# Validation of carbon atmospheric fluxes with remote detection system

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## 1. INTRODUCTION

Carbon cycle is one of the keys of Earth ecosystem work apart from being hardly connected to climate system, water cycle and any other nutrient cycle. Its knowing supposes to improve notably our forecasts on the evolution of the terrestrial ecossystems in future climatic stages, what constitutes one of the main challenges that we face up in the actuality

For this were born the European project of investigation CarboEurope-IP, that has the aim to improve the knowledge and quantify the balance of carbon in Europe. CarboEurope-IP will supply to the European Community a system of observation that will allow to detect regional changes in the reservations and flows of biosferic carbon. In addition to this, CarboEurope-IP will set the scientific bases for a precise system of monitorization of the reservations and flows of carbon in all the European states. It is based in a net of 28 European stations, that gathers 160 centres of investigation belonging to 20 countries, for the measurement "*in situ*" of the level of carbon and of the flows of energy in the forests.

Sensor MODIS (Moderate Resolution Imaging Spectroradiometer) is an instrument installed on two NASA satellites, *Terra* and *Aqua*. Both cover the surface of the Earth each 1-2 days, purchasing data in 36 spectral bands. These data help us to comprise global dynamics of the Earth; behaviour in terrestrial surface, in oceans and in atmosphere aswell. MODIS is exerting a vital paper in the development of validated and global models wich are able to predict global changes that we are suffering and to take responsible decisions referents to enviroment protection.

OBJECTIVE

Main aim of this work is to compare data of gross primary production (GPP) of an eucalipte plantation in Portugal, calculated by the micrometeorological method of the eddy covariance with data provided by an instrument incorporated in 2 satellites of NASA called MODIS.

Will be also compared GPP and Leaf Area Index (LAI) in addition to GPP against meteorological data, on purpose solar radiation and precipitation. Another objectives is treatment of the first half of 2009 data by eddy covariance method to obtain net ecosystem exchange (NEE), GPP and ecosystem respiration ($R_{eco}$) of the site in this period.

# 2. STUDY AREA AND DATA

This work wil be settled in one of the Carboeurope stations wich is located in Herdade da Espirra (38º 32' N, 8º 00' W), in Pegões, next to Setúbal This site is a 300ha *Eucalyptus globulus* plantation , trees spacing 3x3m, established in 1986 with a mediterranic climate. Plantation was submitted in November 2006 to a tree felling due to the age of the trees that were reached their age of cut. In the middle of this plantation we can find a metallic tower with 33 metres height where carbon fluxes and meteorological data measurements are made by eddy covariance method. It drives to preciser results and that is the reason why this method is chosen by the scientific community that integrates the CarboEurope-IP. The measurement equipment İs integrated by: one "data logger" CR10 by Campbel Scientific for the acquisition of meteorological data that creates a file each half hour, with the half values for the period of time of each variable (for precipitation we only take the values corresponded to integrals over the same length period) and an ultra-sonic anemometer *Gill R2* and an open path $CO_2/H_2O$ analyzer *IRGA Li-7500.*

It was taken measurements of some meteorological and soil variables like solar radiation, precipitation and so many others but only this two were interest in this work. Aplication of eddy covariance method allows the obtention of three atmosferic components of carbon cycle in forest: NEE, GPP and Reco expressed in gC/m2. MODIS data provided was LAI, GPP and NPP wich is close to NEE. LAI and GPP are displayed each 8 days and NEE yearly, therefore this last is not very relevant for our study.

MODIS shows Espirra like anet of 49 cells of 1x1 km classified in different vegetation typologies and in the middle of this net it would be the tower.

For the development of the work it was chosen the satellite Earth because the quality of the data was better and also because it would not be interesting do the same study twice and arrive to results almost identical.Therefore, from now on, presented data will be obtained from satellite Earth.

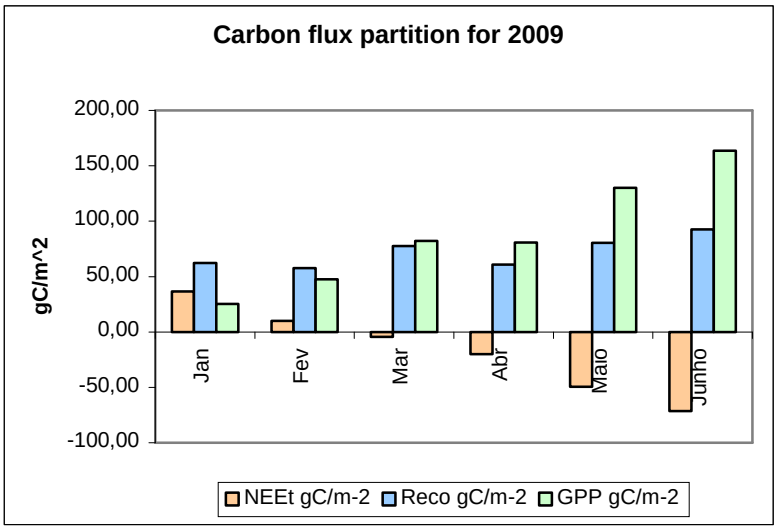
# 3.RESULTS

## 3.1 2009-09-27 DATA

Processing of data with software gave as result this table:

| Mês | Rg | P | NEE | Reco | GPP |
|---|---|---|---|---|---|
| | MJ/m-2 | mm | gC/m-2 | gC/m-2 | gC/m-2 |
| Jan | 235.59 | 90.8 | 36.70 | 62.25 | 25.35 |
| Fev | 348.20 | 86.1 | 10.13 | 57.76 | 47.63 |
| Mar | 554.20 | 13.0 | -4.41 | 77.70 | 82.12 |
| Apr | 577.58 | 31.1 | -20.01 | 60.73 | 80.73 |
| May | 736.34 | 11.6 | -49.53 | 80.55 | 130.08 |
| Jun | 702.86 | 28.1 | -71.28 | 92.45 | 163.74 |

*Table 1. – Meteorological data and carbon fluxes of the first semester of 2009*




*Graphic 1. – Carbon flux partition for January 2009-June 2009*

Pattern of carbon fluxes on first semester of 2009 is similar to it of the previous year. NEE begins being positive but it is going decreasing, it is done negative in the spring and maximum to the beginning of the summer. GPP 2009 also evolves as the one of the 2008. It is minimum in Winter and it grows along the semester to be maximum in the summer due to the increase of the solar radiation.

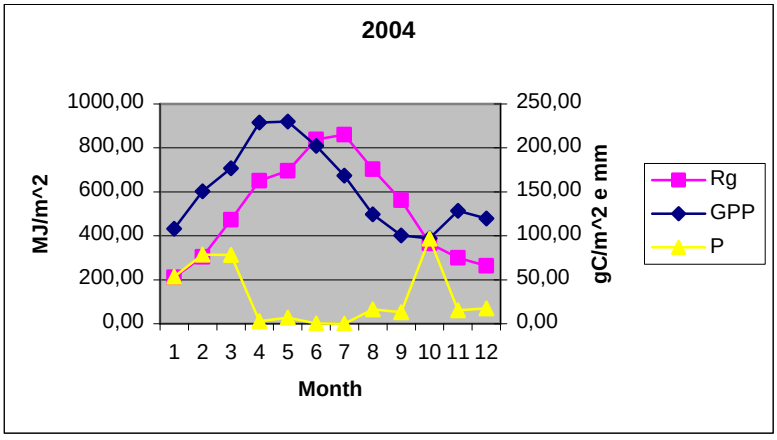
## 3.2. CARBON FLUXES EVOLUTION FOR 2002-2009

### 3.2.1. NEE Evolution

With some help of studies previous with similar subject in the same location (Mateus, J. 2004) it is known that the eucalyptus plantation behaves as strong drain of $CO_2$ during almost the whole year (on certain ocasions at the end of the summer respiration can be higher to the photosynthesis with the resulting liberation of $CO_2$). But that happened when trees were adult 20 meters tall so in 2007, with young trees, tendency is inverted and the system is a carbon emisor. This can be due to heterotrofic respiration (Rh) of soil that is still standing and primary production goes down considerably because trees are smaller. In 2009 NEE begins being positive (gives out $CO_2$) as in the 2 previous years, but on March is already negative (absorbs $CO_2$) and keeps absorbing. We can conclude that 2009 is a transition year between years with the system behaving as a carbon issuer with young individuals and years with the system behaving as sink of carbon with adult trees. Besides, also drought of 2005 affected on the carbon flux because on that summer, when there was a great hydric shortage, the system was emisor of carbon.

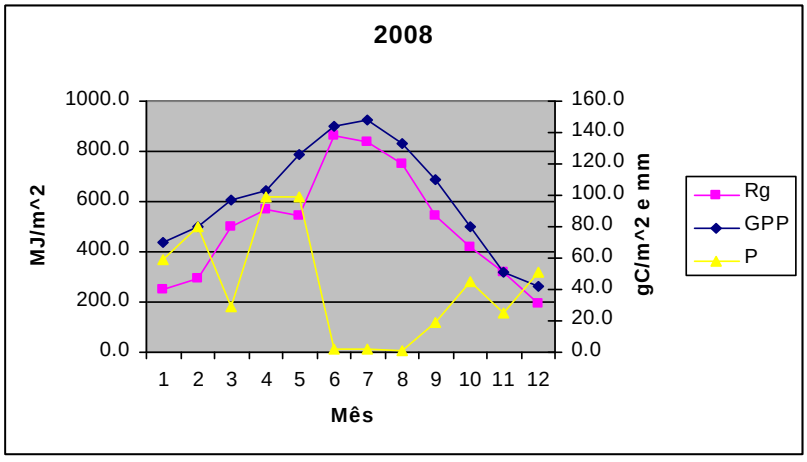
3.2.2. GPP vs Meteorological data

In 2004, year type before cut, GPP increases with solar radiation because there is enough water in soil and trees don't have limitation for growth. But when precipitation downs and radiation is still growing, GPP gets the top and starts to go down because water supplies are runnning out. This descent keeps until precipitation rise again and soil refills with humidity. But the fact of being less solar radiation in autumn, although it was enough water on soil, makes GPP not to reach values as high as at the end of spring.



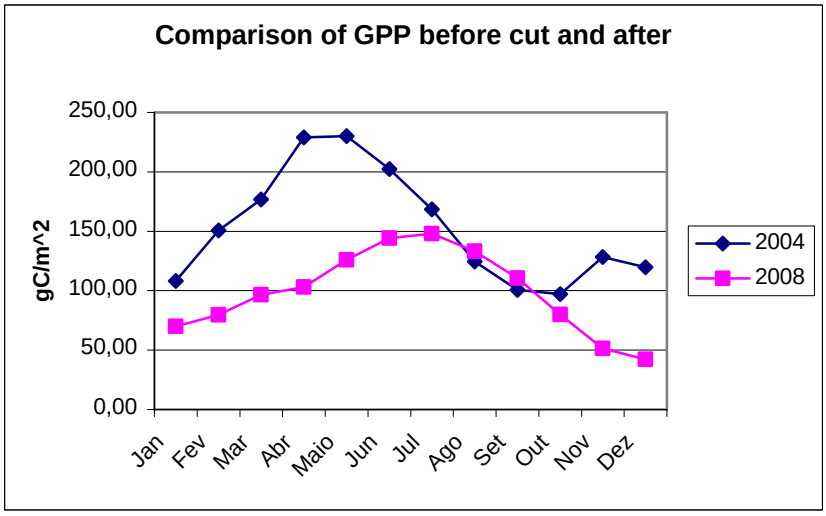

*Graphic 2 – Comparison of GPP against solar radiation and precipitation for 2004*

In 2008 trees were short, among 4-6 meters approximately. We see as the gross primary production increases and goes down consonant the radiation. That is due because in winter and spring there were abundant precipitations and the reservation of water in soil was complete. Summery drought didn´t affect too much to the growth of the plants despite the fact that plants were young with little span and it has not just rain in the summer, because they didn't need a lot of water, and roots were already completely developed, arriving to the deepest layers of the soil.




*Graphic 3 – Comparison of GPP against solar radiation and precipitation for 2008*

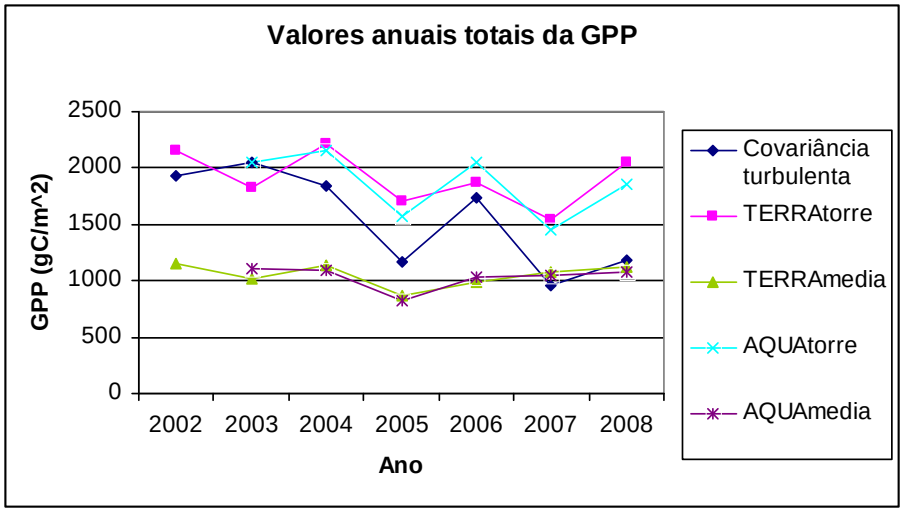
3.2.3. GPP before cut and after




*Graphic 4. - Comparison of GPP before cut and after*

Main difference between GPP befote cut and alter cut is that in 2008 GPP was quite lower due to the less size of trees. In addition to this it is observed a difference in monthly pattern that has to be caused becaue due to this minor size that have the eucaliptes in 2008, they need less water but having some very developed roots that they allow them arrive to the layers mas deep of the soil is them easy absorb all the water that they need in spite of summer drought.

3.3. GPP WITH EDDY COVARIANCE Vs. GPP MODIS




*Graphic 5. –Annual total values of GPP obtained by eddy covariance and MODIS*

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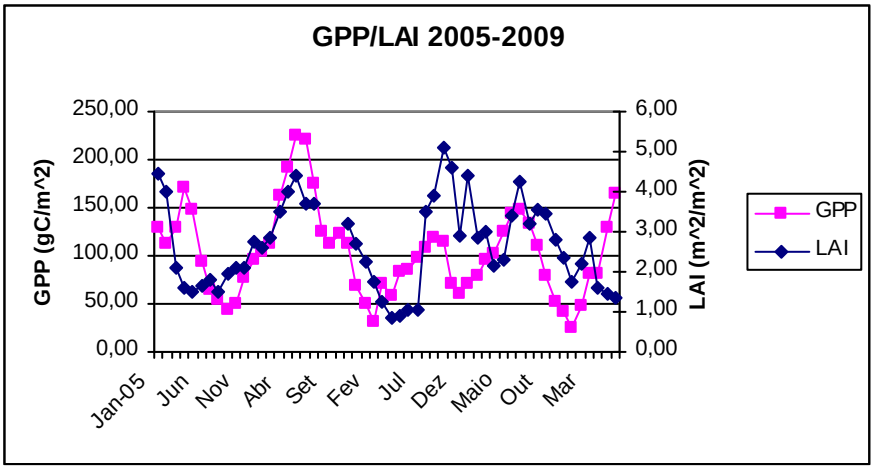
In graph 5 we can see three discrepancies relative to GPP data obtained by direct measurement and remote measurement:

- On first 5 years there is a a reasonable agreement among the measured values of eddy covariance and the measured ones for remote detection in the central cell. That hapens because on those years, when plantation was composed by trees of 20 metres high, the area included by the measures of eddy covariance or "fetch", it was approximately restricted to the surface of 1Km$^2$ corresponding to the central cell.
- In the years after the cut the effect is opposed. In other words without having been altered the location of the measure equipment, fetch will be higher because vegetable covering is lower. In this second case the area corresponding to the average of the surrounding cells of the tower will already be representative of the values of flows of carbon obtained by direct measurement.
- The third discrepancy is settled in the results of 2005, where we can verify that the evaluation of gross primary production for remote detection is quite higher than the measure for eddy covariance. In agreement with authors Coops et al. 2007 the algorithm MODIS algorithm may over-predict GPP at sites where limitation to growth by low-soil water content is not adequately captured by the reduction in stomatal conductance by vapor pressure. In this case in 2005 , precipitation was very scarce, just like the situation described.

In February 2009 the meteorological station bowed to 12 meters, for which data obtained by eddy covariance should begin to be similar to the obtained of the center cell of MODIS where the tower is placed

3.4. GPP vs LAI




This graph shows monthly GPP and LAI and several effects can be observed:

- The effect of drought of 2005: as much LAI as GPP are reduced a lot due to the lack of water.

- In the end of 2006 the shallow cut is verified with the reduction of two parameters. With the vegetation elimination they reduce the square meters of foliate area a lot, and consequently the photosinthetic capacity.
- From Autumn 2007 LAI increases again because young eucalyptus leaves have a density to foliate larger and they have a larger size than adult eucalyptus leaves. Then the index is going lowering gradually as leaves are becoming adults.