

Main objective : Compare two growing seasons on a winter wheat crop to identify impact of climatic conditions on:

- Carbon flows
- Plant growth
- Productivity

MANAGEMENT AND CULTIVARS

2005 vs 2007

Previous crop	Sugar beet crop	Potato crop
Nitrogen fertilization	201.5 kg N ha ⁻¹ 4 fractions	194.5 kg N ha ⁻¹ 3 fractions
Cultivar	Dekan	Rosario
Date of sowing	October 14 th	October 13 th
Date of harvest	August 2 nd	August 5 th

For 2005 and 2007, the managements were similar and classic for winter wheat crop.

CLIMATIC CONDITIONS

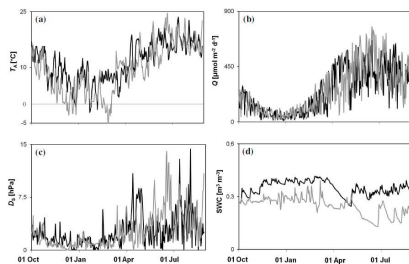


Figure 1 : Seasonal evolution of climatic variables from October 1st to August 31st for 2004-2005 (grey line) and 2006-2007 (dark line): (a) air temperature (Ta); (b) photosynthetic photon flux density (PPFD); (c) air saturation deficit (Ds); (d) soil water content at 5 cm (SWC)

Climatic conditions (between September 1st and August 31st)

Air temperature

Standard → 9.4°C

2004 - 2005 → 9.9 °C

2006 - 2007 → 11.9 °C

Cumulated rainfalls

Standard → 772.0 mm

2004-2005 → 595.1 mm

2006-2007 → 675.1 mm

Particularities in 2005

- In winter, 24 days with average temperature below 0°C (59 days with minimal temperature below 0°C).
- Drought in May-June 2005.

Particularities in 2007

- Milder winter with only 6 days with average temperature below 0°C.
- Drought in April 2007.
- Rainy and cloudy June 2007.

IMPACT ON CARBON FLOWS

Assimilation at leaf scale

An influence of vapour pressure deficit (VPD, [kPa]) on leaf gross assimilation under saturated light (G_s , [$\mu\text{mol m}^{-2} \text{s}^{-1}$]) was identified in 2005 (Hoyaux *et al.*, 2008) and confirmed by 2007 data (Figure 2).

The leaf G_s values varied between 10.05 and 26.39 $\mu\text{mol m}^{-2} \text{s}^{-1}$. In 2007, the leaf quantum yield (α) varied from 0.020 to 0.067 $\mu\text{mol CO}_2$ $\mu\text{mol photons}^{-1}$ with an average of 0.041 ± 0.005 $\mu\text{mol CO}_2$ $\mu\text{mol photons}^{-1}$. During the first season, Hoyaux *et al.* (2008) found a value of 0.046 ± 0.004 .

Leaf photosynthetic capacities are similar on the two years.

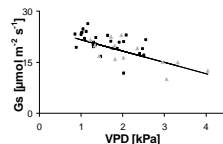


Figure 2 : Influence of vapour pressure deficit (VPD) on leaf gross assimilation (G_s). Dark solid squares 2007 data, Grey solid triangles: 2005 data

Net Ecosystem Exchange

The comparison of carbon fluxes between two growing seasons shows (Figure 3) :

A greater carbon exchange during winter 2006-2007 caused by an important development of vegetation. Lower carbon fluxes in May and June 2007.

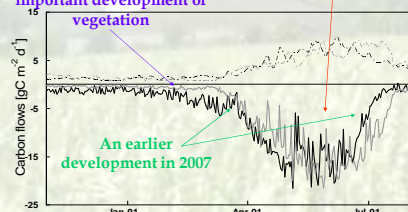


Figure 3 : Comparison of carbon fluxes for 2004-2005 (Grey line) and 2006-2007 (Dark line)

Carbon budget

Table 1: Carbon budget on two years (Units :kg C m⁻²)

	2004-2005	2006-2007
NEE	-0.63 (0.03)	-0.73 (0.04)
GPP	-1.58 (0.13)	-1.68 (0.12)
TER	0.95 (0.13)	0.95 (0.12)
NPP	-0.88 (0.05)	-0.76 (0.05)

More carbon assimilated in 2007 but less sequestered carbon!
Where did carbon go?



IMPACT ON PLANT GROWTH

Growth stage (Zadoks scale)

- In 2005 : the development corresponded to standard for silty areas in Belgium (Table 2)
- In 2007 : the development was earlier due to milder winter (Figure 1). The high air temperature had induced tillering stage in January 2007.
- In 2007 : Earlier flag leaf apparition.

Table 2: Date of growth stages for 2004-2005 and 2006-2007 growing seasons compared with the standard for silty areas in Belgium (Gembloux, 1990)

Zadoks scale	Growth stage	2004-2005	2006-2007	Standard for silty areas in Belgium (Gembloux, 1990)
0	Sowing - Germination	October 14 th	October 13 th	/
10	Seedling growth	End October	October 22 nd	/
20	Tillering	Early March	Early January	End winter - Early March
30	Stem elongation	Mid-April	Early April	April 5 th - 10 th
40	Booting (Flag Leaf)	May 20 th	May 3 rd	May 20 th - 25 th
50	Inflorescence emergence (Ear)	June 1 st	May 22 nd	Early June
60	Anthesis	June 14 th	Early June	/
70	Milk development	End of June	June 19 th	/
80	Dough development	Mid-July	End June	/
90	Ripening	End July	/	/

Growth - Development

Milder Winter

- Greater development during winter 2006-2007 :

→ This one was observed by LAI, dry matter (Figure 4), height

- Advance about 10-15 days for second season since April

Drought period in April 2007

This period took place when the winter wheat was in the stem elongation stage. As a result :

- The flag leaf (F1) was smaller (results not shown)
In 2007 : $0.69 \pm 0.08 \text{ m}^2 \text{ m}^{-2}$ (on May 18th-20th 2007)
In 2005 : $1.23 \text{ m}^2 \text{ m}^{-2}$ (on June 7th 2005)
- The ratio ear/tiller was very lower

Bad climatic conditions at the end of crops in 2007

Wheat leaves were contaminated by fungal diseases and induced a decrease of above-ground biomass (Figure 4).

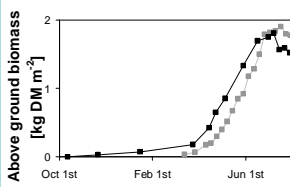


Figure 4 : Seasonal evolution of the above ground dry matter during first (Grey square) and second (Dark square) growing season

Root system

In 2007, at the end of tillering stage, the cumulated Net Ecosystem Exchange (NEE) was equal to estimated Net Primary Productivity (NPP) values. This suggests a zero heterotrophic respiration which is impossible. This could be due to a root biomass under-estimation. Root biomass could be more important than usual due to a longer tillering period.

The great part of assimilated carbon during tillering was transferred to soil and to root system.

IMPACT ON PRODUCTIVITY

Despite that the cultivar "Rosario" used in 2007 has theoretically a better productivity than the cultivar "Dekan" in Belgium (Vancutsem *et al.*, 2007), the yield in grains was lower in 2007 than in 2005 on our site. Three explanations :

- The area of flag leaf was abnormally small (caused by drought conditions in April). This leaf is known to contribute for 30-50 % to grain filling.
- During filling grain stage, in June 2007, the climatic conditions were cloudy and rainy (Figure 1) inducing low assimilation.
- These conditions induced diseases which caused necrosis and reduced the photosynthetic areas despite fungicide treatments applied by the farmer. Meteorological conditions were lesser auspicious to diseases in 2005.

Table 3: Yields and productivity for two growing seasons

	2004-2005	2006-2007
Yield - Grains (DM)	89.4 qx ha ⁻¹	75.0 qx ha ⁻¹
Yield - Straw (DM)	4.20 t ha ⁻¹	3.38 t ha ⁻¹
Grain density	75.5 kg hl ⁻¹	69.9 kg hl ⁻¹
Ear density	440	469

This could also result from a worse carbon translocation to grain in 2007.

CONCLUSION : This study allowed evaluating the impact of milder winter, drought period during stem elongation, and bad climatic conditions during filling grain stage on carbon balance, on crop development, roots system and eventually on yields.

It shows that GPP is not a good predictor of productivity

Where did carbon go?

Gembloux. (1990). Le froment d'hiver. Conduite de sa culture. Les Presses Agronomiques de Gembloux. 212p
Hoyaux J., Moureaux C., Tournier D., Bodson B., Aubinet M. (2008). Extrapolating the gross primary productivity from leaf to canopy scale in a winter wheat crop. *Agricultural and Forest Meteorology*, 148 : 668-679
Vancutsem F., Couvreur L., Bodson B., Herman J.L., Sinnave G., Van Remoortel V., Deroanne C., Frankinet M., Falisse A. (2007) Variétés issues du Livre blanc - Céréales - Édition septembre 2007 - FSAGx et CRA-W - Gembloux 15-46