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Prediction Creation for the Period of 2012–2025 of Kurzeme Region Forests

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Abstract **– In this paper, algebraic difference equation model (Kiviste 2009) for forest growth predictions is examined and adjusted for the use with the data available for Latvian forests. Calculations of soil 0-horizon for Latvian forest types have been made. Linear equation creation from database point approximation has been performed for complete forest stand life cycle coverage. The adjusted algorithm has been implemented to predict Kurzeme region forest situation in the year 2025. Evaluations and updates to the algorithm have been carried out to optimize the results.**

Keywords **– Biological system modelling, forestry, model checking, predictive models.**

I. Introduction

Forests are an important renewable source of raw materials. With the rise in CO_2 emissions and carbon footprint there is a need to estimate the carbon amount. One of the largest carbon sinks is forests and with that there is a need to predict forest growth. Models of forest growth are valuable forest management tools, but now they have also the additional role of carbon cycle evaluation. The current Central Baltic INTERREG project No. CB56 “Pure Biomass” (PB) aims to popularize the use of biomass. One of the ways to achieve this was to give information on how much biomass is currently available and how much will be available in the near future.

At present, in Latvia there are not the necessary data to create an independent model using permanent growth plots, as only now the creation of such plots is underway and the results are due only in 2015 (Donis 2011). At present, the research in Latvia is aimed more at individual tree growth models and economic yield models. A few growth tables for stands are done only for the main species – spruce, pine and birch – but not for other species. In Kurzeme region these three species dominate in approximately 80% of forest stands, but these numbers should be taken with caution as the information of how many of them are actually mixed stands has ben not found yet. As such it was decided to use Estonian models with the assumption that the models could also be used in Kurzeme region due to the geographical vicinity. The Estonian model was an algebraic difference equation that was proposed by Cieszewski and Bella (1989). The model has been already tested in Sweden.

As such part of the PB project was the prediction creation of Kurzeme region forests till the year 2025.

II. Data

As the initial data for modelling, stand records of the Latvian National Forest Inventory (NFI) in Kurzeme region were used. The database holds information on forest stands, their species composition and different parameters, such as stand average height, diameter, site forest type etc., that are needed for the forest management. To optimize the data for modelling, information clearing was done in such a manner that: all records with missing data (age, height, width, volume, bonity), with the flag of protected stands (national parks, industrial restricted areas etc.) and records with update before 2003 were excluded. Additionally, if a stand had more than one record in 2003–2012, only the newest valid record was left in the data.

The used algorithm has many parameters that have to be supplied. Almost all of them can be found in the NFI database. The only parameter that cannot be found is the soil organic 0 horizon thickness – which is the top soil layer that has the most active decomposition process in it. In the original model, the corresponding layer thickness is available as a table for the according site types of Lohmus (1984). However, the Estonian site type classification differs from the Latvian one. Therefore, a conversion was needed for the site type. It was created using Tjarve (2007) as the base for comparison and conversion. The result can be seen in Table I.

The remaining coefficients were defined by Kiviste (2009) and available for most tree species in Forest Modelling Information System (ForMIS) [9].

After the data cleanup, the data was chronologically equalized using the algorithm, so that all stand information would be predicted to the year 2011. The records of the year 2012 were not changed.

In the PB project also a satellite assessment of the forests was created and a comparison was made between the prediction results and the satellite assessment.

III. Algorithm

The main algorithm was created by A. Kiviste using stand data from permanent sample plots in Estonian forests (Kiviste 2009). This algorithm is the single-species approach and it presumes that all the given data is from the single-species stand.

TABLE I

LATVIAN FOREST SITE TYPES AND THICKNESS OF ORGANIC LAYER OF SOIL

Code in DB	Name in Latvian	Name in Latin as described by D. Tjarve	Computed 0Hor (cm)
1	Sils	Cladinosa callunosa	3,5
2	Mētrājs	Vacciniosa	7,25
3	Lāns	Myrtillosa	5
4	Damaksnis	Hylocomiosa	6
5	Vēris	Oxaliosa	3
6	Gārša	Aegopodiosa	2
7	Grīnis	Callunoso sphagnosa	20
8	Slapjais mētrājs	Vacciniosa sphagnosa	20
9	Slapjais damaksnis	Myrtilloso sphagnosa	12
10	Slapjais vēris	Myrtillosoi polytrichosa	13
11	Slapjā gārša	Drypteriosa	12
12	Purvājs	Sphagnosa	40
14	Niedrājs	Caricoso phrragmitosa	50
15	Dumbrājs	Dryopteriosa- caricosa	50
16	Liekņa	Filipendulosa	30
17	Viršu ārenis	Callunosa mel.	15
18	Mētru ārenis	Vacciniosa mel.	10
19	Šaurlapu ārenis	Myrtillosa mel.	11
21	Platlapju ārenis	Mercurialosa mel.	12,5
22	Viršu kūdrenis	Callunosa turf. Mel.	14
23	Mētru kūdrenis	Vacciniosa turf. Mel.	15
24	Šaurlapu kūdrenis	Myrtillosa turf. Mel.	10,5

This is not always true. However, as (Porte et. al 2002) noted, it is difficult to test mixed forest models that are created for stand growth predictions as the stand structure gets more complex. To fully encompass the needs for a mixed species forest modelling, the stand and single tree models should be combined. This, however, has not been done yet in terms of necessary confidence of results.

As described in (Kiviste 2009) – the samples did exclude young stands and very old stands. This had to be taken into account and solved as the used database had data also in those categories.

For the very old stands the solution was simple – it was presumed that these stands would be cut at the model data range end, which usually corresponded with the recommended cutting age. For the young stands the solution was to create linear equations with the same parameters of stand site that could cover the young age gap excluded by the original sample data. With this addition the full growth cycle of the stands can be calculated and modeled.

The main algorithm has a main equation in the form of

$$result=\frac{(P4+IPF2+IPF3)}{\left(2+\frac{4*IPF1*P3^{(-C2)}}{(P4-IPF2+IPF3)}\right)} \quad (1)$$

where: P4 is the parameter in a current time step; result is the parameter in the next time step and P3 is the result stand age.

There are also coefficients IPF1, IPF2 and IPF3 that are computable. Depending on the main parameter that is to be computed, IPF1 and IPF3 have different equations [9]. For the case of diameter:

$$IPF1 = C1 - 306 * log(P5 + 1) \quad (2)$$

$$IPF2 = \frac{IPF1}{50^{C2}} \quad (3)$$

$$IPF3 = \sqrt{\left((P4 - IPF2)^2 + \frac{4 * IPF1 * P4}{P2^{C2}}\right)} \quad (4)$$

where: C1 and C2 are coefficients dependent on tree species; P5 is the 0-horizon thickness and P2 is the current stand age.

For the case of stand volume (m^3 / ha) the IPF1 and IPF3 (for IPF2 the formula (2) is applied) are calculated as follows:

$$IPF1 = C1 - 54348 * log(P5 + 1) + 56290 * P6 \quad (5)$$

$$IPF3 = \sqrt{\left((P4 - IPF2)^2 + \frac{4 * IPF1 * P4}{P2^{C2}}\right)} \quad (6)$$

where: P6 is the parameter for the factor of stand cultivation, if the stand has been planted P6 = 1, if the stand is naturally forested area P6 = 0; P4 in this case is the stand volume.

For the case of standard stem height in the stand the equations for IPF1 and IPF3 are as follows:

$$IPF1 = C1 - 493 * log(P6 + 1) + 1355 * P5 \quad (7)$$

$$IPF3 = \sqrt{\left((P4 - IPF2)^2 + \frac{4 * IPF1 * P4}{P2^{C2}}\right)} \quad (8)$$

The algorithm was used with the time step of one year.

IV. RESULTS

The forest database was used to create the table of conversion from forest type to 0 soil horizon for Latvian forests. The species overall growth graphs have been gained from the database and can be used for the further analysis or growth predictions. The modified algorithm was employed to compute the predictions for the year 2025 and the end results were shown as maps. A subset map of stand volume is shown in Fig. 1. The map was created using the predictions and mapping out the volume parameter. The modified algorithm was evaluated.

V. MODEL EVALUATION

Two separate evaluations were made for this model. The first one was to compare the end result of the predictions – the prediction of 2025 with the overall growth pattern, curve, with the pattern that is available right now from the NFI data. An overall comparison is impossible as there are too many records (444614 altogether), so that a subset was created of 6102 records for the mapping task. A subset of different species and different site bonities was created to compare the curves (Vanclay 1994).

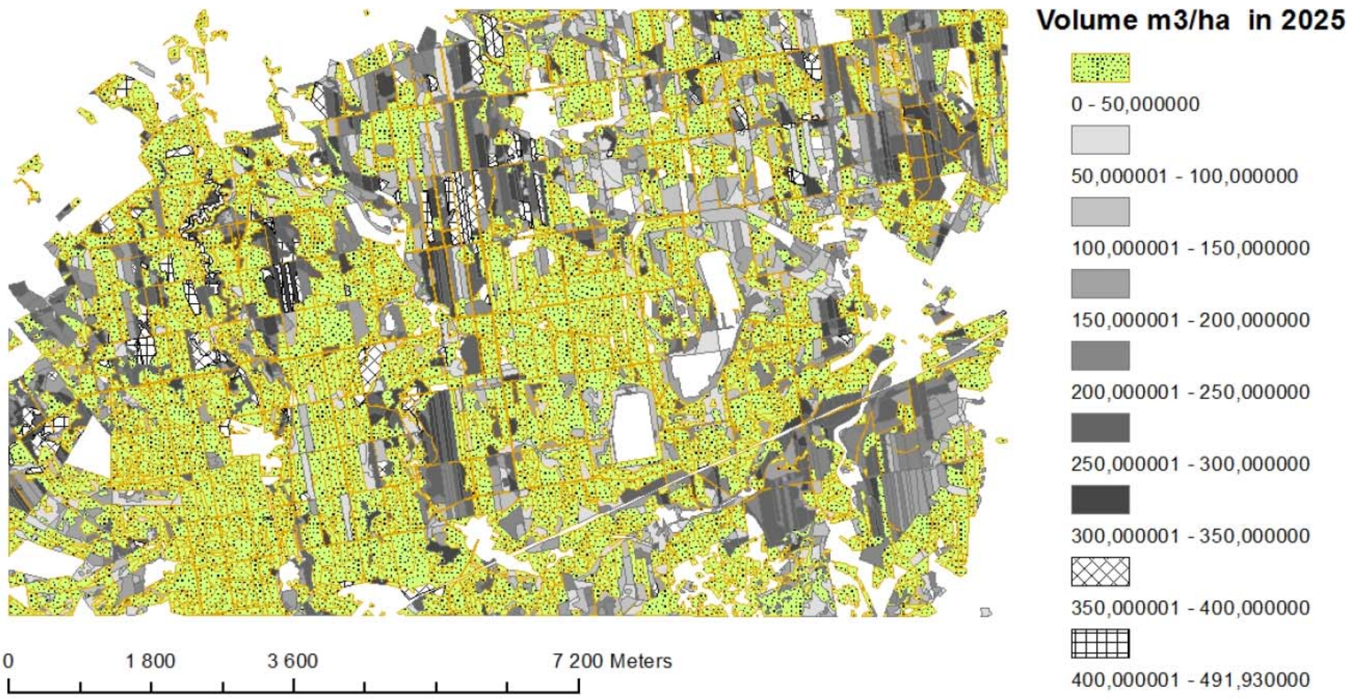

Fig. 1. Map example of predictions – Volume map of the year 2025 for a sample subset.

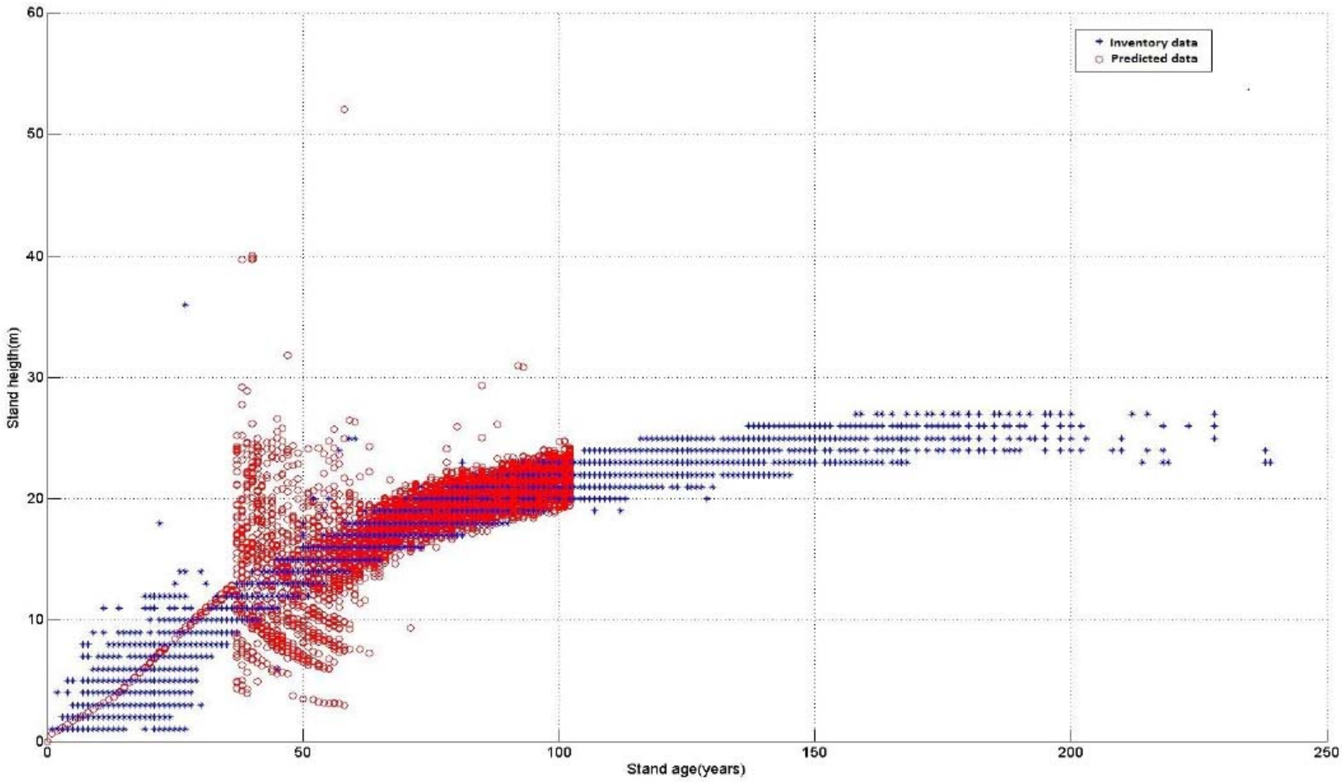

Fig. 2. Example of tree growth pattern and prediction artifacts.

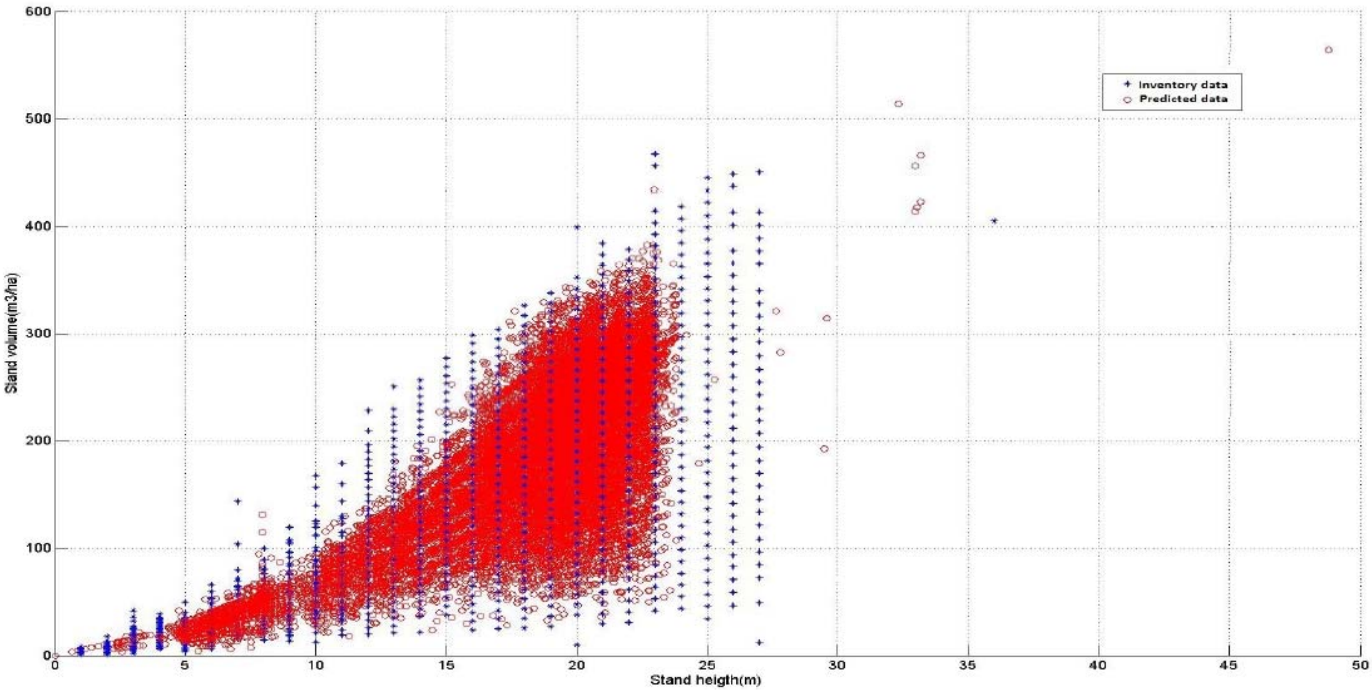

Fig. 3. Example of tree growth pattern without prediction artifacts.

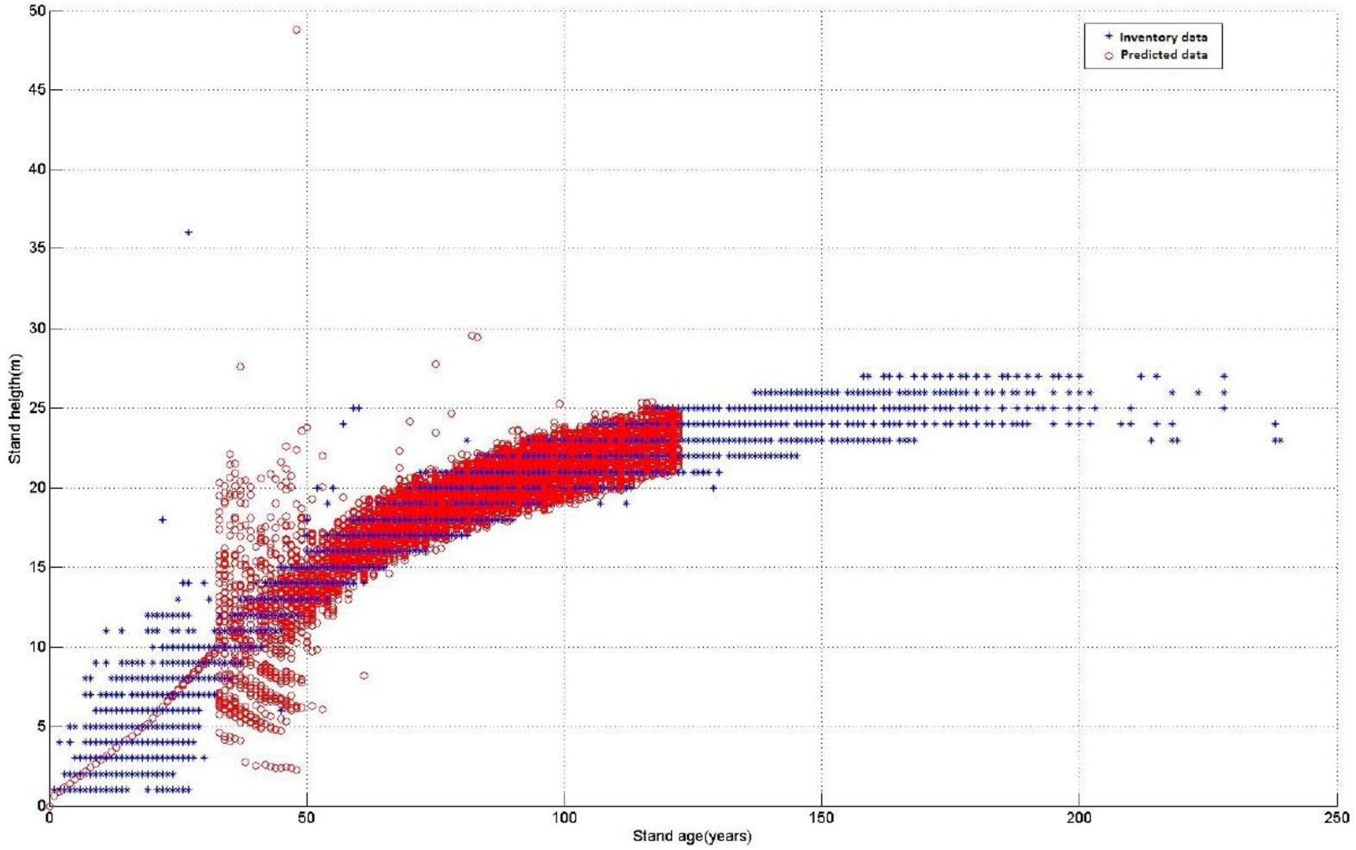

Fig. 4. Example of tree growth pattern with reduced prediction artifacts.

The artifacts in the predicted pattern are shown in Fig. 2. It has to be noted that this kind of outliers can be seen in almost all the graphs in the subset. The only clear graph was the height/volume graph in all combinations (Fig 3). One of the possible reasons was the initial age at what the change between the linear part and the Kiviste algorithm took place. When changing this point from 12 to 18, the branching was less, but it still existed (Fig. 4). The original data were from forest plots that were at least 20 years of age. The updated calculations show that results do not vary when the linear part is extended till the age of 22. So the increase has to be larger for any impact.

This approach, however, does not express how precise the model results are in a numeric, comparable way.

To have the numerical comparison, the second approach – comparison with satellite estimate and ground truth – was used. For the year 2012 there is only limited ground truth available, that alone is not enough to measure the precision of the predictions. However, in PB project time also the assessment of the situation was made based on SPOT satellite images from winter of 2011. Using the ground truth to create the satellite assessment a large enough set consisting of one scene or 43 445 records was created to compare with the prediction.

The comparison with satellite estimate gave the minimum difference of 0 m^3/ha and maximum difference of 575 m^3/ha. The maximum was due to the algorithm reaching the optimal cutting age and, thus, flaging the stands as clear cut, but in reality the stand was still untouched. The average error of this comparison for pine even with such large errors in it was 130 m^3/ha, for spruce 134 m^3/ha, for birch 114 m^3/ha and for black alder and aspen 96 m^3/ha. It has to be noted that these results have been obtained with the predictions, where linear equations are employed till the age of 12. This indicates that with adjustment of this linear/Kiviste switching age and cutting age the results can be improved.

VI. Conclusions

In this publication, the use of algebraic difference equation model to predict forest growth has been described. The original algorithm has been changed to be compatible with the available data. Additional table of soil 0-horizon values dependent on forest type has been created. The predictions have been calculated for the year 2025 and converted to a map format.

The predictions will be used to calculate biomass levels and to create advanced maps.

The model needs a complete analysis to find or mitigate the source of artifact result creation. One of possibilities is to even more increase the stand age that is achieved by the Kiviste model. This, however, will be only possible after the linear term recalculation in order to include larger data sets. Also a limiter could be placed in the algorithm to remove the obvious outliers; this could lead to incorrect results and a changed growth profile.

When the Latvian sample plots are available, it is recommended carrying out an extended testing on these plot data in order to assess if any changes are needed (possible parametric) for the model to be fully reliable.

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