sgurrENERGY
sustainable energy solutions

Wind Regime in Complex Forestry

Carmen Solórzano

SgurrEnergy

- Established in 2002
- Leading independent consultancy specialising in renewables
- Based in Glasgow and Beijing
- 40 experienced professionals
- Broad range of expertise
- Experience in over 20 countries

Multi-disciplinary technical experts

Wind

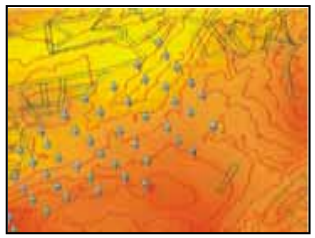
Hydro

Bio-energy

Project Management

Marine

Micro-generation



Due Diligence

Noise & Vibration

Wind Regime in Complex Forestry

- Why is it important to study wind regime in forested areas?
- Dataset used in the study
- Results from the measured data:
  - Wind speed
  - Wind shear
  - Turbulence intensity
- Comparisons between the data and our model predictions
- Conclusions

Why?

- Initially wind farms were built in open areas.
  Nowadays more wind farms built in forested areas.
- Forestry influences wind regime
  → forestry will affect load on turbines
  → forestry will affect energy yield
- We need to understand *in detail* the effects of forestry on the wind regime.

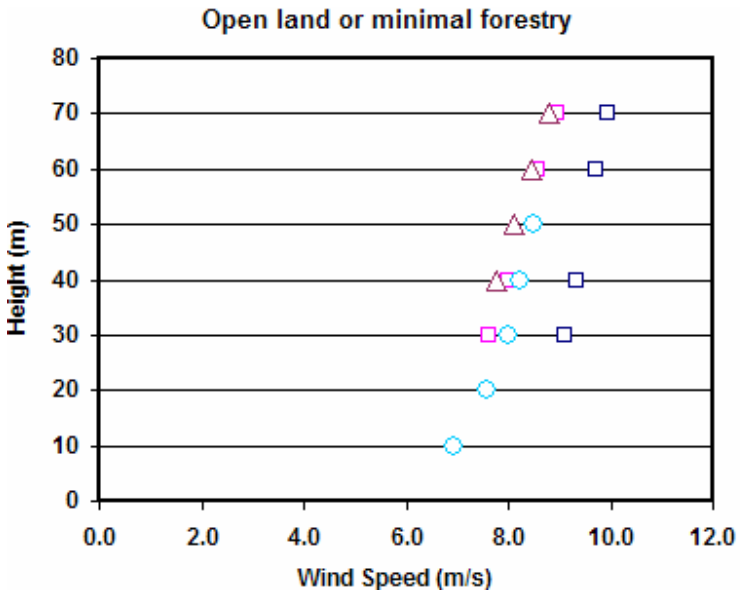
Dataset studied

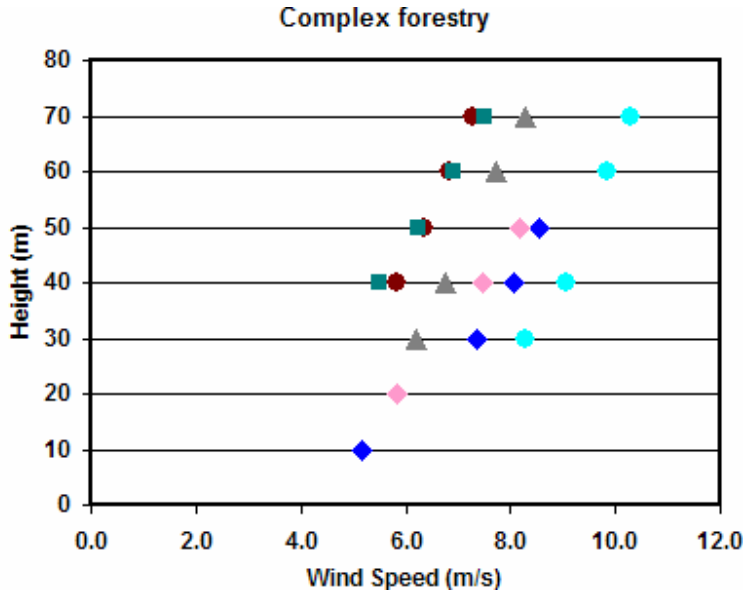
- 10 masts on 4 sites (seven 70m and three 50m)
  - 6 masts in complex forestry
  - 4 masts in open land or minimal surrounding forestry
- Anemometers at 3, 4 or 5 heights on mast, measuring:
  - 10min mean wind speed
  - 10min mean wind direction
  - 10min standard deviation (top anemometer)
- Data periods up to 3.5 years
- Data records used: 4 – 20m/s

Wind Speed and Wind Shear

- Plot average wind speeds across all directions.

Wind shear: wind speed (*U*) variation with height a.g.l. (*h*)

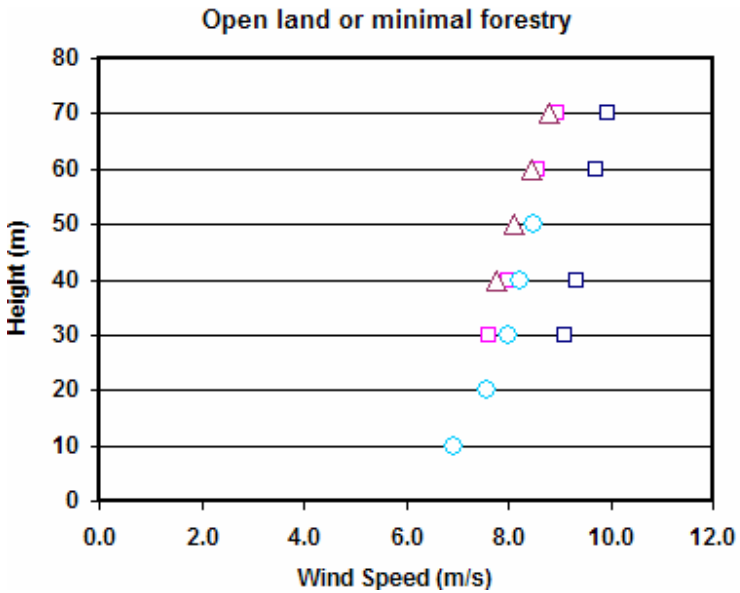


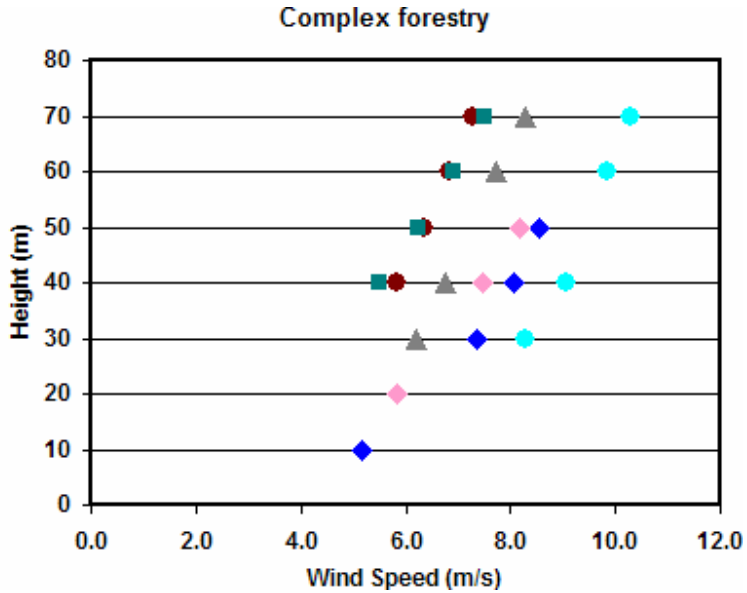


Wind Speed and Wind Shear

- Fit *power law* to data:

$$U(h) = U(h_0) \times \left(\frac{h}{h_0} \right)^{\alpha} \quad ; \quad \alpha : \text{wind shear exponent}$$





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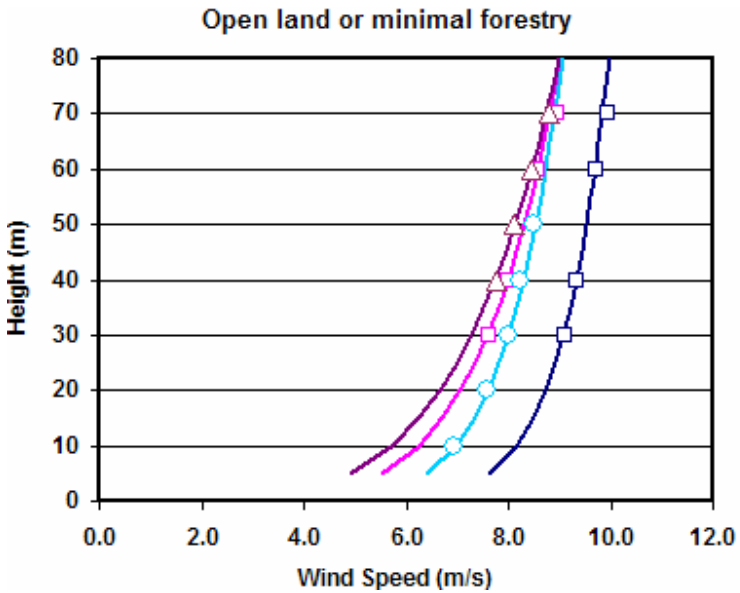
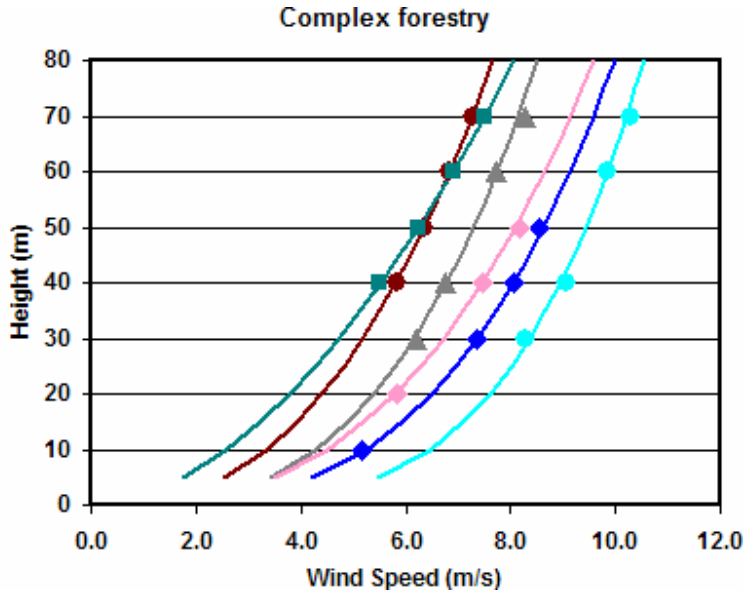


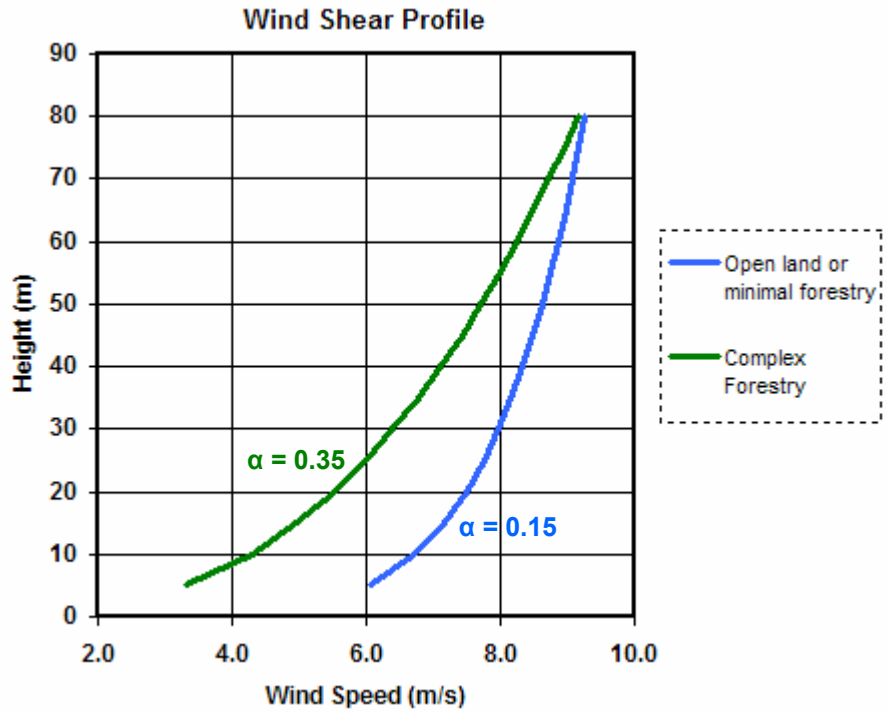


Wind Speed and Wind Shear

Forestry reduces wind speed significantly at low heights

Forestry increases wind shear

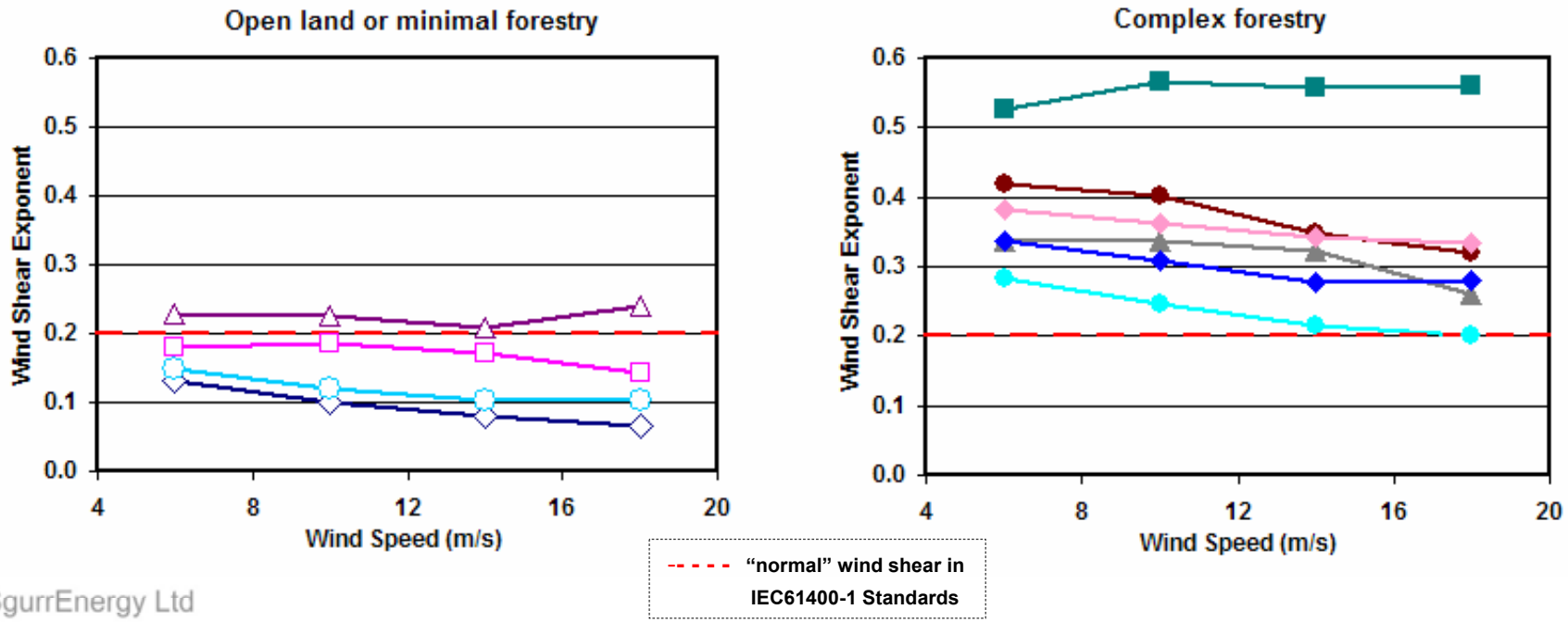
Height (m)	Wind Speed Reduction with Forestry
20	-25%
40	-15%
60	-7%
80	-2%



Wind Shear vs Wind Speed

Wind speed windows: 4-8m/s, 8-12m/s, 12-16m/s, 16-20m/s

Wind shear decreases with wind speed regardless of forestry



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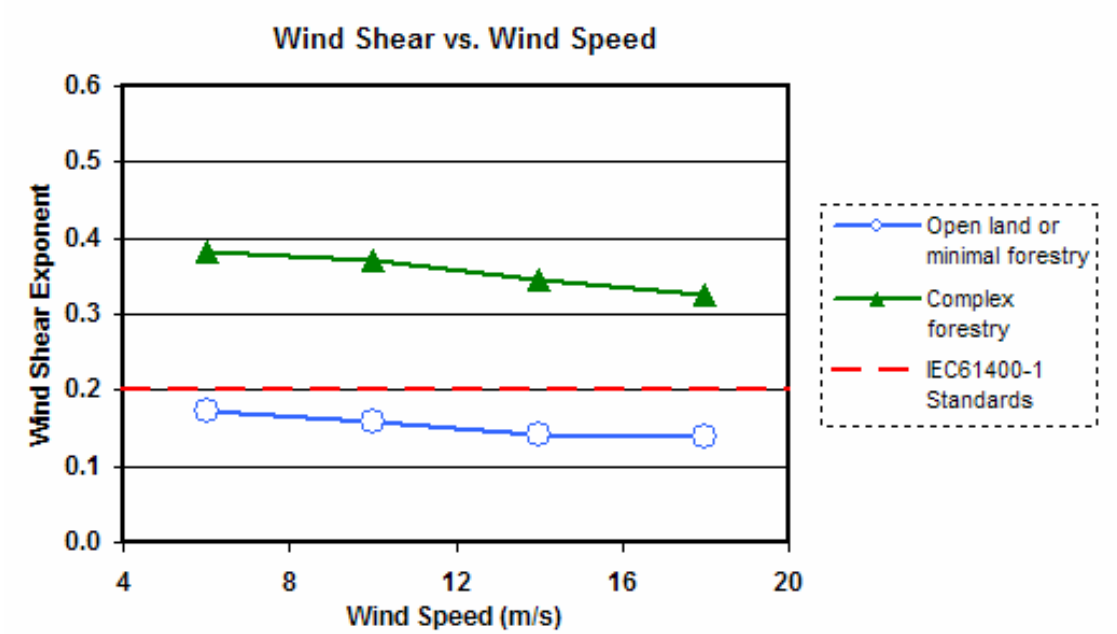

Turbulence Intensity

Turbulence Intensity defined as: $TI = \frac{\sigma}{U}$; σ: standard deviation

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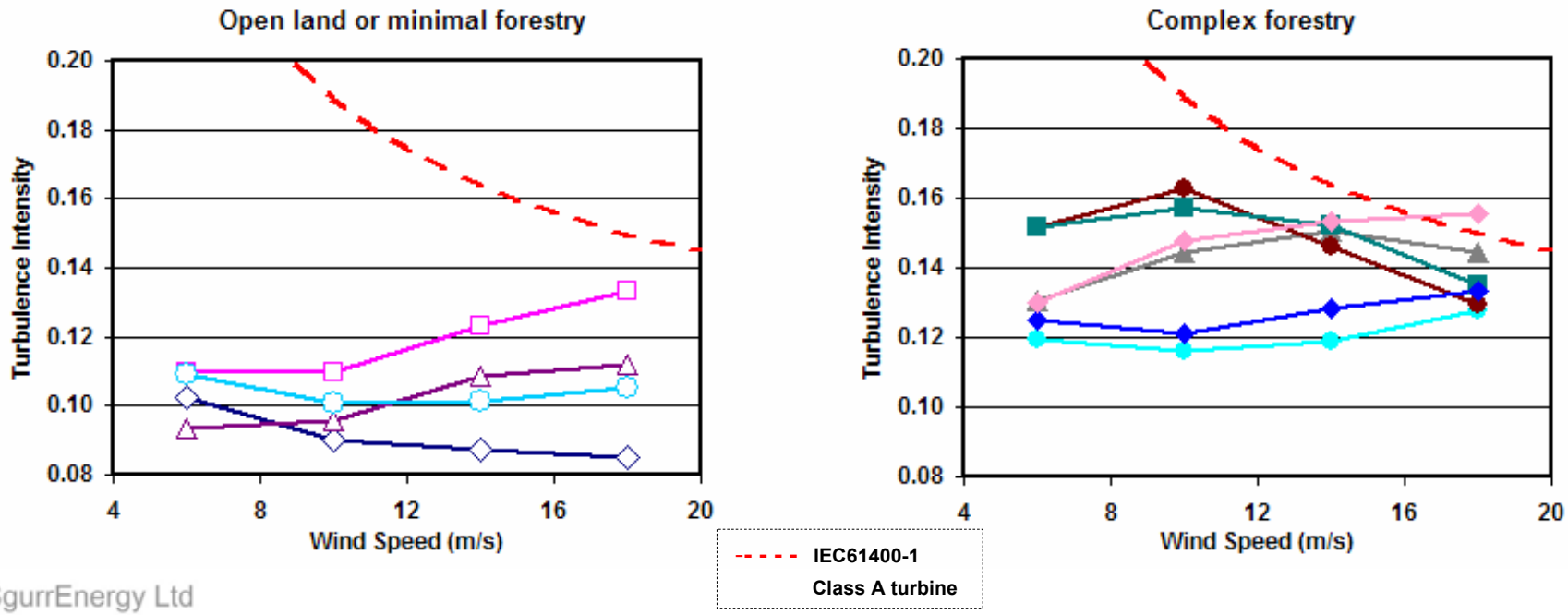
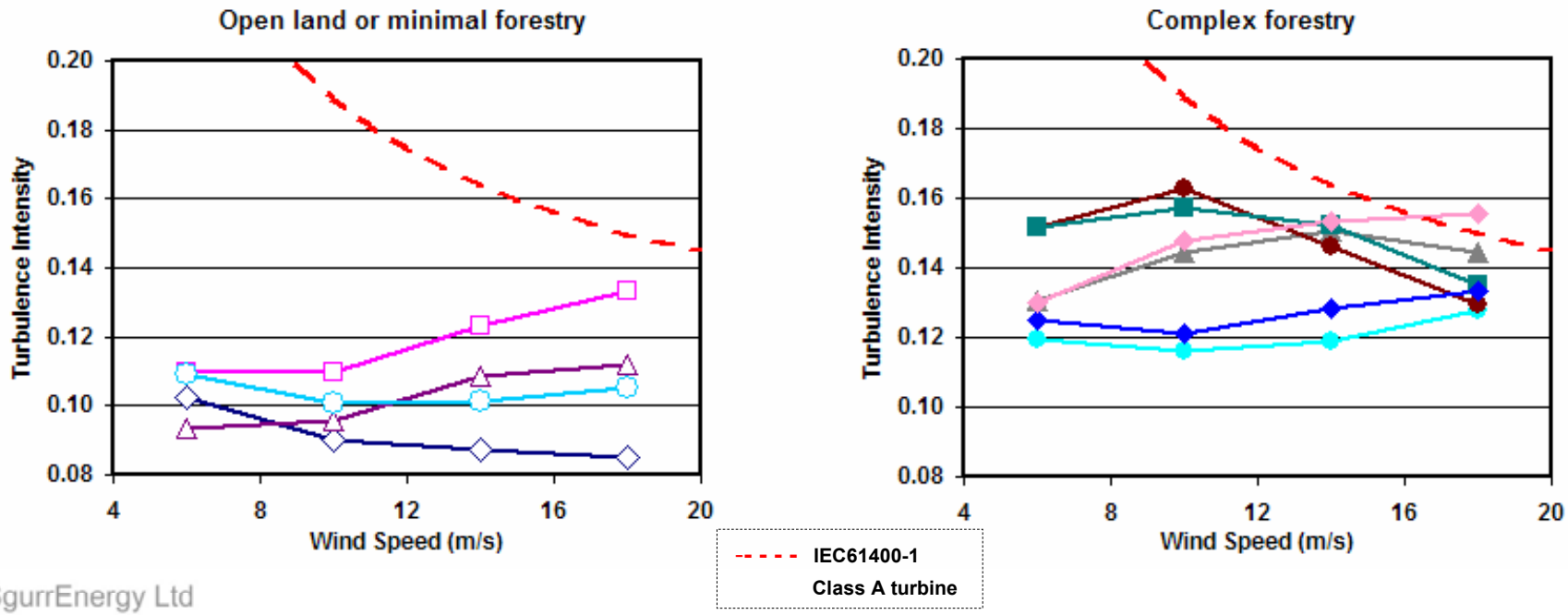


Turbulence Intensity

Turbulence intensity increases with forestry

No clear trend with wind speed



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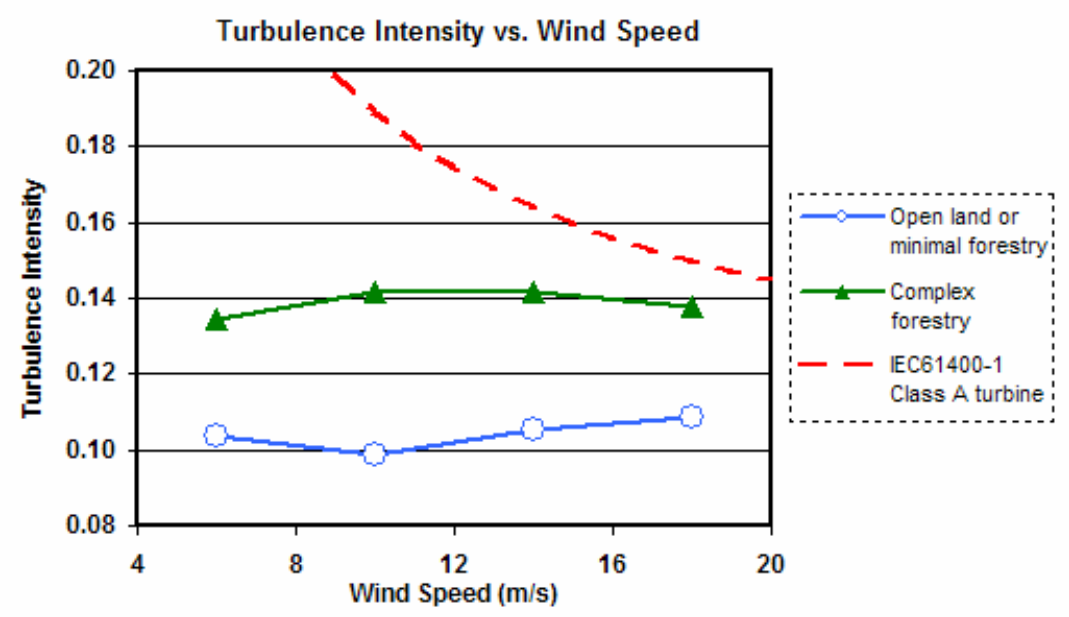
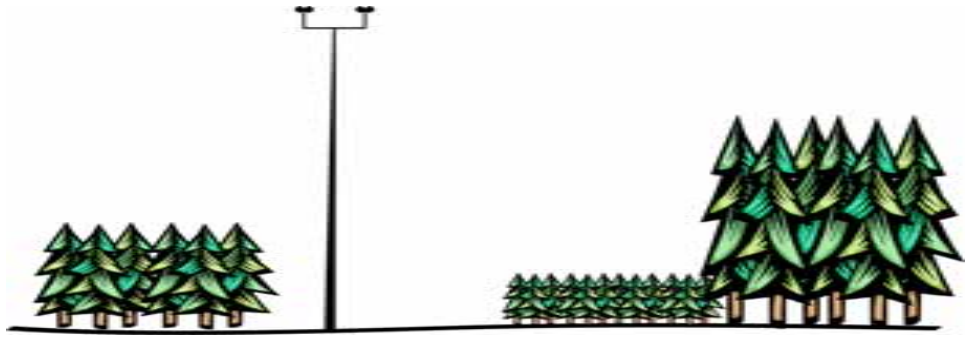


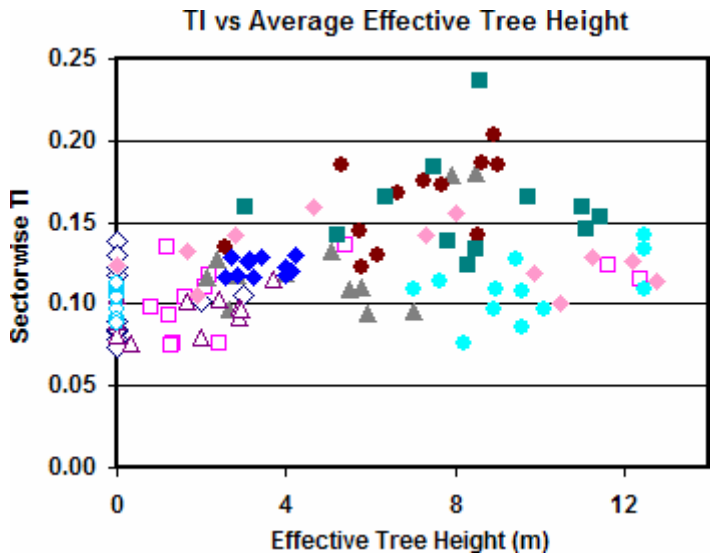
Turbulence intensity and tree height

- Forestry varies for different directions from mast
- Sector wise analysis of tree height and turbulence intensity
- Distance weighting applied:
  - Two weighting schemes tried
- Determine effective tree height from mast:
  - Maximum eff. tree height
  - Average eff. tree height



Turbulence intensity and tree height

- Non-parametric statistical tests: Correlation probability > 99.9%
- Significant scatter → consider other factors (e.g. topography).



Different coloured symbols are different masts

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- Correlation insensitive to distance weighting applied.
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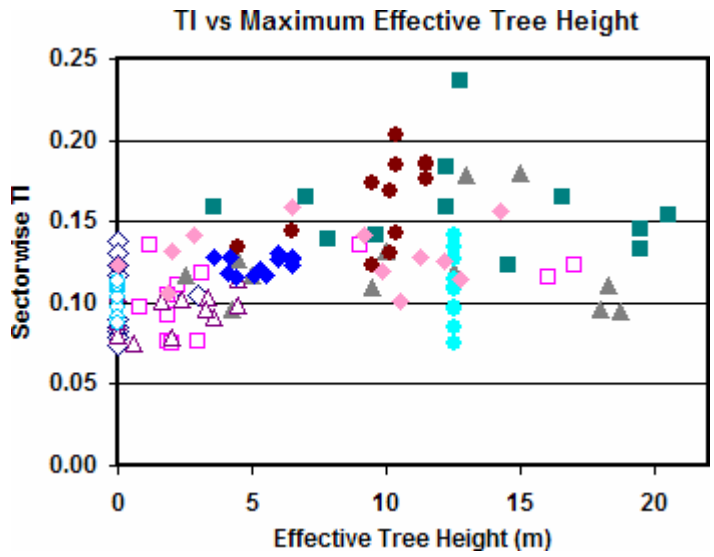

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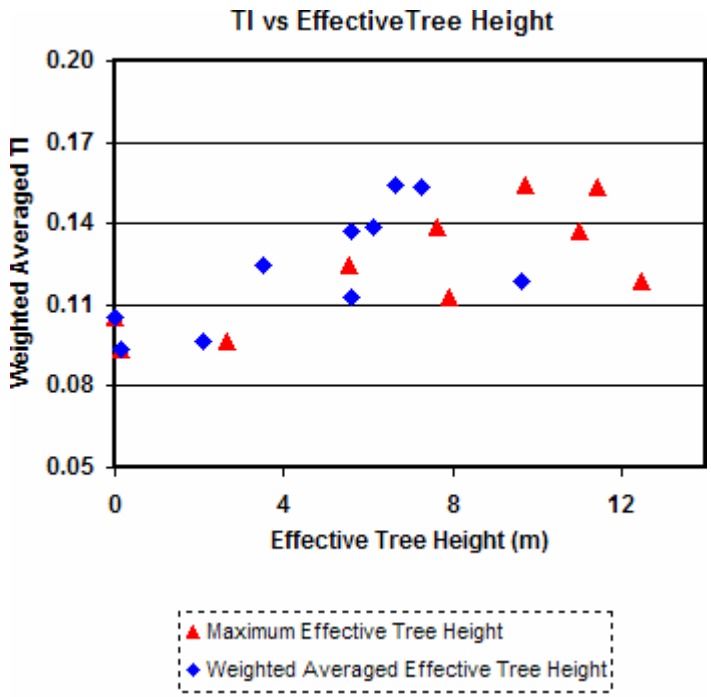
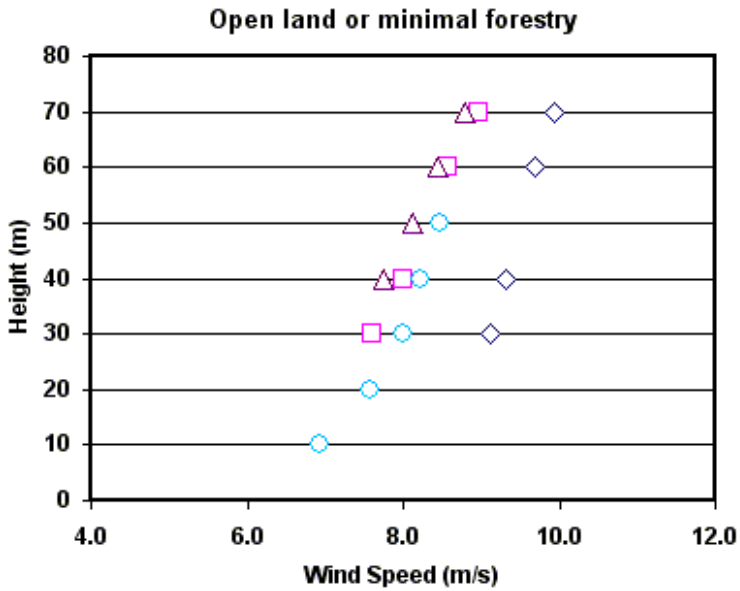
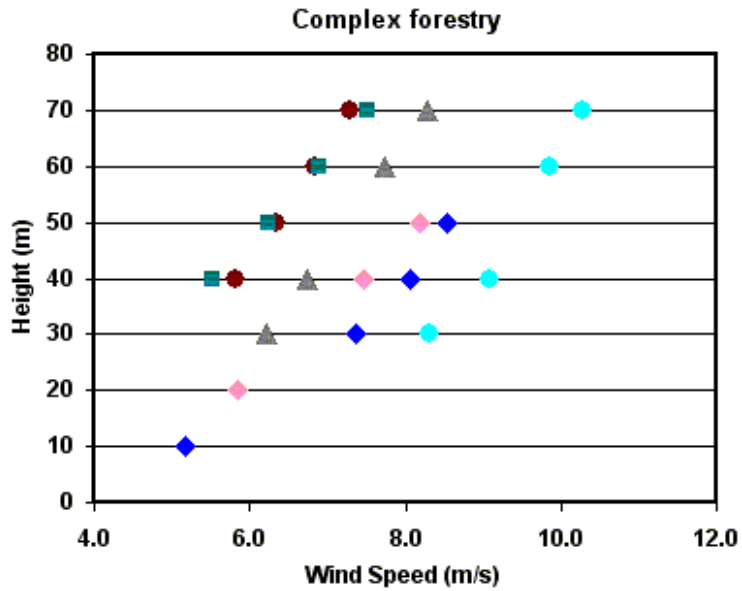


Wind flow modelling

- Using SgurrEnergy forestry maps and WAsP software.





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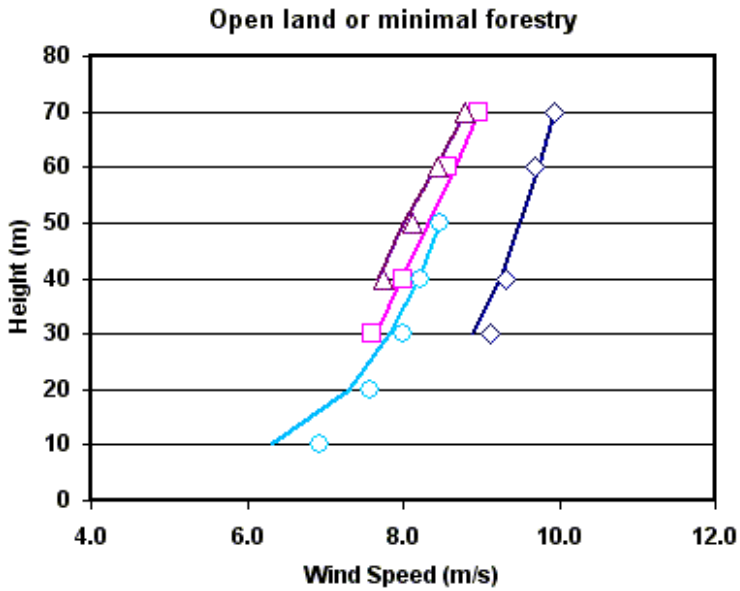
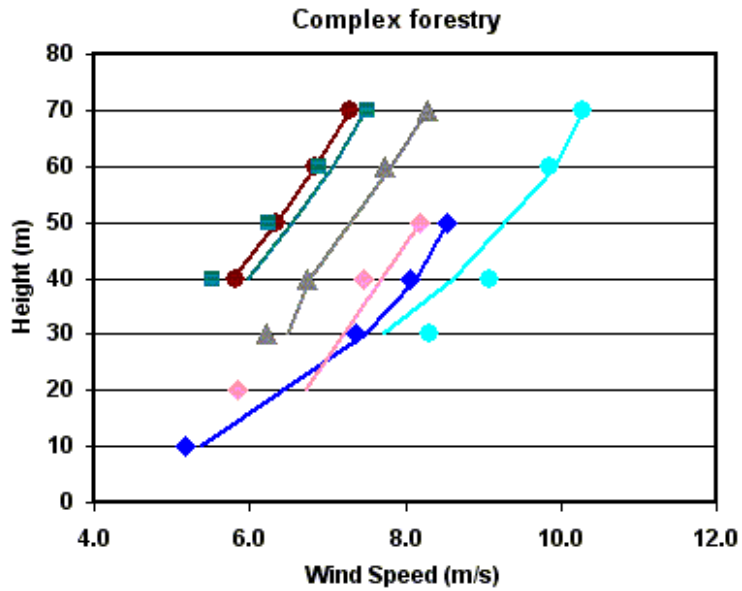
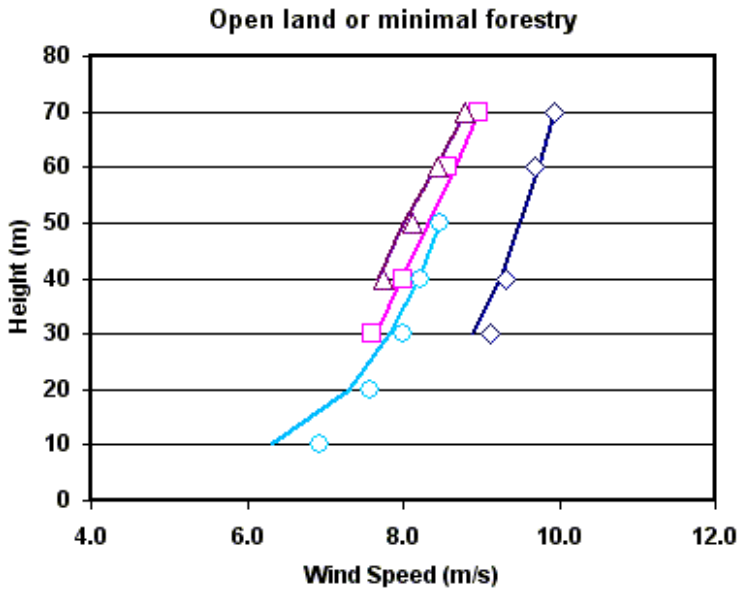


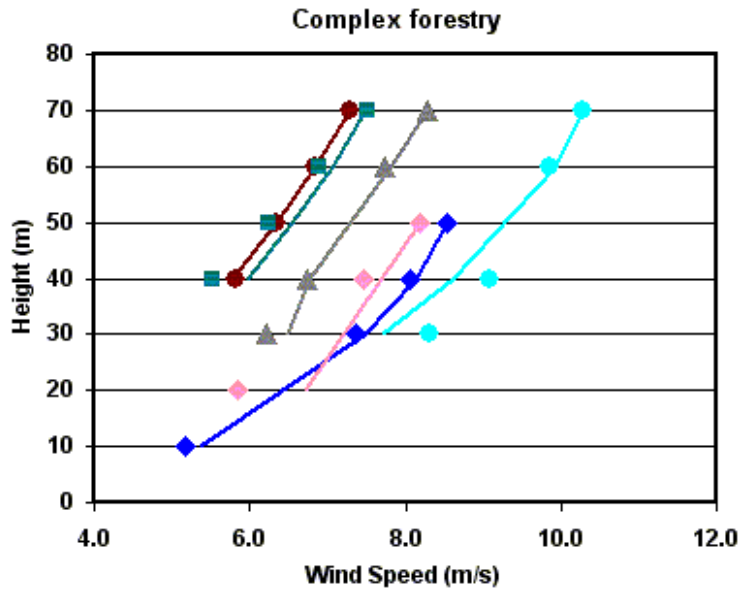


Wind flow modelling

At mast height → all wind speeds agree within 0.1%.

For h ≥ 40m → 75% of wind speeds agree within 1%.





Conclusions

- ***For our dataset***, on average:
  - Forestry reduces wind speed up to 25% at 20m a.g.l. but just 2% at 80m.
  - Forestry therefore increases wind shear.
  - Forestry increases turbulence intensity by 33%.
- Clear correlation between tree height and TI.
- SgurrEnergy modelled wind speeds agree well with data.
- Ongoing work: – TI variation with height a.g.l.;
  – include topographic effects.