Carbon Exchange over Five Years for a 90-year old Managed Deciduous Forest near Long Point, Ontario

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Introduction

- The Carolinian forest biome is characterized by the presence of mixed broadleaf species and is home to a variety of species not found anywhere else in Canada[1]
- Much of the region was converted to agricultural land, effectively removing ~95% of above-ground carbon. Many of these agricultural lands have been abandoned, with forests containing trees younger than a century[2]
- These forests average 2 – 20 times higher productivities than desert, grassland, or shrubland vegetation[3]
- Deciduous forests are characterized by phenological stages (leaf emergence/senescence), varying the timing and duration between forest/atmosphere exchange[4]
- Additionally, interannual climate variability may enhance or reduce water and carbon dioxide exchange[5]
- This study aims to undertake long-term atmospheric monitoring to better understand how Carolinian forests in Southern Ontario respond to variable climate events in terms of its carbon cycling.

Turkey Point Flux Station

- CA-TPD is a 90+ year old deciduous (Carolinian Species) forest, the only non-conifer forest of the four TPFS sites
- Predominantly hardwood species (*Quercus alba, Acer saccharum, Acer rubrum*) with a few scattered conifers (*Pinus Strobes, Pinus resinosa*)
- Unique geographical location between the boreal and broadleaf deciduous forest transition zone. The site is located 5 km SW of Walsingham, Ontario.

Figure 1. a) Location of TPFS sites and b) view of TPD tower from the ground

Table 1: TPD Site Characteristics and Delhi, ON Climate Data

Location	42 38.12 N 80 33.45 W
Average DBH (cm)	22.29 ± 14.02 cm
Average Tree Height (m)	25.7 ± 4.77 m
Stem Density (stems/ha $^{-1}$)	504 ± 18
Mean Tree Basal Area (m^2)	0.0578 ± 0.013

Delhi weather station Climate Normals (1981-2010)	
Average Temperature	8.0 ° C
Rainfall	906.4 mm
Snowfall	129.5 mm
Precipitation	1035.8 mm
Average Frost-Free Period	145 Days

Methods

- Tower-based Closed Path Eddy Covariance (CPEC) system continuously measures half-hourly energy, CO_2, and H_2O fluxes between the forest and atmosphere
- Eddy Covariance (EC) setup comprised of LI-7200 infrared gas analyzer and CSAT3 3D sonic anemometer
- Additional instruments record site-specific meteorology

Figure 2. View from TPD flux tower of the EC instrumentation. An inlet by the CSAT3 (middle) transports gases to the closed path LI-7200 IRGA

- Net Ecosystem Productivity (i.e. net ecosystem CO_2 exchange (-NEE) was calculated by adding the CO_2 flux (Fc) and CO_2 storage from the air column below the EC sensors (i.e. storage flux) measured at 16 m and 36 m.

$$NEP = GEP - RE$$

Net Ecosystem Productivity = Photosynthesis - Respiration

- NEP > 0 ecosystem gains CO_2 from atmosphere (sink)
- NEP < 0 ecosystem loses CO_2 to atmosphere (source)

Results

- High spring temperatures and summer VPD in 2012
- Late season warming, low precipitation in 2016
- 2012 and 2016 highest GDD, 1817 and 1699 respectively

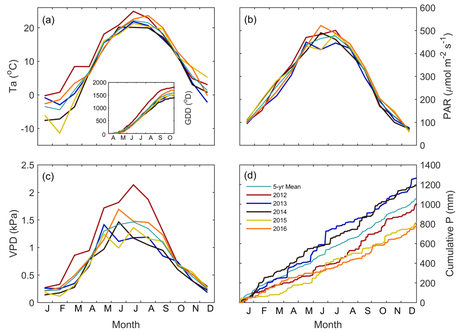


Figure 3. Monthly mean (a) air temperature, Ta and growing season (April – October) degree days, GDD shown in inset (b) photosynthetically active radiation, PAR (c) vapour pressure deficit, VPD and (d) cumulative daily precipitation

- Highest NEP in 2014, high P, high PAR, low VPD
- Drought during 2012, but length of growing season may have been a more important factor determining NEP. High VPD (1-1.5 kPa) for max growing season NEP.
- Late growing season, largely negative start to the year, and late-summer drought caused lower NEP in 2016
- Three years with lowest cumulative NEP (2013, 2015 and 2016) illustrate importance of mid-summer conditions. All values decrease following June –August.

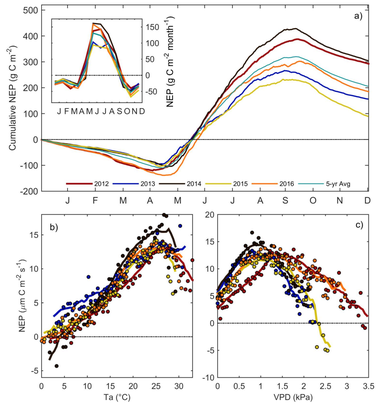


Figure 4. a) Cumulative NEP with monthly totals shown in inset (b) daytime growing season NEP and binned Ta (bin size of 0.5°C) and (c) vapour pressure deficit (bin size of 0.05 kPa). Solid lines shown in bottom plots are moving averages for each year

Results (Continued)

https://phenocam.sr.unh.edu/webcam/

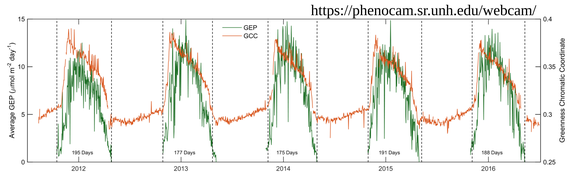
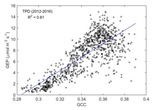


Figure 5. Top: Daily average Gross Ecosystem Productivity (green) and Greenness Chromatic Coordinate (orange) derived from PhenoCam mounted on flux tower. Right: Correlation between GCC and GEP



- Peak GCC occurs soon after leaf emergence, decreasing throughout the summer, lining-up well with GEP
- Appears wetter years, less stressed, don't follow trend
- 61% correlation between GEP and GCC (R^2 ~0.61)

Conclusions

- 5-year mean annual NEP was 205 ± 92 g C m^{-2} $year^{-1}$
- Comparable annual NEP to other eastern North American deciduous forests (167 – 220 g C m^{-2} $year^{-1}$)[1]
- Summer temperatures of 20 – 25 °C and VPD >1 kPa were optimal conditions for maximum NEP
- While GEP start and end matched up with growing season length, the GCC during some years appeared to lag, likely due to interannual climatic variability
  - Air temperature, photoperiod etc.

References

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