Integrated Approach for Quantitative Assessment of Illegal Forest Fellings in Estonia

MAIT LANG[1,3]* MARGARETE JÜRJO[1], VEIKO ADERMANN[2] AND HENN KORJUS[1]
[1]*Estonian University of Life Sciences, Kreutzwaldi 5, 51014 Tartu, Estonia*
[2]*Centre of Forest Protection and Silviculture, Iva 12, 12618 Tallinn, Estonia*
[3]*Tartu Observatory, 61602 Tõravere, Estonia*
E-mail: lang@aai.ee, tel: +372 731 3147

Lang, M., Jürjo, M., Adermann, V. and Korjus, H. 2006. Integrated Approach for Quantitative Assessment of Illegal Forest Fellings in Estonia. *Baltic Forestry*, 12(1): 103–109.

Abstract

Change detection from multitemporal Landsat TM and Landsat ETM+ images was combined with fieldwork and GIS analysis to estimate the share of the illegally felled timber in Estonia for the period ranging from 1999 to 2002. A sample of changed areas (667) was selected from digital change map for the field inspection and detailed analysis. Map layers were created to represent the extent of problems found in the field. Finally, the problem layers were intersected to discriminate between different rule violation combinations and analyse their overlapping. A regression function was developed on the National Forest Inventory data for wood volume estimation. The results showed that for 9.4% of the felling areas the forest management declaration (FMD) was not submitted. 10.3% of the felled timber volume was related at least to one violation of forest felling regulations and 6.3% of the felled timber was connected to the environmental damages and unsustainable forest management. Rather high share of timber (3.6%) that was officially related to the forest theft may indicate the highly problematic issues of legalising (for the forest owner) the illegal logging. Forest management declarations are unreliable source for estimating the state level total volume felled, but they can be probably used to estimate the total logging area.

Key words: change detection, illegal forest felling, satellite images, forest management

Introduction

The issues, related to the illegal aspects in forest logging and illegal forestry, are acknowledged world-wide (WWF 2004). For example, Ottitsch *et al*. (2005) discuss the impacts of illegal forestry in Russia to European timber markets by analysing different data sources like official statistics, timber export, satellite images. Illegal timber from tropical forests is found to be problematic for Italian economy (Pettenella and Sant 2004).

The forests and forestry are important parts of Estonian environment and economy. The share of forest land is 52.5 % of the total land area and total volume of the forests exceeds 400 million m^3. Species distribution is characteristic of the boreal forests and boreo–nemoral forests: Scotch pine (*Pinus sylvestris*) 36 %, birch (*Betula pendula and Betula bubescens*) 26 %, Norway spruce (*Picea abies*) 20 %, grey alder (*Alnus incana*) 8 %, aspen (*Populus tremula*) 6%, black alder (*Alnus glutinosa*) 3 % and others 1 % according to stem volume. Age distribution of the forests is skewed towards mature stands and this stipulates intensive harvesting (Viilup 2002). In 1999 and 2000 the import and export of timber and articles of timber were 168.7 million Euro and 1081.3 million Euro respectively (Liimand *et al*. 2002). For comparison we bring here the state budget for the same period – 3003.6 million Euro.

During Soviet Union occupation time (1940...1991) all land including forests was owned by state or large collective farms. The state owns nowadays 40 % of the total forest land area. Property restitution process created many small private forest owners. Most of them had no experiences on sustainable forest management and took their returned property as an easy source of income.

To assess the consistency policy and the impact of forest regulations to forest management, state needs feedback about the forest management and overview about the forest resources. In Estonia forest management activities like felling and other silvicultural means are obligatory to declare by special Forest Management Declaration (FMD) to the state by forest owner before activity is done. County Environmental Departments are responsible for collecting the FMD-s and organising the routine field checking.

If we compare the total felling area or total felled volume estimates based on NFI data and summary statistics of FMD, we see rather large differences. Declared felling area in 1999 and 2000 was 221.6 thousand hectares and NFI estimated 95% confidence intervals are 129.9...174.3 thousand hectares. Respective declared felled volume was 13941 thousand m^3. NFI data based 95% confidence intervals for total felling volume for the same period are 16792...30801 thousand m^3 (Liimand and Valgepea 2002).

These discrepancies sound alarming although between the NFI and FMD are fundamental methodological differences and problems related to felling volume estimation and the results are not directly comparable. An explanation could be that there is a significant share of illegal logging in Estonia. There are several preliminary estimates for the share of illegal logging in Estonia ranging from 1% (Kosenkranius 2004) to 40 ... 50% (Ahas 2003; WWF 2004) depending on the definition of illegal logging and interpretation of legislation. Official statistics shows 3% share of illegal loggings (Ulm 2005, Volkov 2005).

Illegal felling is a problem for countries in transition. Changing policies and rules of a state and public uncertainty of ongoing processes create a strong background for illegal activities overall. Forest logging can be seen as a possibility for quick earnings. Corruption and legal weakness of law enforcement minimises the risk for prosecution. The choice of forest policy means against illegal felling largely depends on the actual situation in a country, mostly on severity of the problem (share of illegal loggings) and traditions. There is strong public interest to assess and monitor the situation and apply the most appropriate policy means.

This study focused on the problems related to the violation forest felling rights and forest felling regulations. The aim was to estimate the amount of the timber related to these violations and explain the causes of discrepancies between the NFI estimates and the FMDs based statistics using Landsat TM and Landsat ETM+ images for change detection, NFI data, FMD data, field checking and GIS analysis.

Methods

Mapping of the felling areas

For proper statistical sampling an object list is necessary. FMD-s are not suitable while there is no easy to query digital database available and one will miss the felling areas that were not declared. Best available alternative is to use change detection from satellite images to create digital GIS layer of forest felling locations. According to Nilson and Peterson (1994) the spectral reflectance of forest stands decreases rapidly during the first 25...35 years of stand life and remains then rather stable. Thinning caused reflectance changes are detectable using digital image analysis when thinning grade exceeds 20% of stand basal area (Olsson 1994, Nilson and Olsson 1995). The relatively small reflectance change caused by thinnings, on the other hand, is difficult to discriminate from reflectance change caused by differences in forest understory vegetation abundance in the young or sparse stands (Lang *et al*. 2004). To exclude young or sparse stands from the analysis one needs digital forest inventory map over the study area, but there is no such an up-to-date digital forest inventory map that covers all Estonia.

As a basis of our study we used digital maps of forest felling locations made using Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper (ETM+) (Lang *et al*. 2004). The maps were results from two consequent projects and covered most of Estonia (Fig. 1) for the period ranging from summer of 1999 to the summer of 2002.

Figure 1. The study area and the frames of the used Landsat 7 ETM+ and Landsat 5 TM scenes

Lang *et al*. (2004) used TM and ETM+ shortwave infrared (SWIR) band 5 from multitemporal images for change detection. Relative calibration based on dark forests was used to make images radiometrically comparable (Olsson 1993). Earlier the image was subtracted from calibrated later image to create a change image. Simple, cosine based fuzzy discrimination function was used to separate reflectance changes similar to the clear-cut like areas.

Forest areas were identified using the forest mask derived from late winter images. For the first felling area mapping project Lang *et al*. (2004) used the methodology of Peterson (2003) to create the forest mask. In the second follow-up project the public release of forest mask from Peterson (2003) was used.

Determination of sample size and sampling from digital map of forest fellings

The presence or absence of a rule violation can be treated as a binary variable *p*. Using formulas of Ulicny (2001) 95% confidence intervals for binomial distribution parameter *p* for expected average rule violation values 0.01, 0.05, 0.1, 0.5 were calculated. The results showed that more than 700 felling areas must be checked to get reasonable estimates for small values of *p*.

To design the sampling scheme and estimate the sample size we had to find the balance between available manpower for fieldwork and acceptable error of estimates. For fieldwork and data collection about 60 forest specialists from 15 County Environmental Departments were available. County Environmental Departments are responsible for collecting forest declarations and possess paper copies of forest management plans that are not available otherwise. It was agreed that every forest specialist carries out data collection and field survey for about 10...12 felling areas in addition to the regular everyday tasks.

To select a sample of objects from a digital map of felling areas we used a triangle like spaced layer of sampling points. A felling area was included into sample if its border was closer than 100m from the sample point. By trial and error experiments 2800m spacing between the sample points was considered suitable while resulting in 667 selected felling areas (Fig. 2).

Data collection and fieldwork

Forest specialists of respective County Environmental Department visited selected change areas in the field. The areas were delineated and divided into parts in the field according to cause of reflectance change (*i.e.* felling or other) and felling type and ownership. The borderlines of logging plots were mapped using WAAS supporting GPS or from digital ortophotos. The spatial extent of following rule violations was mapped: 1) logging plot too wide; 2) logging plot too big; 3) overthinnig or clearfelling too young forest; 4) new logging plot created beside the existing one earlier than allowed; 5) other. Locations of rule violations were also indicated on map or ortophoto printouts (scale 1:10000).

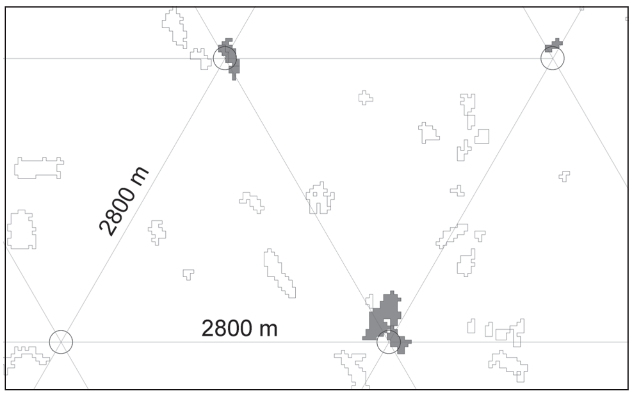

Figure 2. To select felling areas for fieldwork a triangular network of sample points was laid over satellite images based map of logging areas. The areas (filled with grey tone) located closer than 100 metres to the sample points were selected for detailed analysis

The data on planned logging plot size, volume to be felled and felling type (clear-cut or thinning *etc*.) was collected from forest declarations. Type of forest felling for nondeclared areas was determined in the field. From forest management plans the information about the area, site type, site index, main species and stand age of involved stands was looked up.

Most difficult was to find the solution for felling volume estimation. Although the stand volume is related to the stand reflectance and the thinning grade to the reflectance change, the image based felling volume estimates on the stand level were considered as too crude.

Measuring of tree stumps was considered, but was skipped. According to our experiences the tree stump tallying on the sample plots to estimate the stem volume of felled trees has no advantages over volume function concerning the spent time and the error of estimate. This holds true especially for the areas where abundant and high grass layer, slash and regeneration makes finding of stumps problematic. Therefore sample plots to measure the felled trees volume were not established. Only ocular estimate of total volume of growing trees or remained stand relative density was made. The relative density is defined as the ratio of basal area or volume of the growing stand to the basal area or volume of so called normal stand. Stand relative density is often used by experienced fieldworkers in forests and is usually included in forest stand description record in forest stand data. By knowing the area of the forest stand and the values of volume estimation function (*e.g.* species, stand age, site index) the total volume of the timber for that particular stand can be estimated.

All collected alphanumerical data were input into prestructured spreadsheets. Based on spatial GPS measured coordinates or using on-screen digitising of scanned and georeferenced field maps one GIS (Mapinfo 6.5, Mapinfo Corporation) layer was created for felling areas and the second layer for detected rule violations.

Data analysis

We used GIS analysis to assess the spatial overlapping of rule violations and calculate the respective areas of polygons. Overlapping rule violation polygons were split into unique parts to create distinct areas of different rule violation combinations.

To calculate the wood volume per hectare (V_{NFI}) we used NFI measurements based on unpublished model. The general form of the model for V_{NFI} was

$$V_{NFI} = f(\text{Species, Site index, Site type, Stand age}) + \varepsilon, \quad (1)$$

where ε denotes the residual error of the model. For each tree species and site type a regression function was developed. The model is available from authors when needed.

Final step of our analysis was to relate the felled timber volume to the respective rule violation combinations. For the felling areas allowed for clearfelling according to age the estimated total volume (V_{NFI}) was considered as felled. For declared thinning cuttings having no rule violations the declared timber volume taken from FMD was considered as felled. To assess approximately the allowed felling volume ($V_{allowed}$) of thinning cutting for the nondeclared logging plots of younger stands than clearcut age, we used the following approach. Estonian forest management rules state the minimum relative stand density (T_{min}) that may not be exceeded by thinning. T_{min} ranges from 0.45 to 0.7 depending on tree species, decreasing with site index and increasing with stand age. Thinning model to estimate the volume that was probably allowed, but not declared was

$$V_{allowed}=0.6V_{NFI}(0.85 - T_{min}), \quad (2)$$

where V_{NFI} is the total tree stem volume estimated using model (1), 0.85 is the average stand relative density, 0.6 is introduced to simulate average thinning grades.

Results and discussion

Selected 667 change areas were divided into 908 plots according to ownership, cause of reflectance change (felling or other) and felling type (clearcut or thinning). Reflectance change of 179 plots was partially or fully related to other reasons than harvesting of the trees. For 31 plots, where trees had been felled, the FMD was not required according to the law. The analysis of the amount of illegal timber was based on the 697 logging plots that were classified as obligatory to be declared.

The extent of pseudocuttings was surprisingly high, but the reason was rather simple. The area of pseudocuttings was 203.2 hectares *i.e.* 8.0% of the selection size made from the satellite images based change maps. It appeared that 122.2 hectares (5.0%) of changes were caused by errors in the public release of forest map. The error was characteristically located at forest edges and corners facing northwest or west. The error was not caused by shadows cast by trees (Peterson *et al.*, 2004), but was the results of bilinear option used in resampling of the winter images for public release of forest mask (Urmas Peterson, Tartu Observatory, Estonia, personal contacts). In bilinear mode pixel values are interpolated and therefore the structure of image is changed.

1.7 % of the detected changes were caused by misalignment of forest edges in the subsequent images or errors in the cloud mask. 1.3% of the area in the satellite images based change map were natural disturbances like overflowing, results of forest fires or defoliation. Excluding the forest mask errors, the accuracy of detecting the pixels belonging to the clearcut-like areas according to reflectance change in shortwave infrared channel difference image (ETM+ 5 or TM5) was 97%. These results are similar to Saksa *et al*. (2003), who found satellite images to be suitable for operational clearcut detection and pointed out the need for accurate digital forest map.

We analysed the information content of 572 forest declarations to assess the accuracy of indicated planned area size and volume to be felled. Applying robust fitting of the linear regression model we found that measured area size ($S_{measured}$) for a logging plot can be predicted by following linear model $S_{measured}=0.02+0.99*S_{declared}$ with absolute deviation of 0.58 hectares. This model indicates that in general the logging plot size shown in the forest declaration is close to that in nature. The sum of declared forest felling area being 100.6% of measured area size supports the hypothesis that there is no systematic bias in the area on the FMD. However, in the scatterplot of declared area against measured area size (Fig. 3) appear some outliers.

The plots declared bigger than measured refer in some cases to the unfinished management activities, but are mostly declared as sanitation or thinning where the declared timber volume was logged using clearfelling or heavy thinning from smaller area. For an opposite group of logging plots, where measured area is significantly larger than declared area size, some felling type was declared for a small area, but the logging was carried out in a larger extent.

Before interpreting the data on felled volume we make a note about the probable bias in our results.

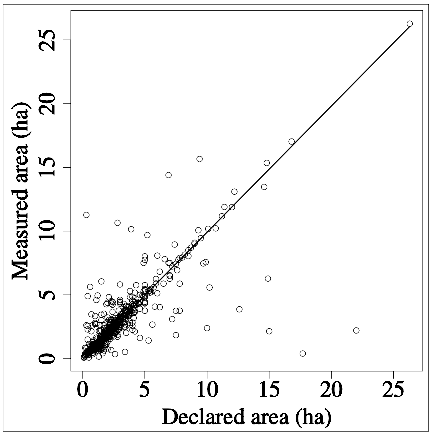

Figure 3. Declared area $S_{declared}$ on FMDs and measured area $S_{measured}$ are generally in good accordance. The line represents the regression model $S_{measured}$=0.02+0.99*$S_{declared}$.

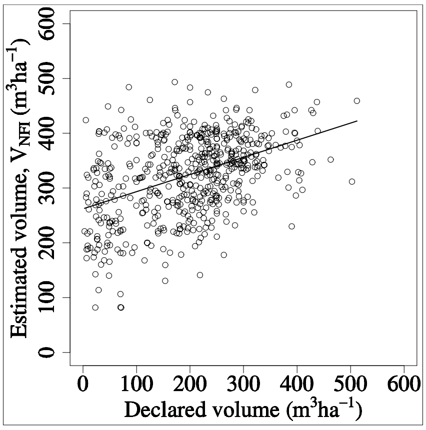

Figure 4. Declared felling volume $V_{declared}$ (*i.e.* a preliminary estimate of the forest manager made before felling) tends to be smaller than appears from the NFI plot data based model estimate V_{NFI} for the same plots The line represents the regression model V_{NFI}=262+0.313*$V_{declared}$.

Our study deals with logging plots that were fully or partially identified from satellite images as clearcuts according to their reflectance change. The probability of inclusion of problematic areas like overthinnings is therefore higher than inclusion of light thinnings or sanitations. Light thinnings cause small reflectance changes that can easily be mixed with the reflectance change inherent from grass layer abundance in different years. Digital forest age mask could be used to exclude regeneration areas and sparse stands having abundant grass layer from the analysis (Lang *et al*. 2004). Unfortunately digital map data cover Estonian forest only partially. Leaving out the light thinnings results in higher cutting volumes per hectare. On the other hand, the fact that Estonian forest management rules allow forest owner to fell yearly the volume in amount of increment without declaration decreases the bias a bit.

Total declared volume was 55% of the model (1) estimate. Applying robust linear regression, (Fig. 4) we found that NFI estimate of cutting volume per hectare can be predicted from declared felling volume per hectare using following regression model V_{NFI}=262+0.313*$V_{declared}$. The discrepancy between the estimated felling volume (V_{NFI}) and declared felling volume contains several components.

The volume declared is usually taken from forest management plans that are based on regular forest inventory and is a preliminary estimate of the forest manager. In regular forest inventory stand volumes are calculated using ocular estimates of stand parameters and tend to be systematically smaller than in sample plot based survey. Therefore the NFI plot data based model estimated volume V_{NFI} is systematically higher than $V_{declared}$.

Second component of discrepancy between the declared and estimated felling volume per hectare is the intentional misdeclaration. In general, the results show that in many cases declared thinning or sanitations appear more like clearfellings in the nature. This means that the felled volume statistics based on the FMD are not reliable. On the other hand, by using change detection from satellite images this kind of rule violations are quite straightforward to detect. Combining different digital databases like satellite images based change maps, regular forest inventory stand maps and data, forest management declarations (not yet in the centralised digital database in Estonia), *etc*. is nowadays possible using regular PC hardware and relational database systems and most of the popular desktop GIS systems. As a result of this kind of the data analysis the fieldtrips can be in the first case concentrated to the areas showing up data conflicts.

To give a general overview about violation of the legislation regulating felling rights and forest felling rules, the results were divided into six distinctly characteristic groups. The share of groups is given as the ratio of timber volume related to that particular group to the total felled volume (V_{NFI}). The results are illustrated in Figure 5. Most of the problems (over 97%) were detected during the field survey in the private or in the company forests.

The first group comprises the timber that has only one problem – not declared. By logging that timber no other forest management rules were broken. Estimated share of this timber was 7.4%.

The second group contains timber that was not declared and logged by breaking the forest management rules like thinning regulations, logging area was larger than allowed *etc*. These kinds of problems were found on 4.4 % of felled timber volume.

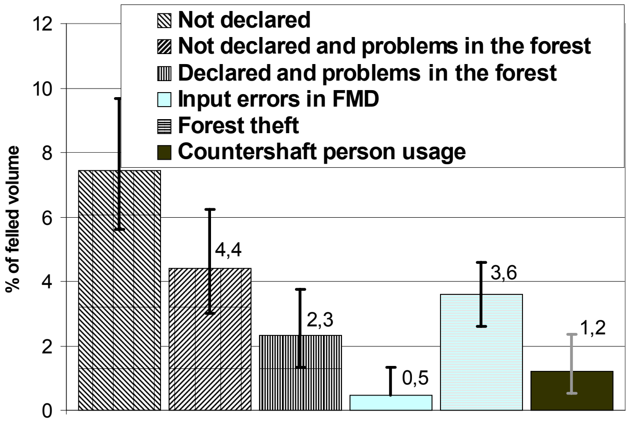

Figure 5. The share of the felled wood related to general rule violation groups

The third group includes the timber that is actually declared, but by timber logging forest management rules were broken. This combination was not found in the state forests. Here belong those logging plots that were declared as thinning cuttings, but the declared amount of timber was felled using clearcutting. Although the average amount of timber in this group (2.9%) is smaller than in the second group, the confidence limits of estimates overlap immensely and it is difficult to say whether the submission of the FMD is a quarantee that forest felling rules are followed.

To the fourth group (0.3%) belong the cases where in declaration were simple filling errors like sanitation cutting declared instead of thinning, wrong stand was indicated by mistake *etc*.

The fifth group of rule violations had forest theft as one of the components. The timber in this group was logged without permission of the forest owner. In addition to forest theft this timber is usually related to the other rule violations. The amount of this share of this timber was 3.6%. Although simple problem at first glance, we suggest that this is an indicator of more serious issue - legislative basis and its application for legalisation of illegal fellings by exploiting the “holes” in the system. This hypothesis is based on few known cases (Volkov 2005), where, after presenting legally logged area *A* as a forest theft, but identifying it as stand *B*, one has legalised loggings in stand *B* when the official criminal case is closed, even stand *B* does not fulfil the criteria for logging. There are more of such “holes” in legislation, but the detailed analysis falls out of scope of this paper.

The last group (1.2%) related to the timber logged using countershaft persons to avoid taxes and responsibility of the violation of forest management rules. Like in the fifth group it is highly probable that this timber has related to other illegality issues. Relatively high amount of this kind of timber is rather an exception than the rule while our random sample included three large forest holdings from Lääne-Virumaa county that were related to countershaft person usage. This group was not presented in the state forests.

Overall estimate of the timber, cut by violating forest felling rules, was 10.3% (8.1% ... 12.8%). This includes 6.3% of the timber that was cut by exceeding the allowed thinning grade or by clearfelling younger stands than allowed. This 6.3 % of the total timber volume and the activities attached to it can be considered as really problematic to the sustainable forestry, because there are usually excessive soil damages related with the logging, the best quality trees are cut and the rest is left standing. The amount of rule violations on thinning cuttings is probably smaller than our estimate because the selection was made from the satellite images based map of cutting areas.

The reflectance change based discrimination of thinnings from satellite images is problematic when the thinning grade does not exceed 25 to 40 % (most of the thinnings in practice) depending on cut tree species *etc*. On the other hand, the used map of felling locations contained probably most of the problematic areas where the forest has undergone heavy thinning or clearcut instead of sanity cutting. As a result, we overestimate the amount of problems and there are neither simple methods nor input data to remove this bias from our estimates.

The FMD as an indicator of forest felling activities is problematic while it appeared that for 9.4% of felling areas the declaration was not submitted at all. These areas, if the owner itself organised the forest felling, would probably never been inspected by routine control. In this point the change detection from Landsat TM like satellite images (although the spatial and temporal resolution of the images is not optimal for Estonian conditions) can be considered as a powerful, objective and cost-effective information source.

Acknowledgement

This study was partially supported by the Estonian Environmental Investment Centre.

References

Ahas, R. 2003. Illegal forestry in Estonia. Available online from http://www.roheline.ee/forest/illegal_logging_estonia.doc.
Kosenkranius, E. 2004. Illegal logging in Estonia. Presentation on

the Joint UNECE/FAO Workshop on Illegal Logging and Trade of Illegally-derived Forest Products in the UNECE Region. Held in Geneva on 16-17 September, 2004 (unpubl.).

Liimand, I., Teder, M. and Valgepea, M. 2002. Economic review. In: Yearbook Forest 2001. Centre of Forest Protection and Silviculture. Tartu, p. 106-137. (In Estonian, with English captions).

Liimand, I. and Valgepea, M. 2002. Fellings. In: Yearbook Forest 2001. Centre of Forest Protection and Silviculture. Tartu, p. 49-60. (In Estonian, with English captions).

Lang, M., Uiga, R., Lükk, T. and Anniste, J. 2004. Mapping the location of forest cuttings using Landsat 5 TM and Landsat 7 ETM+ imagery. Publicationes Instituti Geographici Universitatis Tartuensis 95:64-76. (In Estonian, with English summary.)

Nilson, T. and Peterson, U. 1994. Age dependence of forest reflectance: analysis of main driving factors. Remote Sensing of Environment 48:319-331.

Nilson, T. and Olsson, H. 1995. Effect of thinning cutting on boreal forest reflectance: A comparison of simulations and Landsat TM estimates. *International Journal of Remote Sensing* 16(15): 2963-2968.

Olsson, H. 1993. Regressive functions for multitemporal relative calibration of Thematic Mapper data over boreal forest. *Remote Sensing of Environment* 46:89-102.

lsson, H. 1994. Changes in the satellite –measured reflectances caused by thinning cuttings in boreal forest. *Remote Sensing of Environment* 50:221-230.

Ottitsch, A., Moiseyev, A., Burdin, A. and Kazusa, L. 2005. Impacts of reduction of illegal logging in European Russia on the EU and European Russia Forest sector and trade. European Forest Institute, Technical Report 19. 131p.

Peterson, U. 2003. Forest Mapping for Eastern Baltic region with Landsat Thematic Mapper winter images. Research for Rural Development. Conference proceedings held in Jelgava, Latvia on 21-24 May 2003. Jelgava: Latvian University of Agriculture.

Peterson, U., Püssa, K. and Liira, J. 2004. Issues related to delineation of forest boundaries on Landsat Thematic Mapper winter images. International *Journal of Remote Sensing* 25(24):5617-5628.

Pettenella, D., and Santi, G. 2004. Illegal Logging and Responsibility in Wood Procurement of Italian Enterprises and Customers. Draft Report. Available online from FAO webpage http://www.fao.org/forestry/index.jsp.

Saksa, T., Uuttera, J., Kolström, T., Lehikoinen, M., Pekkarinen, A. and Sarvi, V. 2003. Clear-cut detection in boreal forest aided by remote sensing. *Scandinavian Journal of Forest Research* 18(6): 537-546.

Ulicny, J. 2001. A comparison of binomial proportion intervall estimation methods. Northeast SAS Users Group, Inc. 14th annual conference proceedings. Conference held in Baltimore, Maryland, USA, on 30 September – 3 October 2001.

Ulm, T. 2005. Metsaõigusnormide rikkumised Eestis aastatel 1992-2004. [Forest law violations in Estonia in 1992-2004]. Thesis: Estonian Agricultural University, Tartu (unpubl., in Estonian).

Viilup, Ü. 2002. Forest resources. In: Yearbook Forest 2001. Centre of Forest Protection and Silviculture. Tartu, p. 1-35. (In Estonian, with English captions).

Volkov, A. 2005. Metsaõigusnormide rikkumised Võrumaal aastatel 2000-2004. [Forest law violations in Võru county in 2000-2004]. Thesis: Estonian Agricultural University, Tartu (unpubl., in Estonian).

WWF. 2004. EU accession: Illegal logging. Available online from http://www.wwf.no/core/200404/26d.asp.

Received 03 November 2005
Accepted 19 May 2006

КОМПЛЕКСНЫЙ ПОДХОД ДЛЯ КОЛИЧЕСТВЕННОЙ ОЦЕНКИ НЕЛЕГАЛЬНЫХ ВЫРУБОК ЛЕСА В ЭСТОНИИ

М. Ланг, М. Йюрьё, В. Адерманн, Х. Корьюс

Резюме

Обнаружение изменений на многовременных снимках спутников Landsat-5 TM и Landsat-7 ETM+ было объединено с наружными работами и ГИС-анализом для оценки доли нелегально вырубленного леса в Эстонии в течение периода с 1999 по 2002 г. Образец измененных областей (667) был отобран с дигитальной карты изменений для наружного инспектирования и детального анализа. Были созданы слои карты для представления масштабности проблем, найденных в ходе наружных работ. Наконец, проблемные слои были разрезаны на части для того, чтобы выделить разные комбинации нарушения предписаний и проанализировать их пересечения. Для оценки объема древесины к данным Национальной Инвентаризации Леса была адаптирована регрессионная модель Результаты показали, что из общего количества рубок, в 9.4 % случаев извещения о рубке не были представлены. 10.3 % от объема срубленной древесины были связаны, по крайней мере, с одним нарушением правил по рубке леса и 6.3 % были связаны с природными повреждениями и неприемлимым лесопользованием. Довольно большая доля от объема срубленной древесины (3.6%), официально связанная с воровством леса, может указывать на проблемы узаконивания (для владельца леса) нелегальных рубок леса. Использование извещений о рубке для оценки общего количества срубленного объема на государственном уровне является недостоверным, однако извещения о вырубке могут быть использованы для оценки общей площади рубок.

Ключевые слова: определение изменения, нелегальные рубки леса, снимки спутника, управление лесом.