A note on meteorological variables related trends in the MODIS NPP product for Estonia

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Abstract. The MODIS (The Moderate Resolution Imaging Spectroradiometer) yearly NPP (Net Primary Production) 1 km resolution products were collected over Estonia for years 2000–2010. The MODIS NPP product for forest pixels showed a clear West-East decreasing trend over the Estonian territory. At the same time the trunk volume increment estimates extracted from the Estonian national statistics averaged over the same period showed the opposite trend. The MODIS NPP algorithm seems to overestimate the contribution of meteorological variables and to ignore the role of soil fertility differences. To improve the predictive power of MODIS algorithm to describe local NPP differences, the local meteorological data with higher spatial resolution should be used as an input in the NPP calculations, whereas the algorithm should be modified by optimizing the input parameters and including parameters of soil fertility into the calculation scheme.

Key words: MODIS, NPP, forest productivity, meteorological data.

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Introduction

Starting from year 2000, NASA Earth Observing System provides The Moderate Resolution Imaging Spectroradiometer (MODIS) yearly net primary production (NPP) and yearly gross primary production (GPP) estimates globally at resolution 1×1 km^2. The MODIS NPP products have been tested in several regions of the Earth, either by comparing to the results of ground based net ecosystem exchange (NEE) estimates from eddy covariance towers (e.g. Heinsh *et al*., 2006) or to the indirect estimates from forest inventory data (Turner *et al*., 2004). The aim of the paper is to compare the MODIS NPP product over Estonia to the amount of carbon stored in tree trunks as derived from volume increment data from Estonian national forest databases and to see if the regional differences of forest productivity are adequately described by the MODIS NPP product.

Material and Methods

MODIS yearly NPP/GPP product (MOD17A3) Collection 5 (C5) data (NTSG version) for Estonian territory were downloaded from the NTSG website (ftp://ftp.ntsg.umt.edu) for years from 2000 to 2010. The county map of Estonia was transformed into the sinusoidal map projection to be comparable with the MODIS NPP data. Yearly NPP values were extracted for all forest pixels categorized by the MODIS land cover map as coniferous evergreen, deciduous broadleaf and mixed forests and later the ten-year average NPP values in all counties of Estonia were calculated.

Results

For the ten-year period the average yearly value of NPP of forest pixels was 0.45 kg C/ m^2/year, the respective average estimate of carbon stored in tree trunks from the Estonian national statistics was 0.14 kg C/ m^2/year. This difference can be explained by the fact that less than a half of the total aboveground biomass is stored in tree trunks (Turner *et al*., 2004) and in addition, a considerable part of yearly production (20–40% in boreal forests) is allocated to roots (Gower *et al*., 1999). Although the fraction of photosynthetically active radiation (FPAR) and leaf area index (LAI) are derived in the MODIS NPP algorithm from the MODIS images at 1 km^2 resolution, the coarse (1 x 1.25°) meteorological data input from the NCEP/DOE II (NCEP, 2012) global meteorological reanalysis dataset causes clearly visible zones of different NPP in the simulated NPP in Estonia (Fig. 1).

Within a zone the meteorological input data are simulated to be relatively uniform. As simulated by MODIS NPP product, the most productive zones are situated on the western part of mainland Estonia and on the islands (Saaremaa and Hiiumaa) and less productive in the inland, causing a clear decreasing trend of NPP towards East. However, the Estonian forest inventory data show just the opposite trend (Fig. 2).

Discussion and Summary

In the western part of Estonia, the climate is mild and more favourable for photosynthesis whereas in the inland the weather conditions are less favourable. Three meteorological parameters enter the MODIS NPP algorithm:

1. The incident flux of photosynthetically active radiation, (West-East) W-E decreasing trend is caused by less cloudiness in the islands (Saaremaa and Hiiumaa) and western part of mainland Estonia (Russak & Kallis, 2003).

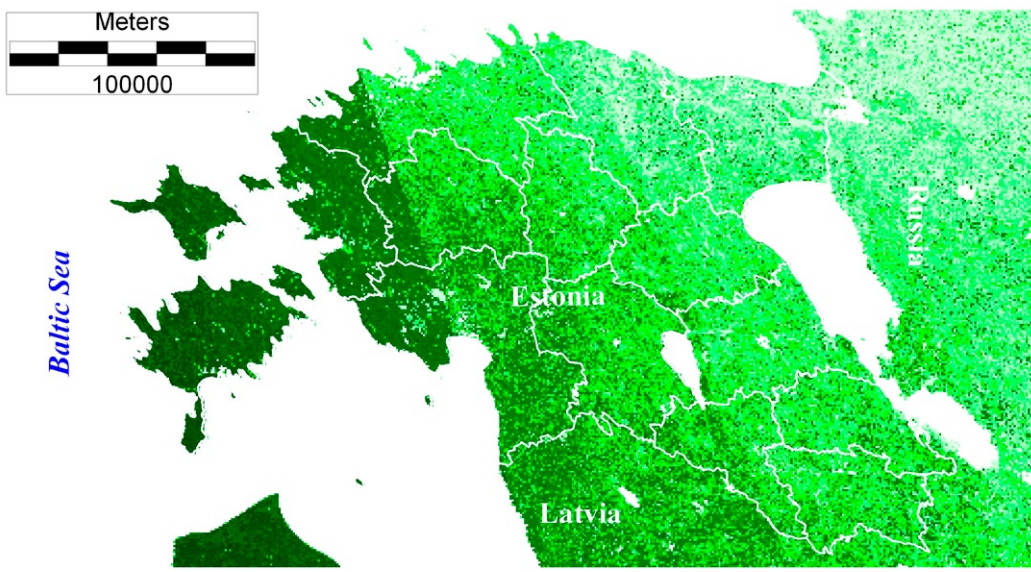

Figure 1. Clearly visible zones of different NPP in the simulated MODIS NPP in Estonia are caused by usage of the NCEP/DOE II global meteorological reanalysis dataset in the MODIS NPP algorithm. County boundaries are overlaid on the map.

Joonis 1. Eesti alal ilmnesid primaarproduktiooni produktil süstemaatiliselt erinevad looduses mitteesinevad tsoonid, mille põhjuseks on MODIS NPP algoritmis kasutatav NCEP/DOE II meteoroloogiaandmestik.

2. Daily minimum and mean air temperatures. In the western part the effective duration of the vegetation period is longer compared with the inland part of Estonia.

3. Daily average water vapour pressure deficit. The air humidity has a decreasing trend towards East and thus in the western part of Estonia there are less days with low air humidity and possible transpiration stress.

So, the W-E decreasing trend in the MODIS NPP can be fully explained by meteorological data. Due to large uncertainty in the fractions of NPP allocated to leaves, branches, understory plants, and to coarse and fine roots, it is rather difficult to judge the validity of state average MODIS NPP products for Estonian forests. However, the regional spatial pattern of MODIS NPP distribution in Estonian forests does not agree with the Estonian national statistics. Can the differences be explained by differences in allocation patterns of trees? Partly, yes, since the soil fertility is higher in the inland part of Estonia and trees in the Eastern part of Estonia can probably afford to grow relatively less roots than in the western islands. What about soil water holding capacity and transpiration? It seems that the present version of the MODIS NPP model over-estimates the role of meteorological parameters and does not take into account the soil fertility and soil water-holding capacity.

With the present set of biome-specific parameters, vegetation period starts too early in the spring and lasts too long in the autumn, especially in the western part of Estonia. The value –8 °C (–6 °C for the deciduous broadleaves in C5) used in the MODIS NPP algorithm for the daily minimum air temperature below which the radiation use efficiency is supposed to be zero seems to be too low.

The present MODIS NPP version is not able to adequately describe the local differences in forest productivity in Estonia. It overestimates the effect of key meteorological factors, such as air temperature, air humidity and cloudiness all causing a W-E decreasing trend in the simulated NPP

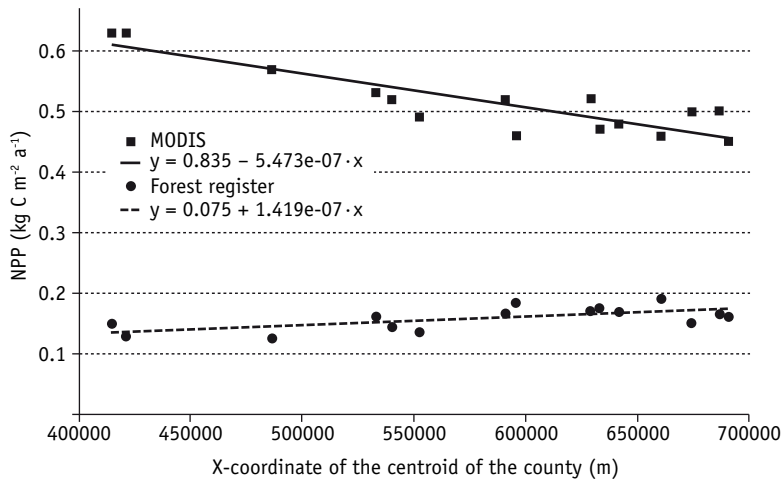

Figure 2. County-wise average MODIS NPP and forestry data based NPP estimates plotted against Eastings of county centroids show opposite trends.

Joonis 2. Ida-läänesuunaline primaarproduktsiooni hinnang Eestis maakonniti metsakorralduse andmetel ja MODIS NPP produktilt on vastupidise suunaga.

and ignores the regional differences in soil type and fertility. To improve the regional prediction capability of the NPP algorithm, the use of higher resolution meteorological data, revising the biome-specific model parameter values and introduction of a soil fertility factor into the model is recommended.

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Meteoroloogilised andmed põhjustavad vigu MODISe primaarproduktsiooni hinnangutes Eesti alal

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Kokkuvõte

Koguti NASA satelliitidel Terra ja Aqua paikneva keskmise resolutsiooniga pildistava spektroradiomeetri ehk MODIS'e (ingl. k. *Moderate Resolution Imaging Spectroradiometer*) aastased primaarproduktsiooni (NPP) väärtused 1 km lahutusega Eesti ala kohta aastatest 2000–2010. Eesti ala MODIS'e metsa pikslite NPP näitas selget lääne-ida-suunalist langevat trendi. Sama ajavahemiku kohta Eesti metsaressursi arvestuse riikliku registri (metsaregistri) andmete alusel tuletatud tüvemahu juurdekasvu hinnangud näitasid vastupidist trendi (joonis 2). MODIS'e NPP algoritm tundub üle hindavat meteoroloogiliste muutujate mõju ja ei arvesta mulla viljakuse erinevusi. NPP regionaalsete erinevuste paremaks kirjeldamiseks MODIS'e NPP algoritmiga tuleks meteoroloogiliste sisenditena kasutada kohalikke kõrgema ruumilise lahutusega andmeid, korrigeerida Eesti oludele paremini vastavaks sisendparameetrite väärtusi ja tuua NPP algoritmi sisse mulla viljakust arvestav tegur.

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