

# ***Interactive comment on* “The influence of soil properties and nutrients on conifer forest growth in Sweden, and the first steps in developing a nutrient availability metric” by Kevin Van Sundert et al.**

## **Anonymous Referee #1**

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General Comments There is growing awareness about the influence of nutrient availability on forest C cycling. To better understand this relationship at global scale, there is a real need to integrating information about soil fertility and ecosystem production at broad spatial scales. However, soil is a spatially and temporally complex growing medium, and efforts to develop simple, useful indices of the production potential of soils face numerous challenges. The authors of this paper seek to take the ‘first steps’ towards creating a single metric to define the relation between soil fertility and forest growth. The authors note that ‘we often lack the soil data and metrics needed to ac-

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curately account for nutrient availability’ and that ‘Such a metric does not exist.’ This prompts the important question of whether attempting to reduce the complexity of soil fertility into one metric with broad applicability is a realistic pursuit.

The central goal of this paper is to evaluate the utility of individual and combined soil parameters for predicted forest growth. The study leverages soil and forest growth data from > 2500 pine and spruce plots spanning much of Sweden’s forest land. Soil x forest growth relations are partitioned along a N-S gradient with productivity normalized for corresponding climatic conditions. The strength of soil x production relations vary between and within regions. Soil moisture class (site wetness) is identified as another critical category that regulates both soil parameters (SOC %) and forest productivity. High SOC (wet sites) with low forest productivity (Fig 5a, 6a) stand out from N-M-S regional gradients. Owing to the strong influence of site wetness on SOC, it is advisable to stratify and analyzed soil fertility x productivity relations by wetness class, not just along N-S gradient. Further, N inputs are 4-5 times higher in Southern than Northern Sweden (Binkley and Hogberg 2016) and thus present a further factor that should be considered with evaluating nutrient and forest productivity across these sites (de Vries et al. 2014).

In addition to examining productivity and soil data from Swedish forests, the authors also evaluate the value of an existing global approach for assigning nutrient constraint metrics. The author’s general intent to validate or modify an existing approach makes good sense, but the fact that the selected approach was developed for crops not forests and is ‘yet unvalidated’ is a bit counterintuitive. Interpretations of the utility of IIASA are reliant on some level of understanding about the strength and limitations of crop-focused IIASA approach. For example, how robust is the approach for predicting plant growth across various soil types? Based on the conditions under which IIASA was developed, how well might it be expected to perform on forest soils and with tree growth? Without clear description of the IIASA (currently some found in Intro, but lacking from Abstract), the paper presents a ‘house of cards’ based on a relatively unknown, and

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possibly weak foundation. Finally, please justify why the simpler approach of originating with 'no' tool and creating one from the ground up with existing data, as outlined in Question 1, is not both adequate and preferable.

Specific and Technical Comments Line 8 Nutrients are one of the factors that influence C cycling. As presented this suggests they are the only or the primary factor. In spite of recent. Line 10 'ideally' The potential value of simplifying ecosystem complexity into interpretable and useful metrics is critically important. However, given the complexity of soils and forest ecosystems, it is worth questioning whether a single fertility metric is an attainable goal. Rather than assuming such an index is 'ideal' this paper might simply evaluate relationships between soil fertility properties and forest growth are robust and broadly useful. Line 10 'Such a metric does not exist' Is the lack of such a metric a major obstacle to understanding of forest production? An objective of this paper should be to quantify how such a metric improves our ability to predict forest growth. Line 12 Insert 'of' between 'combination' and 'soil' Change 'plant' to 'tree' Insert 'forest' before 'nutrient' Line 13-14 Developing this analysis using an unproven metric is counterintuitive. Justify why you did not start out with 'no' tool and build one from the ground up with existing data. Also, explain how the IIASA approach tool developed elsewhere for crops has application for Swedish forests. Clarify how advances from your analysis are independent of potential weakness or limitations of the IIASA approach. Line 19 'not well implemented' Define what that means, especially in light of whether or IIASA provides a useful platform to work with. Line 37/38 Site index is typically an estimate of site productivity, rather than soil fertility per se. The terms are certainly related, but key differences might include factors such as soil depth and hydrology. Line 47 'are more indicative' it's not clear of what. Please revise, clarify. Line 100 What was the size of the forest plots? Are these all plantations or are some natural stands? How are management interventions such as fertilization and thinning addressed and controlled for? What is the average and range of stand age and stand density or basal area?

Line 122 Before suggesting that metric scores can validly 'be assigned to any soil' it

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would be useful to know more about the data that went into development of the IIASA and how well those soil types and crop conditions match the forest soils of Sweden. Line 123 This suggests that the IIASA metric is not sensitive to crop specific requirements. Line 284-285 Use soil moisture classes to stratify fertility by productivity. There appear to be abrupt differences between upland and 'wetland' forests that are at least as significant as the N-S gradients. Line 295 The high SOC of wet soils is less a limitation than the anaerobic rooting environment. Line 296 Consider optima for soil saturation, soil oxygen, or soil moisture like the one currently used for pH. This is independent of SOC. Line 301 It is ironic that the only nutrient examined is of limited value. It should be stressed that total N is a much larger pool than the N that's readily available to plants. The complications of inorganic N inputs across the N deposition gradient, and inorganic N losses (leaching and denitrification) across wetness/saturation gradient are likely considerable. Line 304 This relation appears to stem on the large difference in clay in Wet spruce sites (Fig S3e). Again, stratifying wetland from upland forests might isolate and better resolve these patterns. Line 309 Insert and stress "in the absence of direct soil nutrient data" Line 315/316 General differences between arable and Swedish forest soils could be used to define expectations regarding the utility of the IIASA method and probable modifications. Saturated soils, low-clay soils, low N soils might all define some of those differences. Line 324 High water table, low soil oxygen, soil saturation, wetland soils. Table 1 Units are included for everything but TN, and moisture. How was moisture determined and how well does it estimate relevant seasonal moisture dynamics? Table 2 Sample depths are listed for everything but sand and clay. Figure 1 Specify what 'Species-averaged' means or reword so that the caption and figures are interpretable independent of the text. The range of SOC data (1-3%) is nowhere near the ranges presented in Figure 5 and 6 (0.1 to 100%), where the data is presented on a log-scale axis. Explain or resolve the discrepancy.

Citations Binkley D, Högberg P. 2016. Tamm Review: Revisiting the influence of nitrogen deposition on Swedish forests. *Forest Ecology and Management* 368: 222-239.

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de Vries W, Du E, Butterbach-Bahl K. 2014. Short and long-term impacts of nitrogen deposition on carbon sequestration by forest ecosystems. *Current Opinion in Environmental Sustainability* 9-10: 90-104.

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