Impact of Tree Growth on AEP Estimates and Uncertainty

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MEGAJOULE INOVAÇÃO

windie™

Abstract

As the wind energy matured in a number of markets across the world, the number of ideal sites with high wind resource became scarcer and scarcer. As a result, there is an increasing number of projects located in areas of high wind resource, but with extensive forest cover.

Forests bring about two main difficulties: a) their physical effect on atmospheric flows is to reduce wind speeds at wind height by effectively raising terrain height and increase wind turbulence and wind shear with a consequent impact on wind turbine operating conditions and maintenance costs; and b) their characteristics—tree height, foliage density—change in time, as trees grow during the wind farm operational lifetime (as well as changing with the seasons) It follows that, calculations of long-term wind farm production based on measurements collected when the forest was still young will tend to overestimate AEP and underestimate site assessment quantities. As such, a new is presented to take into account these effects on AEP values and also account for the increase in the uncertainty that this new variable entails.

Methodology

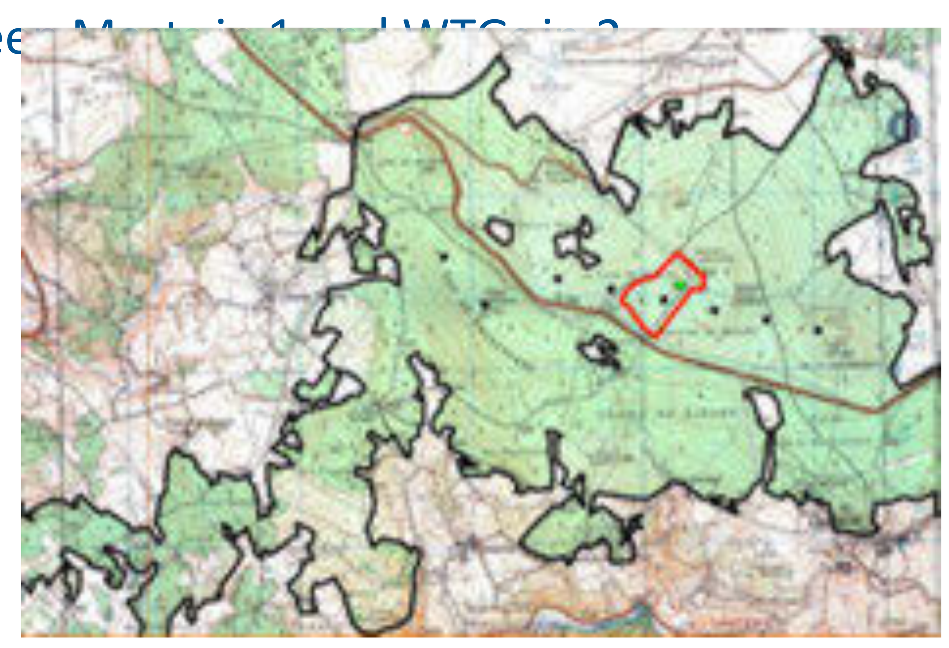
WINDIE™ CFD (Castro, 1997) wind assessment studies consist of simulations describing the wind flow from a number of directions at a given site. Boundary conditions are idealized profiles of wind speed and turbulence quantities or, instead, boundary conditions extracted from mesoscale simulations which incorporate regional wind patterns and thermal stratification signatures. Forest characteristics are described explicitly in the model through additional terms in momentum and turbulence equations (Lopes da Costa 2006), in terms of tree height, leaf area index (LAI) and the species-dependent vertical variation of leaf density.

When accounting for tree growth, one must transport wind not only in space but also **extrapolate into the future**. Therefore, one must simulate the wind flow conditions during the measurement period, as well as the operational conditions which will be affected by changes in the forest during the wind farm lifetime. Having both sets of results, it is then possible, provided boundary and inlet conditions were identical in both sets of simulations, to **relate wind conditions in the past at the mast location, to wind conditions in the future at turbine locations**.

The algorithm consists thus of 3 steps:

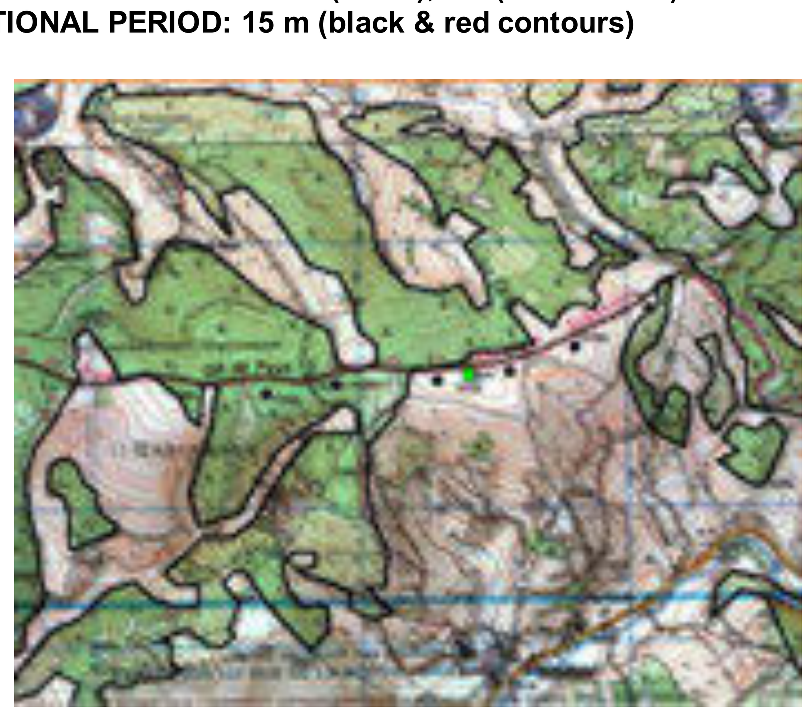
1. Simulations Using Forest Characteristics during Measurements.
2. Simulations Using Projected Forest Characteristics during WF Lifetime.

WF #1, Forest height (inside black contour):
MEASUREMENT PERIOD: 5 m
OPERATIONAL PERIOD: 15 m



WF #2, Forest height:
MEASUREMENT PERIOD: 12m (black), 0m (red contour)
OPERATIONAL PERIOD: 15 m (black & red contours)

WF #3 (NORTH), Forest height (inside black contour):
MEASUREMENT PERIOD: 10 m
OPERATIONAL PERIOD: 15 m

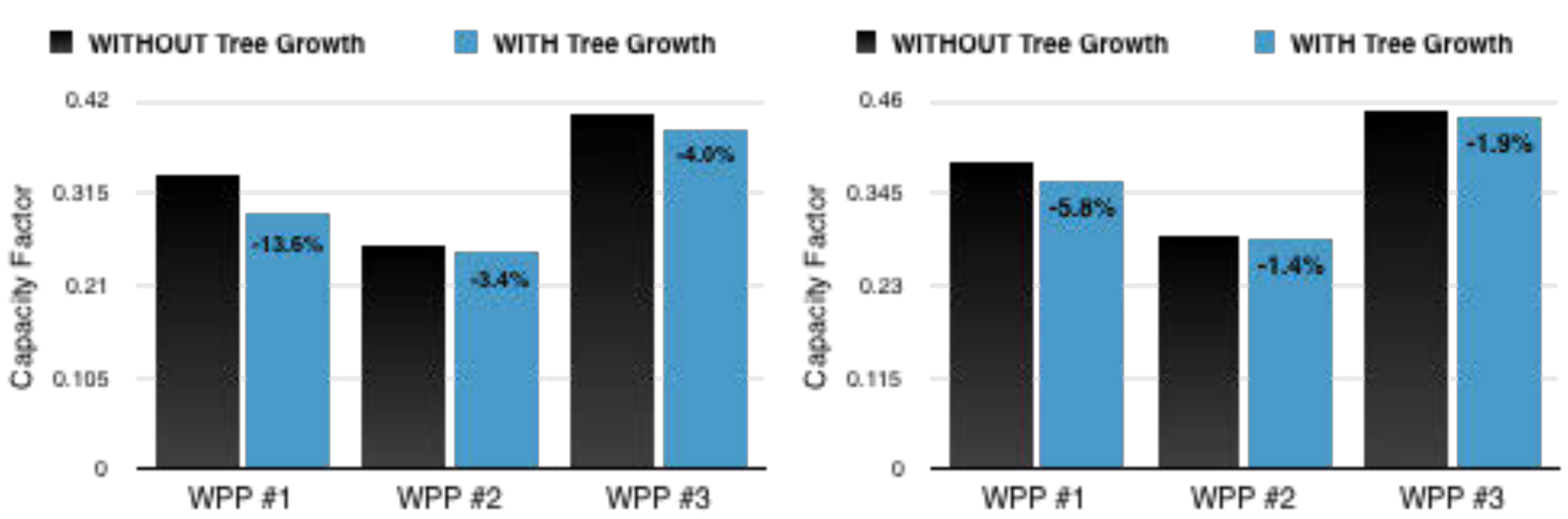


WF #3 (SOUTH), Forest height (inside black contour):
MEASUREMENT PERIOD: 10 m
OPERATIONAL PERIOD: 15 m

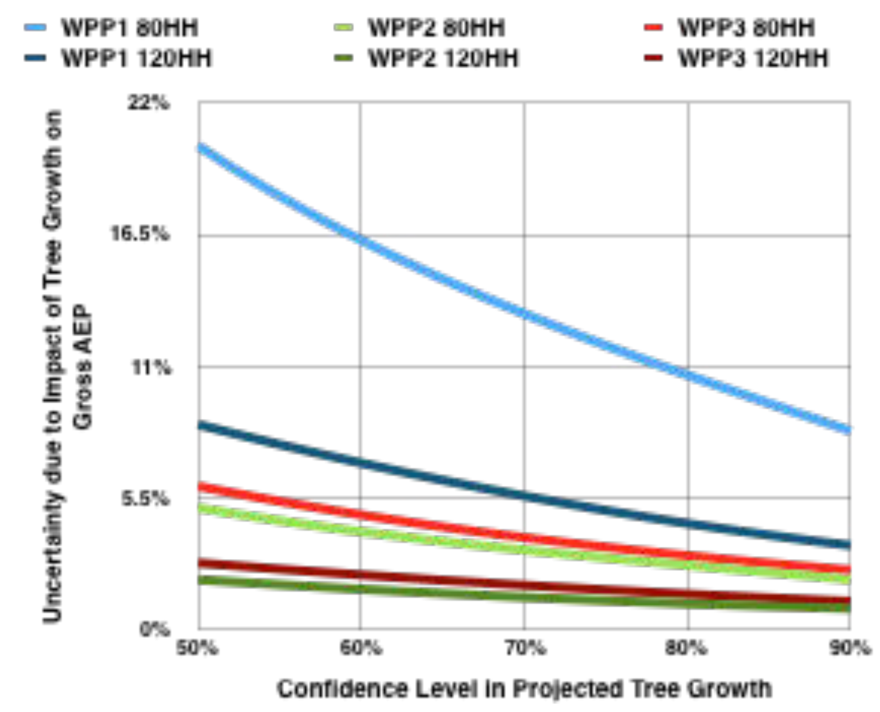
As can be seen, the 3 wind farms present an interesting range in changes in forest characteristics. Whilst at wind farm #1, tree height is expected to triple (200% increase), owing to the very young age of the saplings during the measurements, that increase is much reduced for wind farm (#2) (25% increase) and is moderate for wind farm #3 (50% increase).

Results

The following figures show the impact of the tree growth as estimated by WINDIE™ CFD model in terms of the wind farm capaciy factor (this is defined as the annual estimated wind farm production, AEP, over the maximum production possible in a year, so it can be seen as a form of wind farm efficiency).



It can be observed from the above results that the impact of tree growth can be considerable. Reductions in capacity factor of **as much as 13.6%** (relative)—or 4.6% absolute (from 33.6% to 29.1%)— were estimated for WF#1 where tree growth is predicted to be more significant. Nevertheless, even for WF#2, where tree are estimated to grow by only 3 m, the estimated reduction in capacity factor is about 0.9% (absolute) which represents still a significant impact in overall wind farm production. The more pronounced values were obtained, as expected, at the lower hub height of 80m agl



As to the impact of tree growth on uncertainty, this is dependent on the degree of confidence one has regarding the real growth that the forest will incur in the future. As such, several confidence scenarios were considered: between 50 and 90%. Naturally, the impact on uncertainty follows the impact on AEP with the highest values occurring for wind farms #1, then #3 and finally #2.

The graph also highlights the considerable dependence that the final uncertainty of the gross AEP will have on the level of confidence in the future forest scenario. That is to say that, it is important for the wind farm developers and their consultants to have accurate information regarding the future of the surrounding forests as well as to research the specific life cycles and growth patterns of the native species.

Conclusions

Impact of forest growth on AEP:

Depreciations in AEP can be significant <u>and vary significantly</u> (from 50 to 400 FLH or 1 to 4.6% in Capacity Factor)

Impact of tree growth can vary significantly even in WFs in close proximity and justify individual detailed studies to take it into account.

Impact of forest growth on uncertainty:

Level of uncertainty will depend on confidence in projected tree growth.

Increase in uncertainty can be significant, justifying detailed studies from an economical point of view.

Impact of tree growth on uncertainty can vary significantly between WFs.