstedt (1998) in which rotation ages were based on a survey of a sample of estates and were higher than those in the recommendations of the National Forestry Board; a distinction between farmers and non-farmers were made.

Furthermore, studies in Norway (Antón-Fernández & Astrup, 2011) and Sweden (Holm & Lundström, 2000) tried to reflect the actual forest management in large scale forest simulations by statistical models based only on biophysical forest stand variables using data from national forest inventories.

A method for modelling the consequences of possible changes in forest owners' objectives was presented by Pukkala *et al.* (2003).The method is based on normative harvest scheduling model rather than an empirical harvest choice; however, the optimization is done for utility functions based on combinations of management goals reflecting both economic values and amenities. The goal weights in the utility functions are set as hypothetical scenarios.

5. "Fact finding" research on spatial information

Multiple actors are interested in spatially explicit data for NIP forests. Between 1979 and 1993 a publicly funded inventory of private forests (such inventory, the s. c. ÖSI, was carried out in Sweden (Appelstrand, 2007). A proper forest inventory comes at big costs. That limits the choice of information acquisition methods concerning spatial information for NIPF areas. This is not to say that the specific data acquisition methods must be cheap per-se but rather that the data for each specific application must come at low costs. Thus defined, the domain of "fact finding" research in relation to spatial information over NIP forests in Sweden currently includes various information acquisition methods based on satellite remote sensing and, since recently, on laser scanning.

Satellite remote sensing-based forest inventory methods are, of course, developed not solely to address the information needs for NIPF areas and are a large and well established independent field of research. Therefore, it is neither possible nor necessary to review the entire range of methods or to dive into advanced methodological issues here. A Comprehensive review can be found, for example, in McRoberts *et al.* (2010). Rather, remote sensing based datasets over NIPF areas that are currently available in Sweden will be discussed.

Presently, the only up-to-date (the ÖSI data from 1979-1993 is still used sometimes) publicly available spatial datasets with forest attributes such as height, volume by species, age and biomass for all forests in Sweden are the so-called kNN Sweden (kNN datasets) (SLU, 2012). In pattern recognition, k-Nearest Neighbor (kNN) is a non-parametric method for classification and estimation (Cover & Hart, 1967). The application of kNN in forest inventories was pioneered by Finland in the 1990 and is now adopted as standard in Finland and Sweden and being introduced in other countries (Tomppo *et al.*, 2008). The popularity of the method might come from the relative simplicity and the possibility to estimate several attributes simultaneously. In countries where there is a sample-plot based NFI (with geo-referenced sample plots), the inventory plot data provide ready reference datasets that can be used in the pixel-wise estimation.

The main issue with the satellite image-based kNN method, when deriving forest variables, is accuracy, which is rather poor at pixel level for some attributes. At pixel level, the relative root square mean error (RMSE) in kNN Sweden products is around 60 – 80 % for standing volume estimates (Reese *et al.*, 2002). The method is week in the estimation of age and volume of old and high-volume forest and in estimation of volume by species (Reese *et al.*, 2002). Another problem is that the RMSE used as an indicator of accuracy in some studies is not really a variance estimator and therefore is difficult to handle the uncertainty in actually inferring anything from the spatial datasets (McRoberts, 2011).

Currently, there is an opportunity for producing better quality spatial forest datasets using the airborne LIDAR (Light Detection and Ranging) data collected by the Swedish Land Survey (in Swedish: Lantmäteriet) for construction of a new Digital Elevation Model (Lantmäteriet, 2012). The principles of LIDAR-based forest attribute estimation have been described in numerous publications (e.g. Næsset, 1997). However, as the primary purpose of the data collection is the elevation model and not forest inventory the properties of the collected data (e.g. point density) will not be optimal for forest inventory applications. Another issue that affects the airborne LIDAR based inventory as much as satellite remote sensing-based methods is its low ability in estimating forest age. Nevertheless, the Swedish Forest Agency will soon make the new laser scanning-based spatial forest datasets available to landowners and other actors (Swedish Forest Agency, 2014).

Detailed land-use and land cover data on agricultural land is acquired by the authorities from farmers' applications for support payments and is available publicly. Thus this type of data does not currently present a challenge although extraction of useful information might be problematic. Furthermore, as it was already pointed out there, is some land that escapes from both this type of surveying and the forest inventories. Complete coverage is present in the satellite based land-cover datasets such as the Swedish Land Cover Map (SMD) in its original form and upscaled to the EU CORINE (Lantmäteriet, 2005). SMD was produced using a maximum-likelihood classification of Landsat satellite images (Hagner & Reese, 2007).

6. "Policy options" research on spatial information

There are, of course, studies dealing with the quality and value of forest inventory data in general using, for example, cost-plus-loss or simulation approaches (e.g. Duvemo & Lämås, 2006). But it is hard to find studies analyzing the implication of those types of information or data that are practically available for NIP forest areas. In Finland, Mäkelä *et al.* (2011) compared datasets based on two variants of kNN estimation with a dataset based on traditional stand-level field assessment by simulating forest development for 50 years. Based on the comparison the authors concluded that using kNN- based data as inputs to MELA scenario analysis tool is promising.

2 Objectives of the thesis

The overarching objective of this thesis is to investigate the prerequisites and develop methodologies and tools for scientific policy support concerning NIP land use and forest management with a focus on landscape level. Such investigation requires a model of how such policies emerge and how they can affect land use and forest management. The model also needs to explain how research outputs of different types can affect policies. Based on such model it is then possible to hypothesize what aspects of NIP land ownership are likely to be at the focus of policies as well as what knowledge on the part of policy makers is important for the success of a policy. Consequently, relevant research areas can be identified and the research assessed with respect to policy-making needs. These tasks are addressed in the summary chapter of the thesis. The objectives of the individual studies were as follows.

I. Investigate hypothetical scenarios of landscape scale coordination of land use such as spatially targeted forest type conversion in terms of required landowner participation.

II. Investigate recent and on-going agricultural land use change in Kronoberg County, southern Sweden, agricultural policy settings and availability of spatially explicit data on agricultural land.

III. Investigate quality aspects of spatially explicit data on forest attributes available for NIP land in Sweden. Develop an accuracy assessment method for ad-hoc categorical maps derived from available continuous-scale remote sensing-based forest attribute estimates with known accuracies.

IV. Assess the conventional approaches of predictive modeling of landowners' forest management behavior for their applicability in construction of policy scenarios concerning NIP forest management in Sweden. Develop a practical method for inferring forest management specifications from qualitative scenarios on socio-economic drivers of forest management.

3 Contributions of the papers

3.1 Paper I

Paper I adds to the body of literature in the research area 2 described above. The study discusses landscape level biodiversity conservation strategies in the context of NIP land ownership using a set of hypothetical scenarios of forest type conversion in a 4,000 km2 area in southern Sweden with the long-tailed tit (*Aegithalos caudatus*) as a target species.

A previously published model and a spatially explicit dataset were used to assess the probability of occurrence of the long-tailed tit on a pixel basis. Probabilities were assessed for the present situation and for a set of hypothetical scenarios. Habitats of the long-tailed tit are characterized by high proportion of old deciduous trees. The occurrence of the bird is furthermore affected by the proportion of old deciduous forest (ODF) in the surrounding landscape (Jansson & Angelstam, 1999). The scenarios involved increasing the amount of ODF and differed by the proximity of the added deciduous forest patches to the existing ODF patches. The scenarios were static in the sense that the dynamics of the present forests and the time necessary for the added deciduous forests to qualify as old was not considered. Rather, the different end states were compared. The amount of high probability habitats (HPH) i.e. patches where the probability of occurrence of the bird according to the model exceeded 80%, was used as a measure of the conservation effect.

The nearer the added ODF were located to the original ODF the higher was the resultant area of the HPH. With a doubled area of ODF the scenario ("Selective 0.5") where the additional ODF were allocated randomly but within 0.5 km distance from existing ODF resulted in twice as high area of HPH as the scenario ("General") in which the same amount of additional ODF was allocated randomly within the whole landscape. This result could be interpreted as a clear indication of the superiority of spatially targeted conservation policies. However, if the envisaged policy is based on voluntary participation rather than on land expropriation, it is necessary to think of realistic landowner participation rates. For example, while Selective 0.5 is twice as efficient as the General, it requires roughly twice as high proportion of forests for conversion (within 0.5 km distance from existing ODF). The proportion of converted forest can be considered as a proxy for the participation rate among the landowner or/and as the affected proportion of each estate. It is reasonable to expect that the marginal costs of land owner participation increase with the participation rate or/and the degree to which estate level economic goals are compromised. Thus, depending on the actual costs of the incentives the selective strategy might not be the most cost-efficient despite its theoretic superiority.

3.2 Paper II

Paper II contributes to the research area 4 by presenting new information on some changes in agricultural land-use in Kronoberg County in southern Sweden following the 2003 reform of the Common Agricultural Policy (CAP) otherwise called as "decoupling" (due to the fact that support payments were "decoupled" from production). The study analyses the effects of an accomplished policy option rather than anticipates the effects of a hypothetical one; however, its findings bear upon future development of land-use in the region in various ways. Furthermore, the study contributes to the research area 5 by accomplishing a multitemporal analysis of land-use data from the Integrated Administration and Control System ("IACS data") in Sweden.

Agricultural land-use throughout the EU has undergone substantial change since the 2003 CAP reform. According to the official agricultural statistics, in Kronoberg County there was a decrease of cereal cultivation concurrently with an increase of cultivation of temporary grasses in line with the rest of the country; the area of permanent pastures and the total of arable land decreased slightly (Swedish Board of Agriculture, 2011). However, the totals of the categories do not show the transitions between them. In order to establish the pattern of inter-category transitions, the IACS data on land-use at field level for the period 2002 – 2010 was analyzed.

The study was able to show that while the pastures in 2010, expressed in hectares, amounted to as much as 93% of the pastures in 2002, only 76 % of the original pastures persisted if considered not as a number of hectares but as concrete pieces of land. The difference (17%) was compensated mainly by transition from temporary grasses, while the loss of the original pasture was mainly to the "no data" category i.e. land which does not appear in the farmers' applications for support payments. The implications of this fact might be that the region is losing a land-type with high biological values. Whether this is so depends on what happens with the pastures when they fall out from the statistics' coverage; there is no such data. However, it seems likely that the land is no longer grazed when the landowner has given up on applying for support payments, which are paid on condition that the land is grazed. From the SWOT-analysis conducted by the Kronoberg County administration as part of the preparation for the new Regional Development Program (2014 – 2020), it is not clear whether the county authorities are fully aware of this development. The document states with certain emphasis that even though the total agricultural area has decreased between 1999 and 2010, the area of pasture has remained practically constant (Länsstyrelsen i Kronobergs län, 2013).

In addition, the study assessed the extent of grassland (temporary grasses and permanent pastures) utilization in 2010 through estimating the consumption of forage based on the number of cattle. The estimated proportion of surplus grasslands ranges from 6%, based on most conservative assumptions, to some 28% of the total agricultural land. It is worth to note, that 28 % of agricultural area corresponds to the sum of areas of about 40% of the smallest farms in the county. These results offer a quantitative confirmation for the concerns voiced by the county administration in the published SWOT-analysis. It highlights the lack of grazing animals for maintenance of pasture land and the presence of a large area of "idling" arable land under temporary grasses on which the conditions for renewed active cultivation are deteriorating with time (Länsstyrelsen i Kronobergs län, 2013).

3.3 Paper III

Paper III contributes to the research area 5 by presenting a method that can, in some instances, enable a more informed use of spatial datasets with estimates of continuous-scale forest attributes such as kNN Sweden. The method addresses construction and accuracy assessment of categorical maps on the basis of estimates of continuous-scale forest attributes.

Many landscape ecological assessments construct ad-hoc categorical maps by classifying map units using existing estimates of continuous forest attributes such as, for example, tree species, standing volume and age as predictor variables. Some of the examples from Sweden are Andersson *et al.* (2012), Mikusinski & Edenius (2006), Stighäll *et al.* (2011) and the Paper I of this thesis. In these and many other studies the considerable uncertainty of the original forest attribute estimates is not considered when they are used in constructing a new categorical map. Nor is the accuracy of the new map assessed in any way. As a result, map products with no indicators of accuracy are produced and used in the assessments. Accuracy measures of the original forest attribute estimates i.e. the classifier variables are sometimes referred to as indirectly indicating the accuracy of the derived categorical maps. However, combining uncertainties of several variables entering a class definition is a mathematical task that a plain intuition will likely fall short of accomplishing.

The uncertainty involved in classification can be described by class membership probability. It refers to the probability that a given map unit actually belongs to the given class. Class membership probabilities can be used to steer the assignment of class-labels and/or can serve as an accuracy measure of the classification. The paper presents a graphical probabilistic model of Bayesian Network (BN) type for estimating membership probabilities at map-unit (pixel) level for chosen class definitions. The graph-representation allows for easier specification of the relationships between variables but otherwise denotes no more than a joint probability distribution. The model requires: (i) the knowledge of probability distributions of the respective (i.e. those that enter the model) forest attributes in the mapping area in general (the so-called prior distributions) (ii) specification of the relationships between all connected variables as bivariate probability distributions. The first requirement can be fulfilled by approximating the distributions from the respective spatial dataset or, when possible, obtaining data from other sources such as NFI. The second requirement includes the relationship between the true values of the estimated variable and it estimates. In effect, this relationship refers to the estimator performance of the original continuous forest attributes and is characterized by bias and variance. This information must be available for the original continuous-scale estimates.

The presented method was applied for estimation of class membership probabilities at pixel level under a classification scheme involving deciduous dominated forest and other forest in a 647,000 ha large mapping area in southern Sweden. Forest attribute estimates from kNN Sweden datasets were used as inputs to the model. The computed probabilities were used to compare different map construction methods: (i) such in which the forest attributes' values from the datasets, rather than the probabilities, directly steer the assignment of class labels and (ii) such in which the computed class membership probabilities steer the assignment of class labels. The obtained results were an average accuracy of 0.48 for deciduous dominated forest class in the map constructed using the common method (i) and a potential for a minor improvement to 0.50 in the map constructed using the probability based classification method (ii). These accuracy measures should be understood as “user’s accuracy” i.e. that 48% of all pixels labeled as deciduous actually are deciduous on the ground.

3.4 Paper IV

Paper IV contributes to the research area 4 by presenting a method for using conventional forest simulation tools in forest policy scenario analyses. The method is based on representing forest management in a structured way that facilitates the practical inference of the alternative forest management configurations under different scenario assumptions.

The paper introduces forest policy scenario and forest management scenario as distinct notions. A forest management scenario starts from assumptions about forest management expressed in forest management specifications from which the dynamics of forest state parameters and flow variables, such as harvest, are inferred with help of the formalized models built-in in the simulation tool[2] (fig. 2a). A forest policy scenario starts from a driver-scenario i.e. assumptions on the socio-economic context for forest management specified as a number of economic and non-economic elements from which a forest management specification is inferred. In the next step, the forest management specification is used in the simulation tool to infer the forest development as defined above (fig. 2b). Thus, the chain of inferences that produces a scenario starts one step further back from the finish in forest policy scenario construction as compared to forest-management-scenario construction.

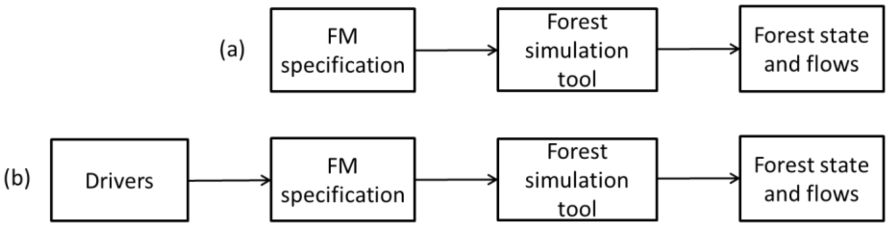

Figure 2. (a) Forest-management-scenario construction; (b) forest-policy-scenario construction. FM – forest management.

Representation of the actual present forest management is a task that the forest policy scenario analysis shares with forest management scenario analyses. The

2. Here, “forest simulation tools” denotes any computerized tool capable of simulating long-term forest development at a regional or landscape scale based on a given forest management specification. All other possible classifications based on whatever aspects of the tools are irrelevant here.

paper presents a framework which structures the representation of forest management in any given forest area as a combination of forest management styles, which themselves are combinations of forest management programs. This can be conveniently visualized in a matrix form (fig. 3). Therefore the framework was named “behavioral matrix”. The rows of the matrix are the management styles by a particular owner type; each management style is assigned certain percentage of the forest area. The columns of the matrix are each associated with its own management program. Each cell of the inner matrix shows the area proportion of the respective management program within a management style. The representation per se (many simple programs or a single complex program) can be neither right nor wrong even in principle; only the correctness of the contents, the forest management specification as a whole, can be evaluated using forest data and simulation. Thus, the quality of representation depends entirely on the empirical validity of the forest management programs and the associated area proportions. But, as said before, there can be infinitely many valid combinations of forest management programs and associated area distributions.

		Forest Management program					
Forest management style	Area %	FMP1	FMP2	FMP3	FMP4	FMP5	FMP6
FMS1	30	55	11	20	7	7	0
FMS2	20	40	26	10	9	10	5
FMS3	15	20	41	10	11	13	5
FMS4	17	10	50	0	17	16	7
FMS5	18	5	45	0	35	10	5
Total, area %	100	30	31	9	15	11	4

Figure 3. An example of behavioral matrix for a forest area. FMP – forest management program; FMS – forest management style.

The management style category might seem redundant since in the end it is the area distribution over management programs that determines the forest management specification passed to a forest simulation tool. The rationale for using forest management styles is that they can be associated with forest owner types. Typologies based on forest owners’ objectives have been developed in many countries where there is a substantial NIPF ownership (Dhubháin *et al.*, 2007). Furthermore, Favada *et al.* (2009), Karppinen (1998) and Kuuluvainen *et al.* (1996) confirmed that harvest decisions are affected by forest owners’ objectives. Thus the findings of typology-studies can be used to reflect the pattern of heterogeneity in the actual forest management. Furthermore, forest management styles being a composite category themselves allow for explicit representation of the heterogeneity within each style by combinations of forest management program. This reflects the fact that different parts of the same estate can be managed in different ways (this has been empirically by Ingemarsson *et al.* (2004)) or/and the fact that the forest owner types are somewhat mixed. Finally, management styles in one-to-one association to forest owner types play a central role in inferring forest management specification from the socio-economic context i.e. the drivers in alternative forest-policy-scenarios using various types of knowledge on forest owner behavior.

Given the framework, a change of forest management specification can be realized (i) as a change in the land distribution over management styles with or without introducing new ones or (ii) as a change of the land distribution over forest management programs within the management styles with or without introduction of new management programs (iii) as a combined change of both. Obviously, the behavioral matrix itself does not solve for the researcher the task of inferring forest management specifications from scenario-drivers. The researcher’s options in addressing this problem depend on the nature of the scenario-drivers. Given qualitative rather than quantitative scenario-drivers, which is rather normal in explorative scenario analyses, the task becomes one of developing a forest management specification consistent with the scenarios rather than predicting it in a strict sense. Nevertheless, this task presupposes extensive knowledge of forest owners’ socio-economic characteristics and attitudes; it must build on the previous quantitative and qualitative research.

Within FP7 project INTEGRAL, the presented approach to forest policy scenario analysis including the behavioral matrix (with some local adaptations) was applied in a number of case studies across Europe. The paper in this thesis illustrates the presented method by describing its application in a case study area in southern Sweden.

4 General discussion

Three specific properties of NIP landownership such as (i) spatial constraints, (ii) landowner behavior and (iii) spatial information have been shown to be important with respect to policy making and research on land use or forest management issues. Six research areas were defined by classifying the research related to each of the properties above into "fact finding" and "policy options" types (Table 1). The research in each of these six areas has been outlined in section 1.3. The contributions of this thesis belong to the research areas 2 "Policy options" research on spatial constraints (Paper I), 4 "Policy options" research on landowner behavior (Papers I and IV), and 5 "Fact finding" research on spatial information (Papers II and III). Now it is time to ask what further contributions could be required and/or anticipated from research. What changes in NIP landownership properties could be expected such that would change the conditions for land use and forest policy making?

Carlsson et al. (1998) demonstrated that variation in the occurrence of habitats is affected by the habitat size, shape and the landownership spatial pattern. This means that some habitat types might be distributed between estates more unevenly than others. The implications of their finding relate to the discussion in Kurttila *et al.* (2001) concerning the equity of distribution of economic losses due to conservation in multi-ownership landscape-ecological planning. Furthermore, this relates to the discussion in paper I of this thesis. The between-estate variation in the occurrence of existing habitats is especially important in light of the fact that the conservation policy in Sweden presupposes voluntary forest conservation measures by landowners beyond the legal requirements (Appelstrand, 2007). The underlying assumption of this strategy is that the conservation goals can be reached by small contributions from large number of landowners. However, this assumption does not hold for habitat types that are very unevenly distributed among estates. This issue motivates further research to clarify protection priorities of forest ecological structures with different spatial properties.

The discussion above relates also to the enduring question of scale at which the provision of the various ecosystem-services from forest land could or should be combined, i.e. segregation versus integration of forest management objectives at stand scale. Namely, the same question can be asked in relation to estate as an analysis unit. As the discussion traditionally goes, segregation refers to forest land use such that stands or larger spatial units are assigned one dominant objective rather than a combination of conflicting objectives with an inherent trade-off. The TRIAD (or three-zone) approach proposed by Seymour *et al.* (1999) is one of the most cited zoning strategies (Côté *et al.*, 2010). In Sweden, the segregative approach at landscape level was fist studied by Andersson *et al.* (2006). Integration, conversely, requires a greater consideration of non-timber services at a stand level i.e. strictly multiple use. In fact, the integration idea is organically tied to the concept of multiple-use forestry. Somewhat paradoxically, both ideas seem to be receiving second-wind concurrently. According to Côté .*et al.* (2010), the segregative functional zoning approach is gaining popularity in North America. In Sweden too, the TRIAD approach has been at the focus or at least mentioned as a possible alternative in recent publications by Ranius & Roberge (2011) and Angelstam *et al.* (2013). At the same time, there is a movement in forest research, maybe with a stronger basis in central Europe, that advocates for increased integration of biodiversity conservation and timber production goals, "integrated forest management" (e.g. Kraus & Krumm, 2013). Obviously, spatial constraints inherent to landscapes consistent of small estates should be considered in this discussion. Landscape level zoning in small-scale landownership conditions implies the equity and distribution issues mentioned above. In Swedish conditions, perhaps, a within estate-scale segregative approach could be evaluated. To my knowledge, no such study has been published.

The spatial constraints of small-scale ownership might however become lesser in the future. For one thing, a tendency of ownership concentration is observed in Sweden (Eriksson, 2008). Thus in the future there could be somewhat larger properties. For another thing, the tendency to delegate the management of forest properties to professional organizations might allow for realizing some forms of coordinated multi-property forest management planning by such organizations.

With regard to landowners' forest management behavior, there is clearly room for more empirical research. One specific example of a problem that could be the object of intensified empirical research in the future is the cross-boundary forest management planning relating to the discussion above.

Amacher *et al.* (2003) also pointed out this research line as important in the future. From the relevance for policy point of view, such research that describes and explains the actual behavior of the landowners rather than only their objectives and attitudes would be very valuable. This relates to another future research direction proposed by Amacher *et al.* (2003) namely integrating landowner behavior in large scale landscape models. Timber supply modelling based on aggregation of individual harvest choice models is another research challenge with promise of policy-relevant application (Polyakov *et al.*, 2010; Pattanayak *et al.*, 2002). An alternative approach to formalized modelling of landowner behavior is combining qualitative inferences with quantitative forest modelling as described in paper IV. Furthermore, the study of landowners' behavior needs to continue in the future, because of concurrent general changes of attitudes in the society at large and the demographic changes among landowners. The empirical typologies of ten years ago might soon become questionable. On the agricultural land use side, as traditional farming undergoes structural changes, more land becomes available to other uses than food production, for example, for fast-growing tree plantations. As there will be more part-time farmers or "hobby owners", the agricultural land use allocation decisions will to a lesser extent be following production logic. We might see more agricultural land managed for "amenity values". The extensification of land use discussed in paper II can serve as an illustration of this development. These processes will also require further research on landowners' characteristics and decisions.

With respect to availability of spatial information in the future, seeing the rapid development of the remote sensing based forest inventory and land-cover mapping methods in the recent decades (e.g. McRoberts *et al.*, 2010), it is easy to imagine that soon all land surface of Sweden will be laser-scanned with such point density which will allow for more accurate standing volume estimation than what is possible today. Laser scanned data could help also in monitoring the state of abandoned agricultural land. On the other hand, forest age, which is an important variable in ecological assessment, is not likely to be estimated with high accuracy by means of remote sensing even in the future, at least not before remote-sensing time series will exceed typical forest rotation ages in length. Moreover, assessment of other ecosystem services than those amenable to growing stock and tree species might require data which is presently not collected. Thus, the landscape ecological analyses and planning will probably continue facing limitations of data quality which per se could motivate more research on data quality implications for policy options.

5 Conclusions

Paper I demonstrates that theoretical efficiency gains such as increased conservation benefits per habitat area unit from land use coordination at landscape level need to be considered with caution. When NIP ownership dominated areas are concerned, any coordination strategy needs to be analyzed in terms of required participation of landowners. One of the factors that is likely to affect the landowners' responsiveness is to what degree the estate level goals might be compromised by the required action. This study provides an additional support to calls for more social research on landowners' willingness to participate in conservation programs or to engage in cross-boundary coordination of forest management.

Paper II presents evidence that during 2000's a significant portion of the originally reported pastures' area in Kronoberg County has been replaced by land previously reported as temporary grasses on arable land. In view of high biological values associated with old pastures, the replacement is not equal to the loss. Furthermore, the study indicates an overall extensification of grassland utilization in the county. I believe that this information should be considered in the evaluation and planning of measures directed towards maintenance of varied agricultural landscapes which is one of Sweden's official environmental quality objectives.

Paper III presents a method for improved classification and accuracy assessment of ad-hoc categorical maps based on continuous-scale remote sensing estimates of forest variables. Remote-sensing based data on forest attributes and land cover is an important source of information for both scientific assessments and political debate related to land and forest use issues. Accuracy estimates enabled by the presented method might have effects on the results of certain types of landscape ecological assessment using remote sensing-based data, e.g. such as in paper I.

Paper IV discusses the potential benefits of conducting mixed, qualitative-quantitative forest policy scenario analyses using qualitative expert inferences of landowners' responses to external influences and quantitative inferences of forest dynamics, enabled by forest simulation tools. Moreover, the paper presents an approach to representing forest management in a structured way that facilitates the practical inference of the alternative forest management configurations under different scenario assumptions. In other words, it links qualitative driver scenarios to quantitative forest dynamics simulations. Forest policy scenarios can be with advantage used as a basis for discussing policy options and as a general foresight method. The presented method can strengthen the appreciation of this kind of scenarios through making the qualitative inferences regarding forest management more retraceable back to socio-economic context and behavioral assumptions.

The thesis as a whole focuses on those properties of NIP land use and forest management that were identified as crucial from the policy support point of view. However, the addressed properties are, per se, at the focus of rather distinct research disciplines such as forest planning (spatial constraints), economics (landowners' behavior), and forest inventory and remote sensing (spatial information). This demonstrates that multidisciplinary work is required in order to produce scientific policy support matching with the needs of policy making.

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