SERBIA FOR EXCELL, WORKSHOP, 2018

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UNIVERSITÀ DEGLI STUDI FIRENZE
DISPAA
DIPARTIMENTO DI SCIENZE DELLE PRODUZIONI AGROALIMENTARI E DELL'AMBIENTE

UNIVERSITÄT FÜR BODENKULTUR WIEN
BOKU
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EUROPEAN COMMISSION
Horizon 2020
EUROPEAN UNION FUNDING FOR RESEARCH & INNOVATION

CO2 EXCHANGE DYNAMICS IN AGRICULTURAL ECOSYSTEM: A CASE STUDY OF WHEAT

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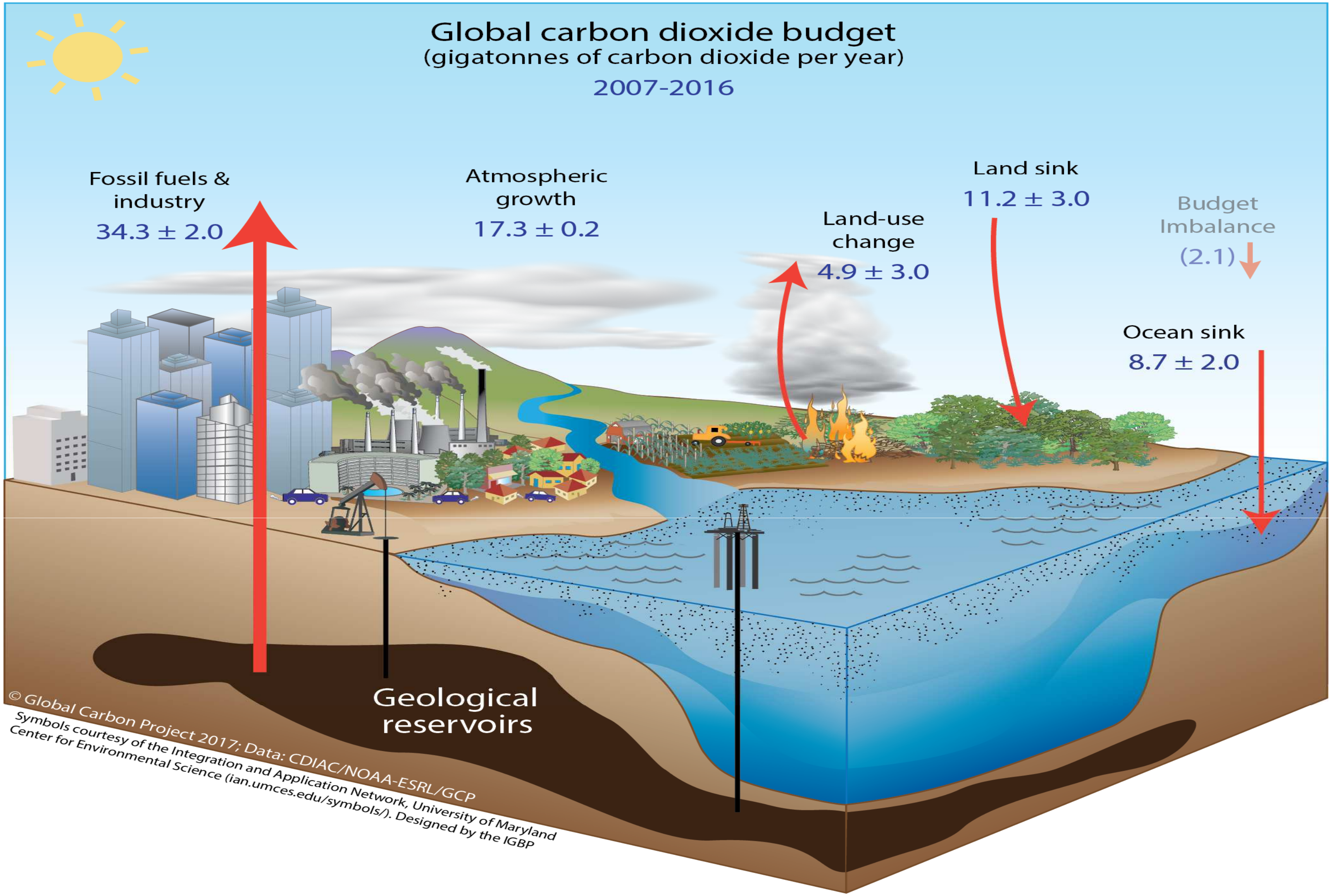
Workshop 2018

CONTENT

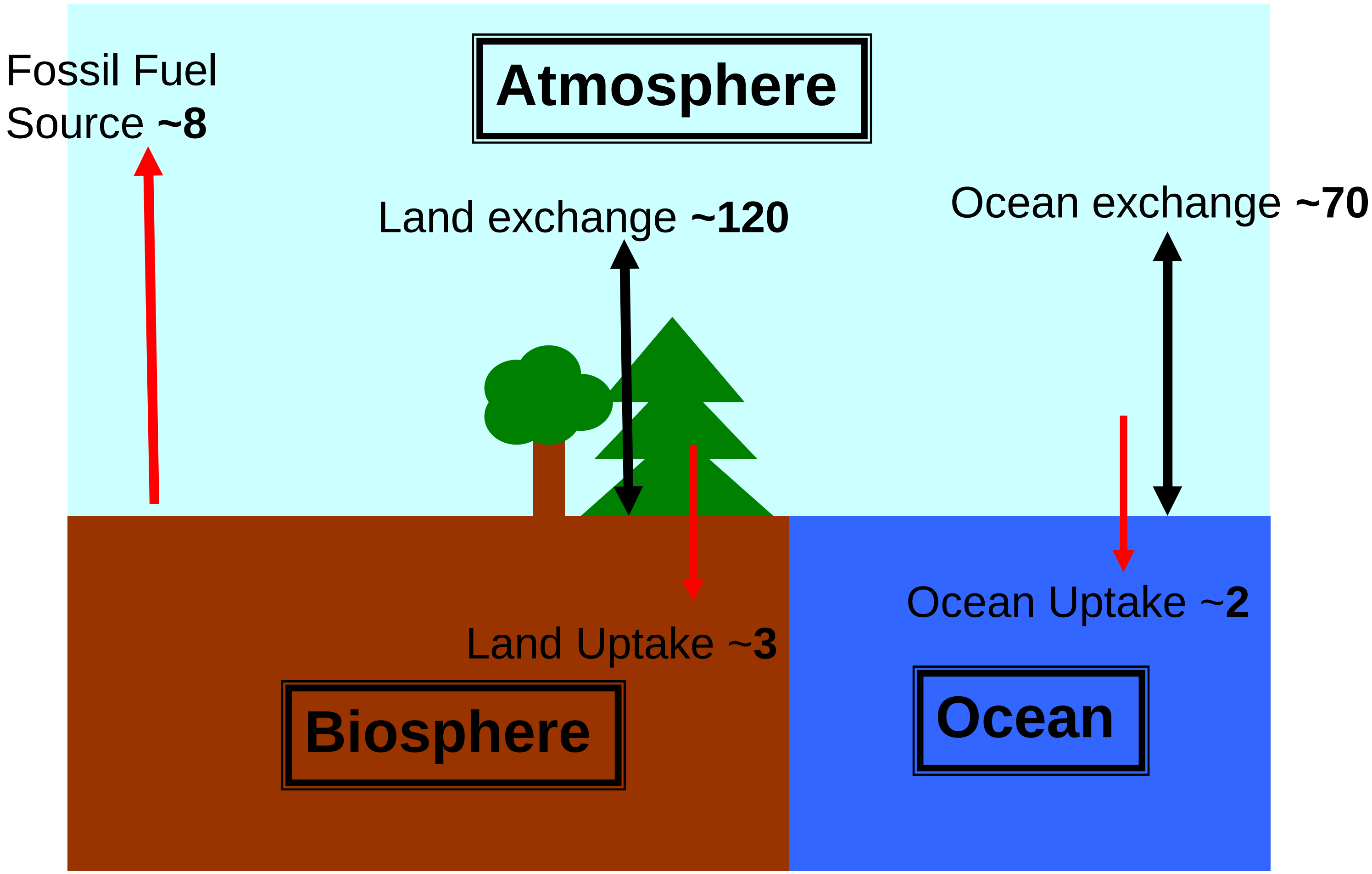
- **Introduction**
- *Eddy Covariance System*
- **Materials and Methods**
- *Experimental Field, Eddy Covariance Measurements*
- **Results and Conclusion**



Source: CDIAC; NOAA-ESRL; Le Quéré et al 2017;
Global Carbon Budget 2017

- 1 Gigatonne (Gt) = 1 billion tonnes = 1×1015g =1 Petagram (Pg)
- 1 kg carbon (C) = 3.664 kg carbon dioxide (CO2)
- 1 GtC = 3.664 billion tonnes CO2 = 3.664 GtCO2

Global Carbon Cycle

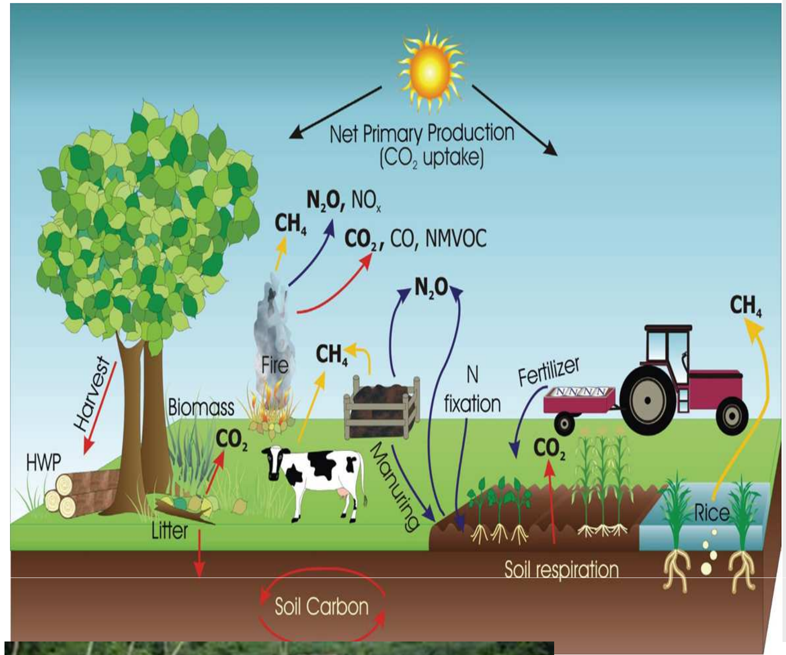


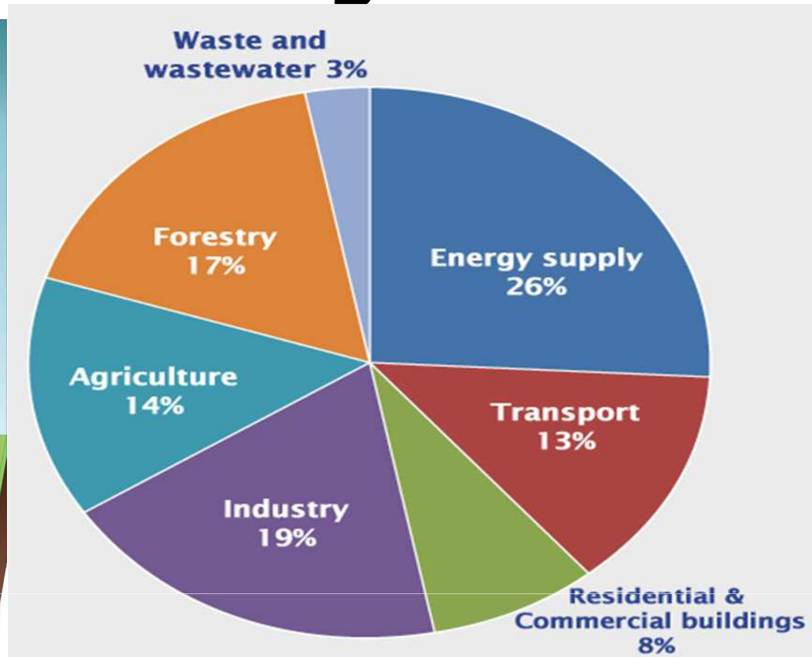
fluxes [GtC yr^{-1}]

Source: https://climate.nasa.gov/.../1_keppelaleks_carboncycle_16oc ... (26/06/2018)

(LeQuere, 2009)

Greenhouse gases





?

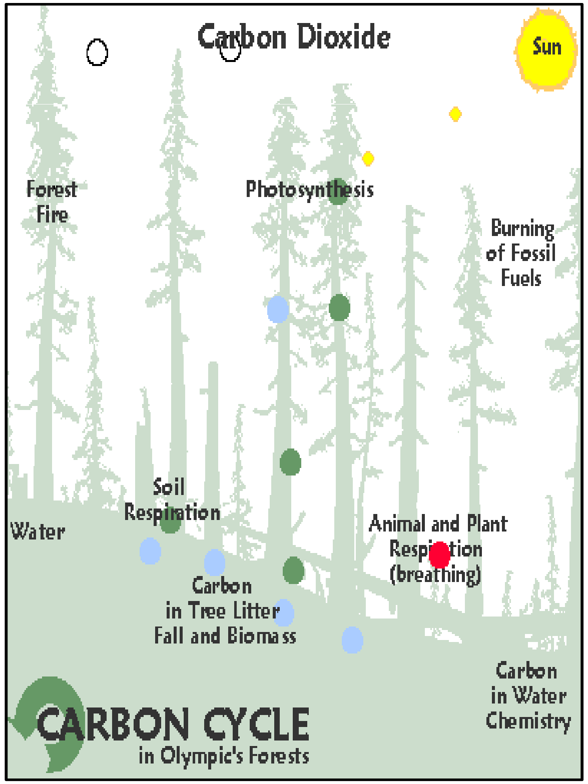
Introduction

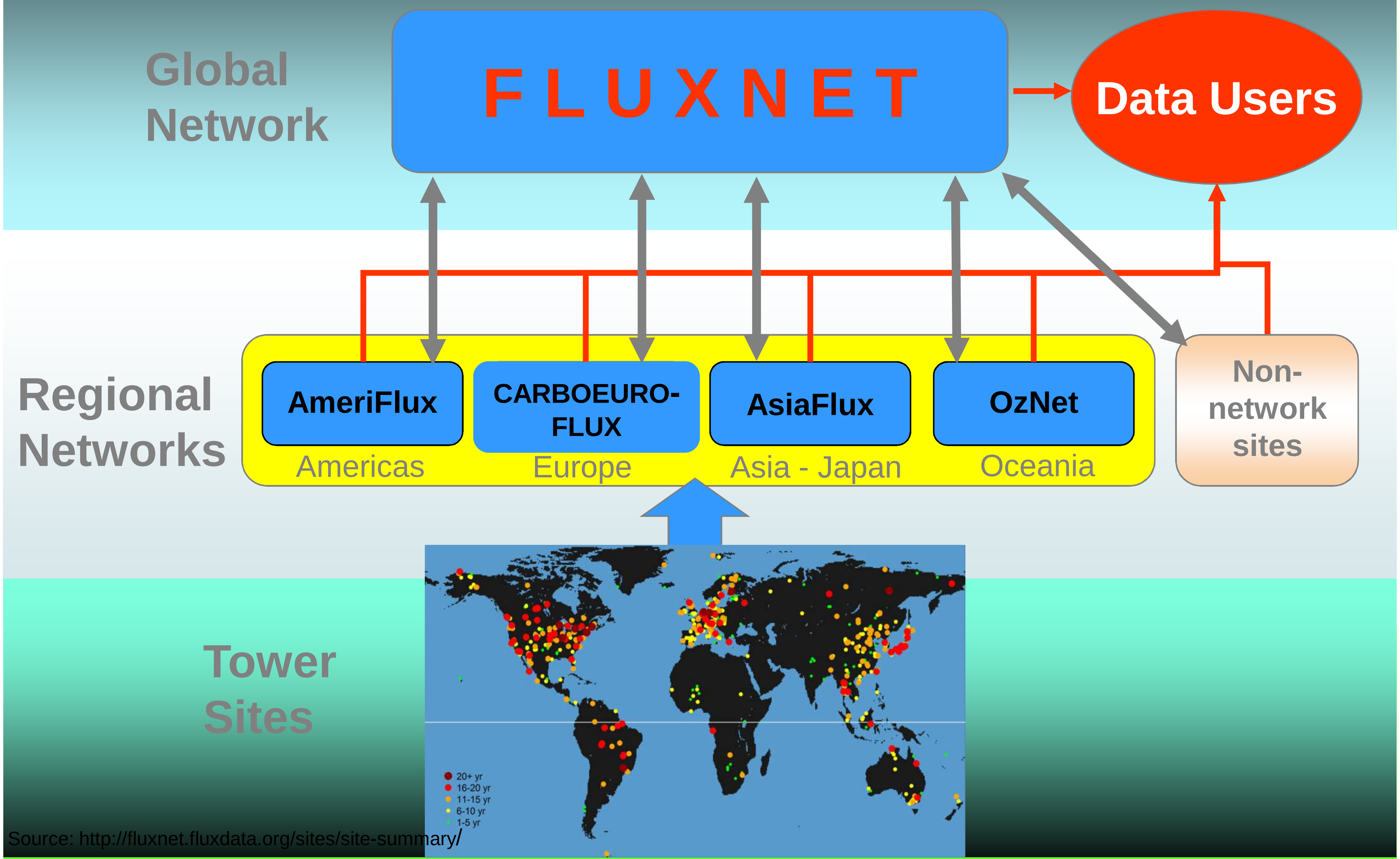
To determine fluxes of these gases field studies are conducted over;

- Forests
- Wetlands
- Grasslands
- Soil surfaces
- Tundras
- Deserts
- Agricultural areas.

INTRODUCTION

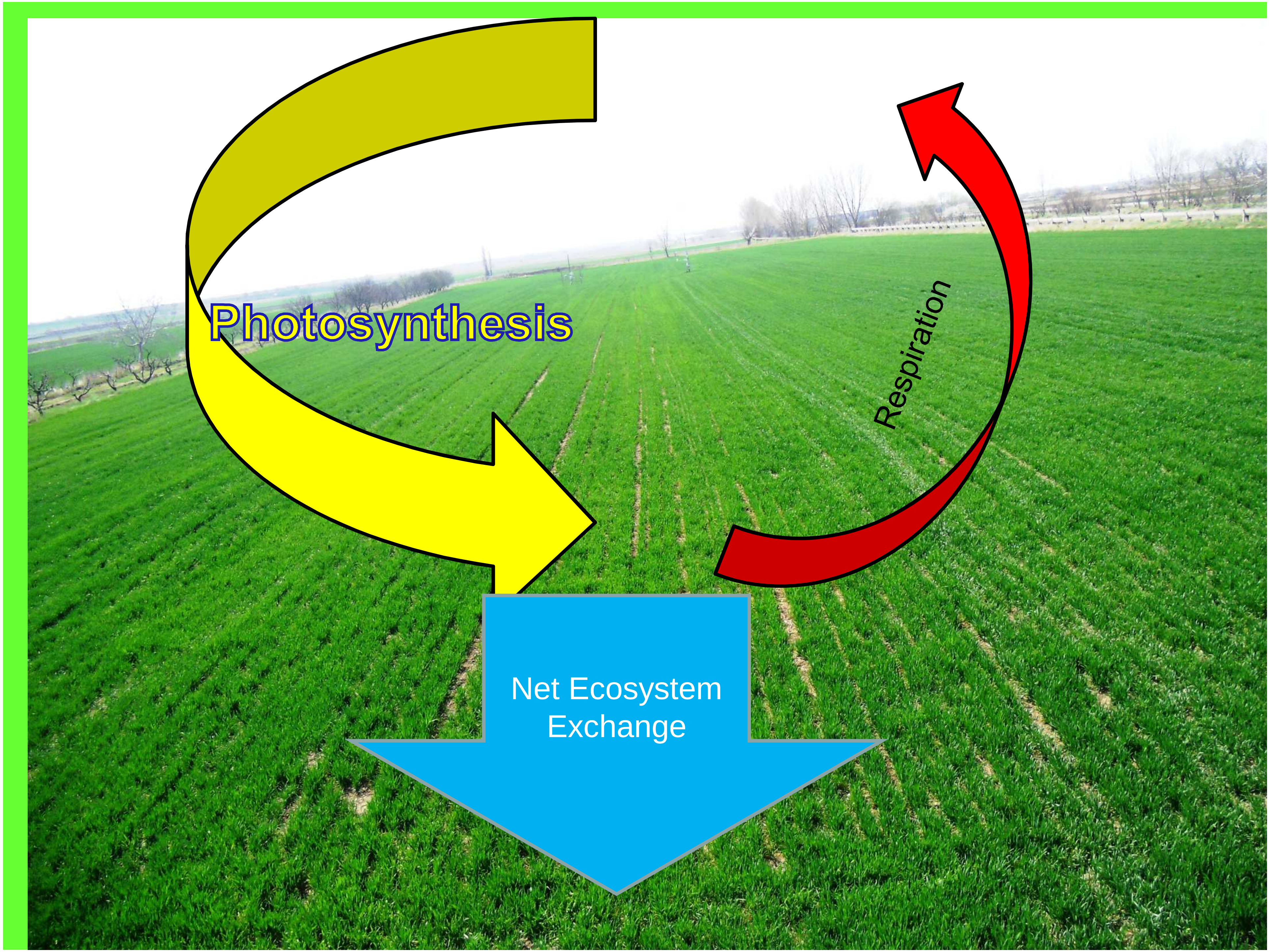
- In these ecosystems, plants both capture and release carbon but mainly have a decreasing effect on atmospheric carbon dioxide concentration.

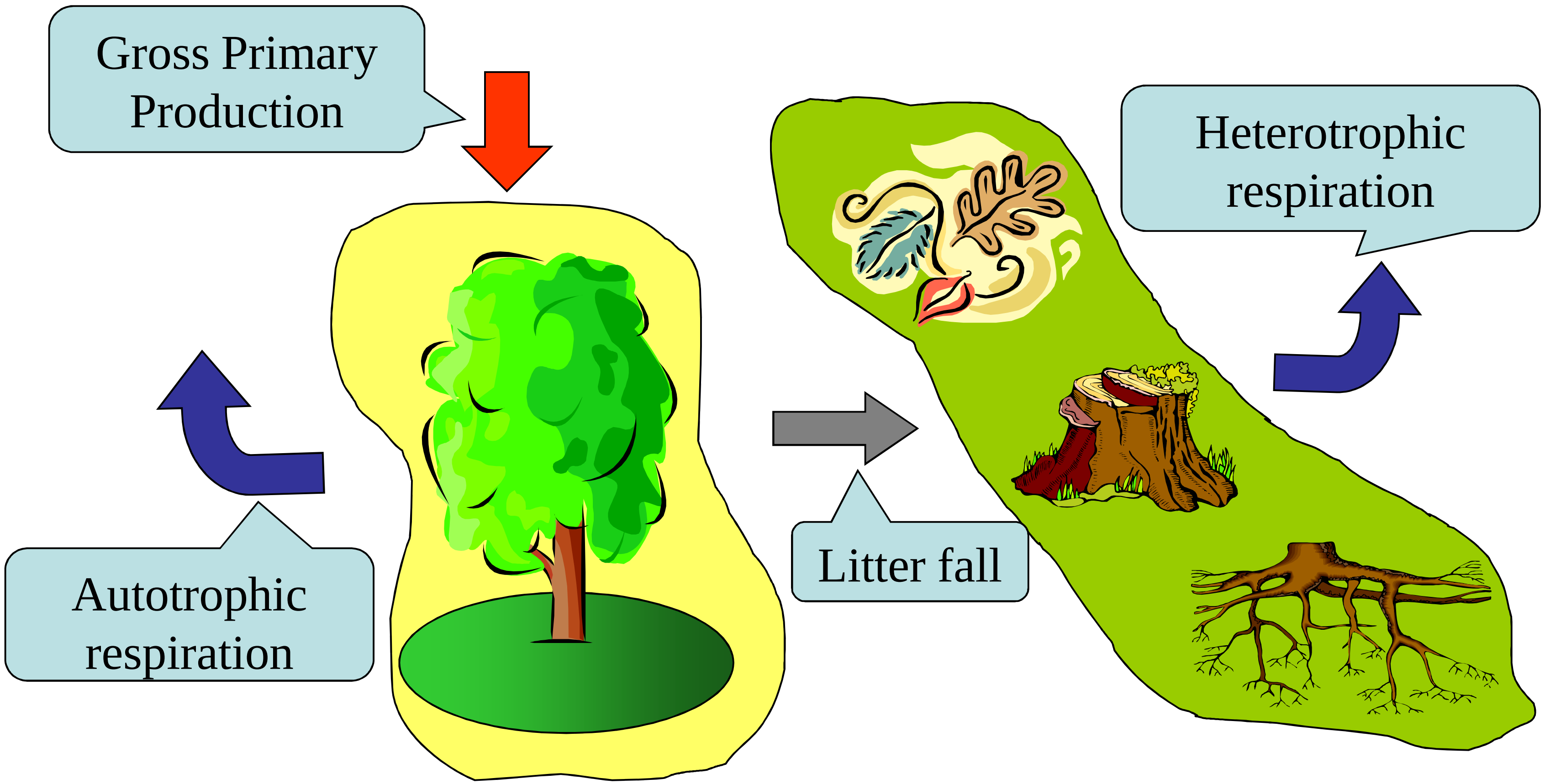




Source: http://fluxnet.fluxdata.org/sites/site-summary/

Ref: http://www.fluxnet.ornl.gov/fluxnet/


Photosynthesis
Respiration
Net Ecosystem Exchange



Gross Primary Production
Autotrophic respiration
Litter fall
Heterotrophic respiration

Terms for Carbon exchange

- ***Gross Primary Productivity (GPP)***

GPP = Net Photosynthesis integrated over space and time

Ref: http://www.clas.ufl.edu/users/mcmack/ee20031/

Werth D, Avissar R (2004)

Net Primary Production (NPP)

What is the NPP?

Net Carbon Gain by an ecosystem

NPP= GPP – R_a

Carbon-Uptake processes (GPP)
Carbon loss processes (respiration) (R)

Ra: Respiration of plant component, called **'autotrophic respiration'**

NPP=ΔB+L+C

where ΔB is growing rate of biomass; L, the litter production (litter fall); C the consumption by insects.

Net Ecosystem Exchange (NEE) and Net Ecosystem Production (NEP)

NEE=NEP

NEE=NEP=NPP - Rh

Rh: Respiration of heterotrophs including the animal and microbial consumption of the organic matter produced by plants

NEE=NEP=GPP - Re

Re=Ra+Rh

Re: Ecosystem Respiration

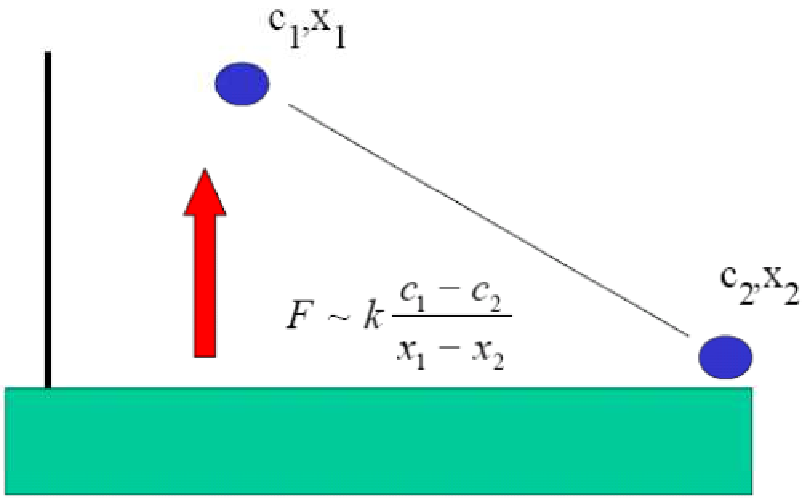
Net Ecosystem Exchange (NEE)

- Net CO2 exchange with the atmosphere, i.e., the vertical and lateral CO2 flux from the ecosystem to the atmosphere.
- NEE= R_e - GPP
- NEE= R_a – R_h - GPP

- NEE= NPP – R_h
- \- NEE (a net flux to the ecosystem or Carbon SINK)
- \+ NEE (a net flux to the atmosphere or so Carbon source).
- But, the sign of NEE may be reversed in the literature.

Flux Measurement Methods

- Micrometeorological Methods
  - **Eddy Covariance**
  - **Gradient**
  - **Relaxed Eddy Accumulation**
  - **……….**



In biometeorology, we rely on Fick's Law of Diffusion to quantify the diffusive transfer of matter. Fick's Law of Diffusion states that:

a chemical species diffuses in the direction of decreasing mole fraction. the flux density is proportional to a diffusion coefficient and a gradient

$$(F \sim k \frac{c_1 - c_2}{x_1 - x_2}).$$

- Eddy Covariance
- What is covariance?

$$\mathrm{Covar}(X, Y) = \frac{1}{N} \sum_{i=0}^{N-1} (X_i - \bar{X})(Y_i - \bar{Y})$$

$$\mathrm{Co\ var}(X, Y) = \frac{1}{N} \sum_{i=0}^{N-1} (x_i' y_i') = \overline{x' y'}$$

Eddy-Correlation Approach-Working Principle

- Mathematically, "eddy drifts" can be expressed as the multiplication of the vertical wind speed by the

$$F = \overline{\rho_a w s}$$

$$F = \overline{(\overline{\rho_a} + \rho_a')(\overline{w} + w')(\overline{s} + s')}$$

$$F = \overline{(\overline{\rho_a}\overline{w}\overline{s} + \overline{\rho_a}\overline{w}s' + \overline{\rho_a}w'\overline{s} + \overline{\rho_a}w's' + \rho_a'\overline{w}\overline{s} + \rho_a'\overline{w}s' + \rho_a'w'\overline{s} + \rho_a'w's')}$$

$$F = \left(\overline{\rho_a}\overline{w}\overline{s} + \overline{\rho_a}\,\overline{w's'} + \cancel{\overline{w}\,\overline{\rho_a's'}} + \cancel{\overline{s}\,\overline{\rho_a'w'}} + \cancel{\overline{\rho_a'w's'}}\right) = \cancel{\overline{\rho_a}\overline{w}\overline{s}} + \overline{\rho_a}\,\overline{w's'}$$

$$F \approx \overline{\rho_a}\,\overline{w's'}$$

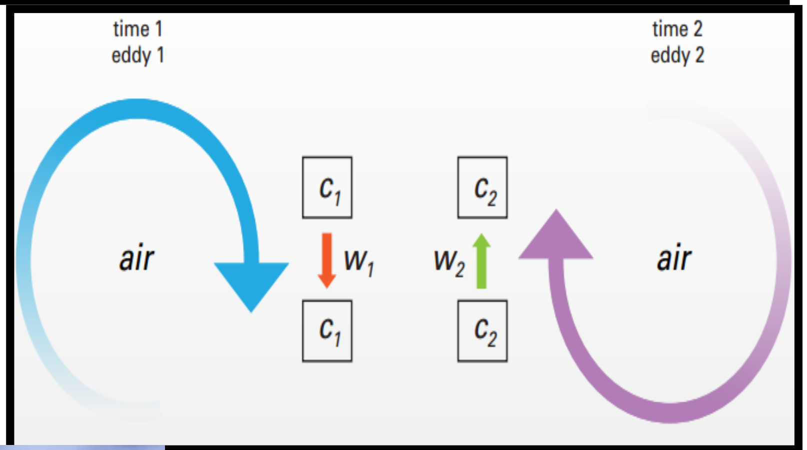
Methods – eddy COVARIANCE

- General

$$F = \overline{\rho}_d \overline{w's'}$$

$$F_c = \overline{w'\rho_c'}$$

- Fluxes are calculated from covariances of vertical wind speed and gas concentration



Sensible Heat Flux (H):

$$H = \overline{\rho} C_p \overline{w'T'}$$

Latent Heat Flux (LE):

$$LE \equiv \lambda E = \lambda \frac{M_w / M_a}{\overline{P}} \overline{\rho_d} \overline{w'e'}$$

Turbulence over a surface

Flux of water vapor >>>> Covariance of w and q

Flux of sensible heat >>>> Covariance of w and T

Flux of CO_2 >>>> **Covariance of w and ρ_c**

Parameters in Flux Measurement

- **Micrometeorology**
  - PAR, Ta, RH, Wind, Wind Direction, VPD, Ts, CO_2
- **Eddy covariance fluxes**
  - NEE, H, LE, Rn, G
- **Vegetation Characteristics**
  - species, height, age, density, site history,
  - LAI, biomass
- **Soil Characteristics**
  - physical and chemical properties

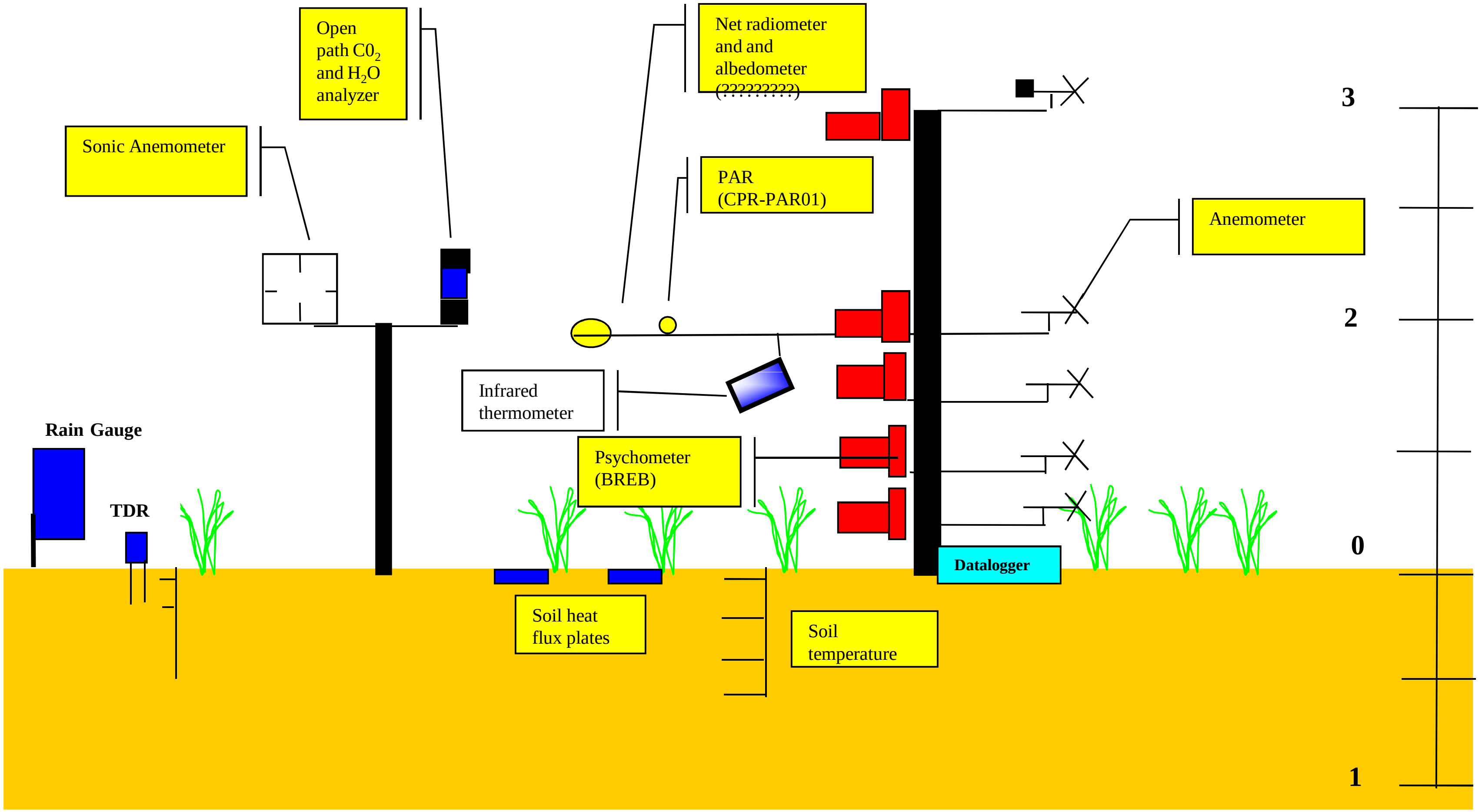
Advantages of EC

- GOOD TIME RESOLUTION (Hz)
- MANY DATA
- REPRESENTS CANOPY FLUXES
- DIRECT MEASUREMENTS
- EVALUATES FLUXES DIFFERENT TIME SCALE
- PROVIDE PROCESS INFORMATION

Disadvantages of EC

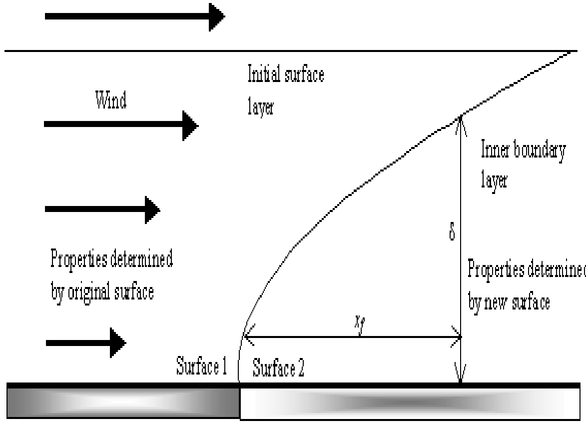
- Need a large and smooth area
- Expensive instruments
- Nighttime biases
- Footprint problem
- Not applicable in complex terrain
- Gap filling problem
- Insufficent wind
- Precipitation or sometimes irrigation (for open path sensor)
- Power for pumps (especially problem in the forest for closed path sensor)
- Need many inlets for closed path sensor

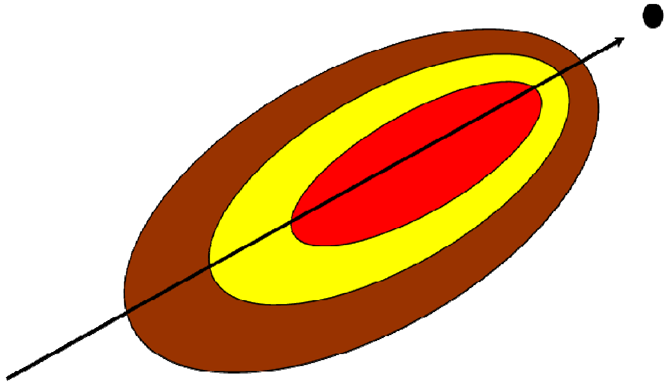
Design of the system

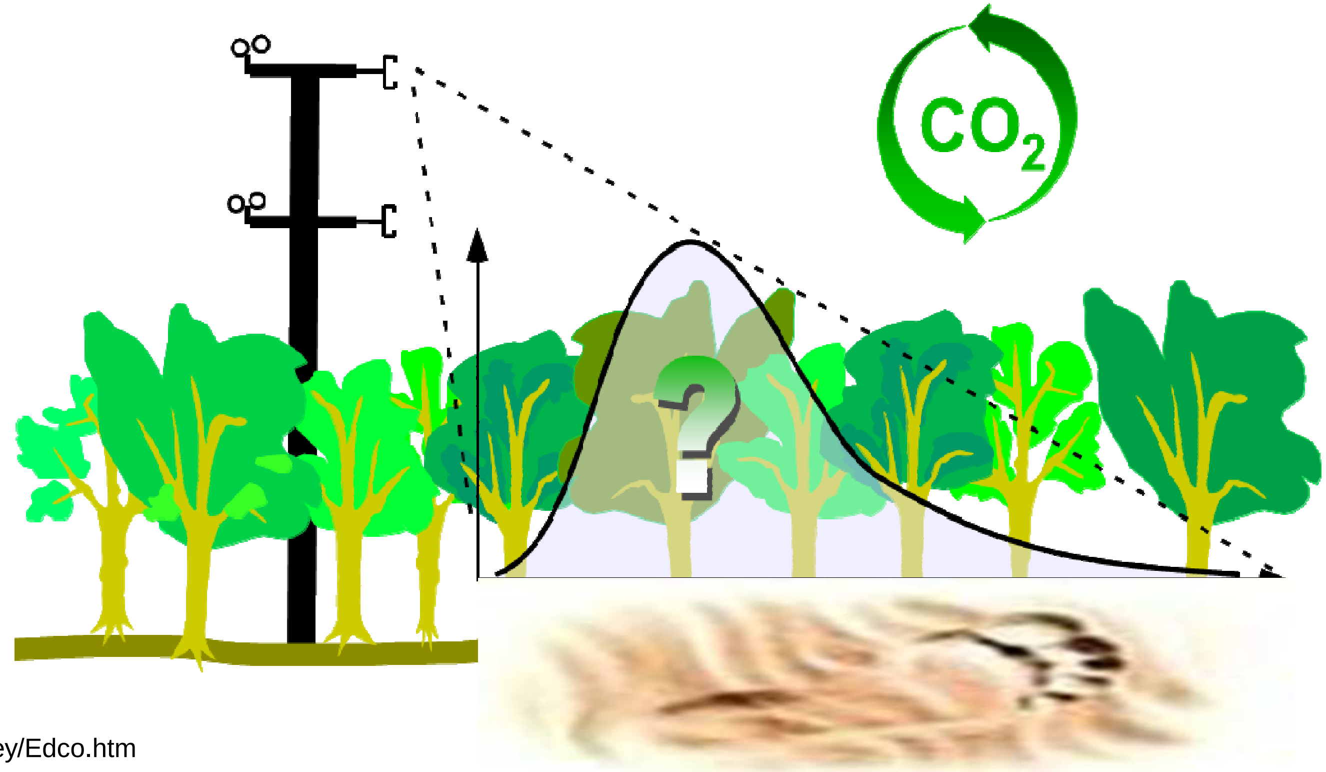



CALIBRATION

Fetch and Footprint







$$X_f/200 < \delta < X_f/20$$

(Monteith and Unsworth, 1990)

http://cloudbase.phy.umist.ac.uk/people/dorsey/Edco.htm

Typical Shortcomings of EC Measurements:

Closure,
Bad weather conditions (rain, typhoon, calm wind conditions during nighttime).
Technical problems,

...

CORRECTION OF EC DATA

-Removal of spiky noises

-TILT CORRECTIONS (Coordinate rotations etc.)

- Webb-Pearman-Leuning equation (WPL)

$$F_c = \overline{w'c'} + 7.386*10^{-3}*LE + 0.0383*H$$

Micromol m-2 s-1

Scheme of Corrections and Data Handling with Eddy Covariance

US-anemometer plus sensor of concentration

- Data control (‚despiking')
- Conversion in physical units

raw fluxes

- Schotanus: T_{sonic} into T
- Rotation (how?): allignment of sonic
- ~~Brook, 78~~
- [Webb et al., 80]: correction for temperature dependent density changes
- Moore, 86: unsufficient frequency response

turbulent fluxes

- u* correction: not turbulent situations, limited fetch
- quality control: stationarity, internal turbulence characteristic, footprint, etc.
- Data gap filling (ensemble mean, look-up tables, non-linear regression, ANN)

complete data set based on turbulent periods

- vertical advection (drift correction)
- horizontal advection
- horizontal flux divergence

complete data set of fluxes

Results (annual budgets) depend
(i) on the suitability of the site,
(ii) on all elements of the measurement chain,
(iii) on methods applied during data handling, and
(iv) on methods applied for data gap filling.

GAP filling

– ***Gap filling (Nighttime)***

Ecosystem respiration (Re) is modeled using nighttime fits of NEE to 2 cm soil temperature (or air temperature) when there is sufficient turbulence (U* > 0.1).

- ***Daytime Re***

We can then calculate daytime Re using the fits.

-Missing flux data can then be filled using a sum of the estimated gross fluxes if T and PAR are available.

Filling Daytime Data Gap

- (Falge et al., 2001).

$$NEE = \frac{GPP_{\max} \alpha PPFD}{\alpha PPFD + GPP_{\max}} + R_e$$

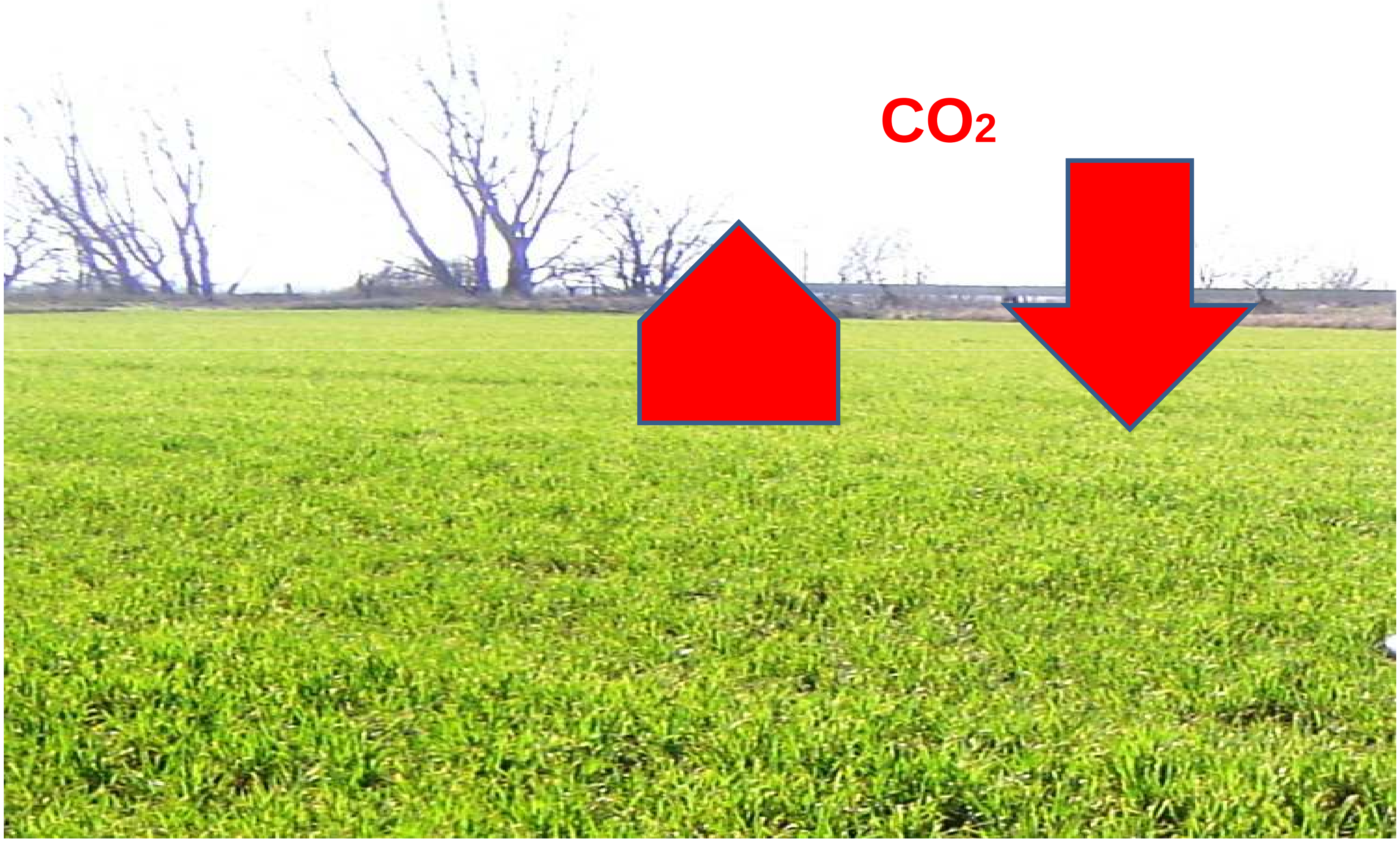
Filling Nighttime Data Gap

- Lloyd and Taylor (1994)

$$R_{e,night} = R_{e,T_{ref}} \, e^{[(E_0 / (T_{ref} - T_0)) - (E_0 / (T_{s2} - T_0))]}$$

where, Re,night, is the night time ecosystem respiration, Re,Tref, simulated Re at a soil temperature of 10 oC (in K), Ts2 is the soil temperature in a depth of 2 cm (in K), Eo and To are fitted parameters are 308.56 K and 227.13 K, respectively (Falge et al., 2001).

We are measuring CO_2 fluxes above crops since 2009.



purpose

it is aimed to

(i) **MEASURE AND ESTIMATE THE VARIATION OF THE CO_2 FLUXES BY MEANS OF THE NEE, GPP AND R_E OF WINTER WHEAT OVER TWO GROWING PERIODS BY EC METHOD FOR THE FIRST TIME IN THE CONSIDERED REGION;**

(ii) **DETERMINE THE RELATIONSHIPS BETWEEN CUMULATED CO_2 FLUXES AND VEGETATION DYNAMICS SUCH AS BIOMASS, LEAF AREA INDEX (LAI), NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI); AND**

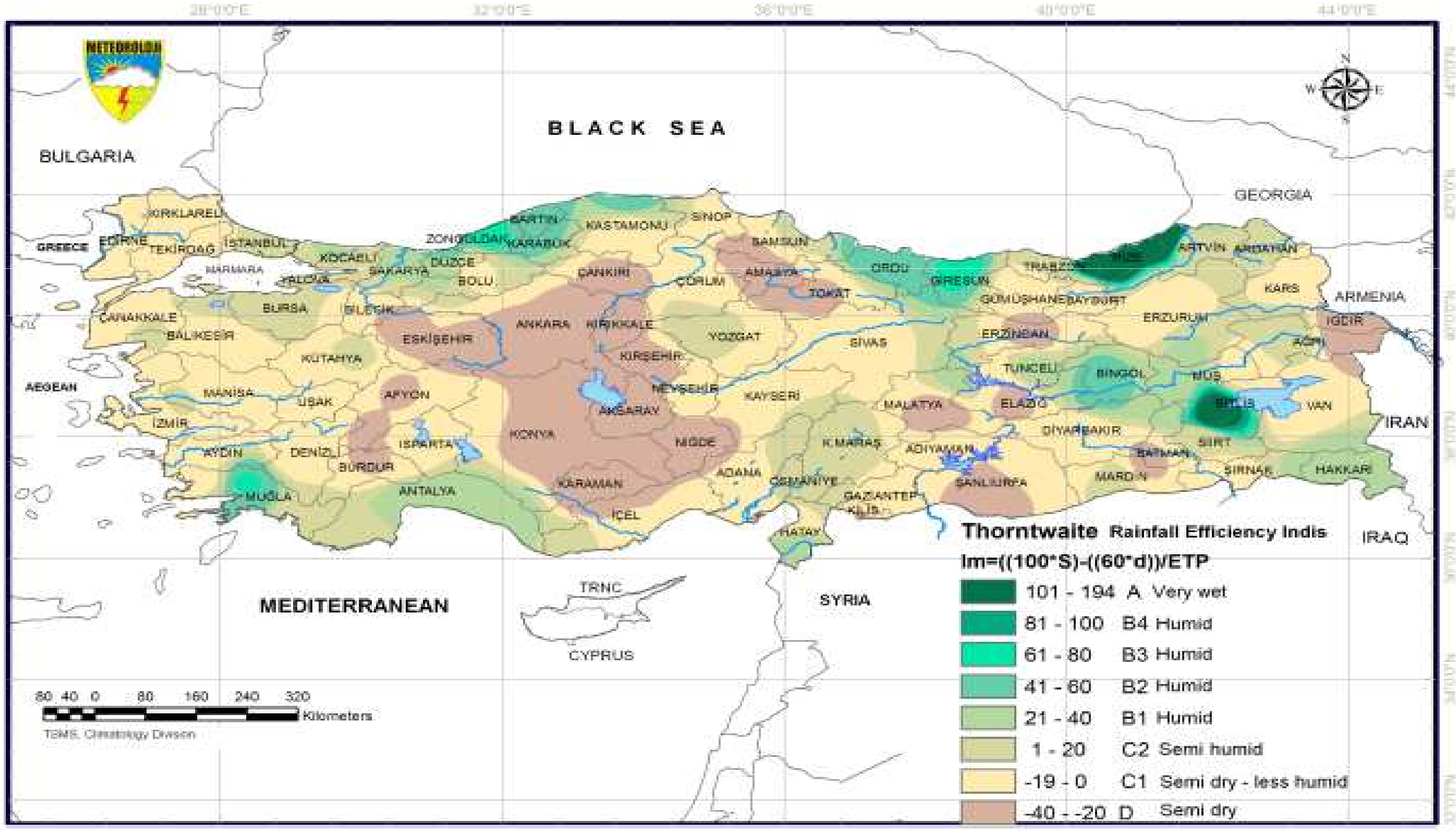
(iii) **INVESTIGATE THE PHENOLOGICAL PERIOD WHICH PLAYS MAJOR ROLE IN CARBON EXCHANGE.**

LAND RESOURCES (million ha)

- Area of Turkey ……………… 77.95
- Agricultural Land 28.05
- Irrigable Land …………………. 25.85
- Economically irrigable land.............8.50
- Irrigated Land ……………...approx. 5.20

Mean (arithmetic) Annual Precipitation .. 646 mm

- 501 billion m^3 Precipitation
- 274 billion m^3 Evapotranspiration
- 186 billion m^3 Surface flow
- 41 billion m^3 Infiltration



Şensoy ve ark., 2013

Research Area -Site Description

The research project was carried out over a winter wheat field in Kırklareli city located in the Thrace Region of Turkey

[1] Eddy Covariance Measuring System

[2] Agrometeorological Station

Ref: http://www.google.com/intl/tr/earth/index.html

Experiments and Observations

Table 1. Phenological development of winter wheat during two growing periods.

Phenological stages	2009-2010 Growing period	2010-2011 Growing period
Planting	Oct 9th, 2009	Oct 25th, 2010
Emergency	Oct 17th, 2009	Nov 5th, 2010
Second leaf	Oct 21st, 2009	Nov 10th,2010
Third leaf	Oct 26th, 2009	Nov 15th,2010
Tillering	Nov 25th, 2009	Dec 7th, 2010
Stem elongation	Mar 31st, 2010	Mar 29th, 2011
Earing	Apr 26th, 2010	May 10th, 2011
Flowering	May 10th, 2010	May 19th, 2011
Grain filling	May 24^{th,} 2010	Jun 1st, 2011
Maturity	Jun 4th, 2010	Jun 13th, 2011
Harvest	Jul 6th, 2010	Jul 8th, 2011

Table 2. Major agricultural management activities during 2009-2010 and 2010-2011 growing periods.

Applications	Growing period of 2009-2010	Amount	Growing period of 2010-2011	Amount
Fertilization	Oct 9th, 2009	46 kgN ha^{-1}	Oct 25th, 2010	46 kgN ha^{-1}
Fertilization	Mar 3rd, 2010	69 kgN ha^{-1}	Feb 11th, 2011	69 kgN ha^{-1}
Fertilization	Apr 8th, 2010	82.5 kgN ha^{-1}	Mar 25th, 2011	49.5 kgN ha^{-1}
Herbicide treatment	Nov 26th,2009	0.750 l ha^{-1}	Nov 2nd, 2010	3 l ha^{-1}
Fungicide treatment	Mar 2nd, 2010	1 l ha^{-1}	Mar 28th, 2011	1 l ha^{-1}
Fungicide treatment	May 5th, 2010	0.6 kg ha^{-1}	May 16th, 2011	0.6 kg ha^{-1}

Measurements

- **Agricultural Meteorological Station Measurements;**

To examine the EC measurements simultaneously with meteorological variables like;

maximum, minimum and mean temperatures, relative humidity (Hygrometer MP100A, Rotronic Instrument Crop),

wind speed and direction at 0.5, 1, 2, 5, 10 m level (NRG #40C Anemometer and NRG #200P Wind Direction Wane, NRG Systems),

global solar radiation (CMP3, Kipp&Zonen),

net radiation (NR LITE, Kipp&Zonen),

soil temperature at 2, 5, 10 and 20 cm level,

soil water content at 0-30, 30-60 and 60-90 cm (CS 616 TDR type, Campbell Scientific)

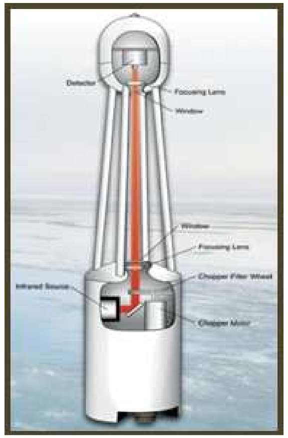
were also measured during the experiment period.

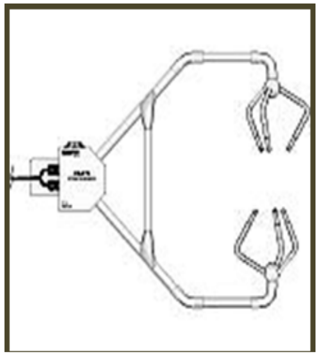
- **Eddy Covariance Station Measurements;**

EC measurements were conducted using two types of sensors; namely a 3D sonic anemometer (CSAT3, Campbell Scientific) and an infrared gas analyzer (LI-7500, LI_COR Biosciences) in a temporal resolution of 10 Hz.

Eddy covariance system

- High Frequency Measurements (10 Hz)
- 30 min averaged data



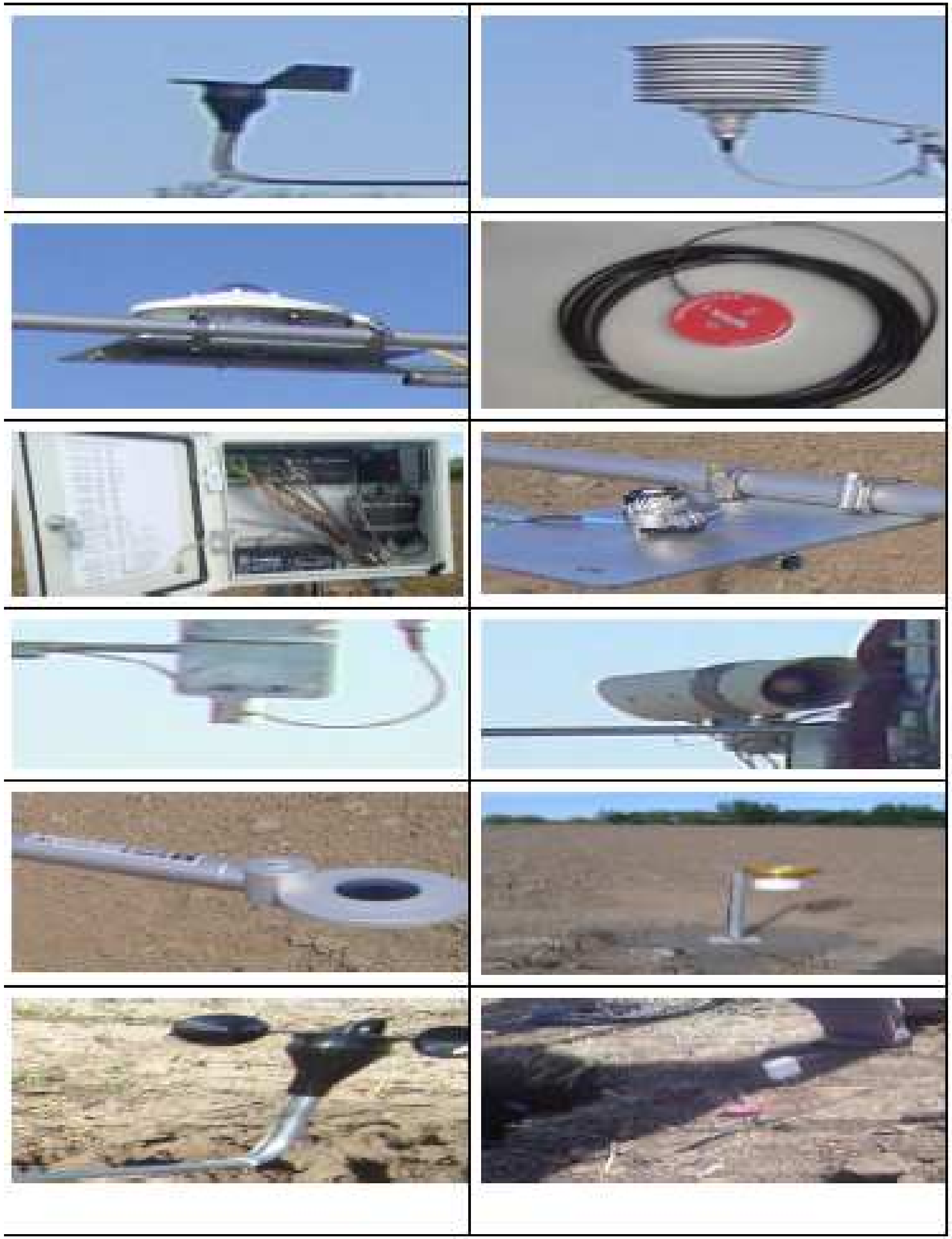


3D sonic anemometer

Infrared Gas Analyzer (IRGA)

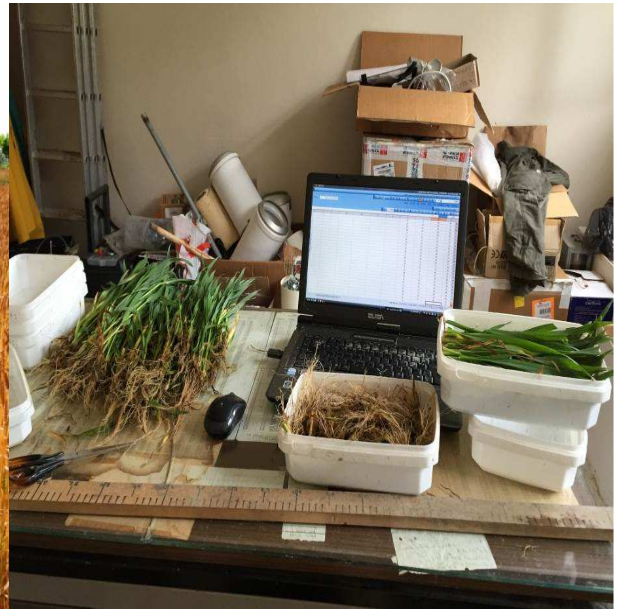
EC SYSTEM

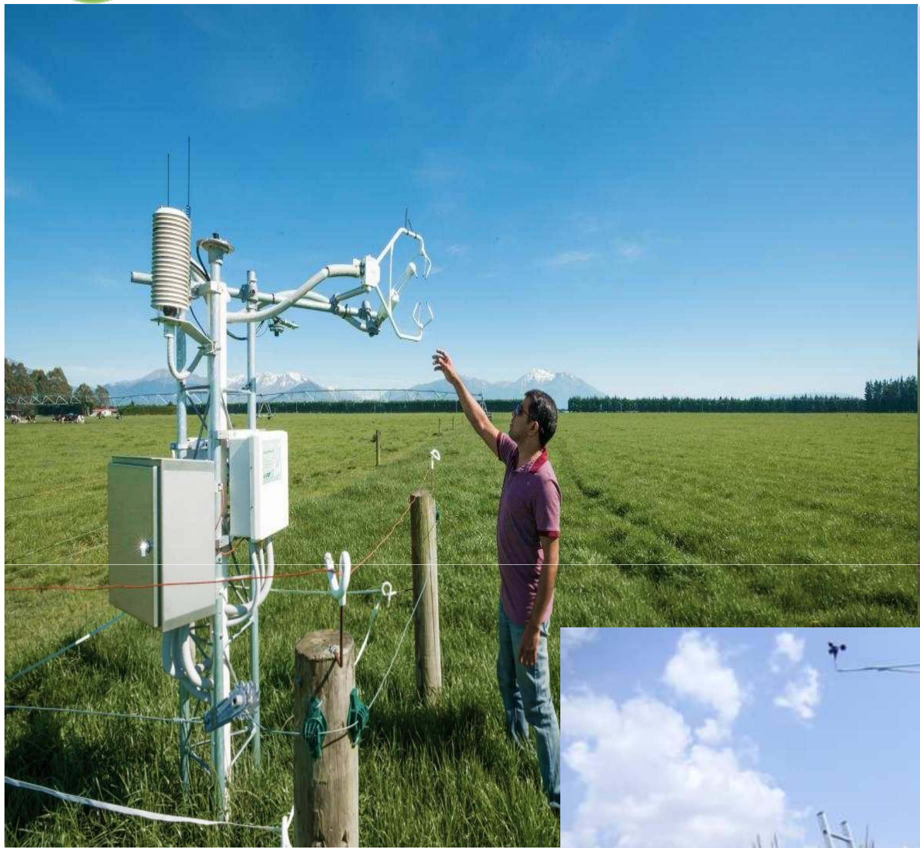
Measurements



FIELD studies








2009 12 16

Flux Corrections, Gap filling and Flux Partitioning

During the data processing;

•Spike Removal

•Frequency Response

•WPL (Webb, Pearman, Leuning)

•Coordinate Rotation Corrections have been applied to the EC data set.

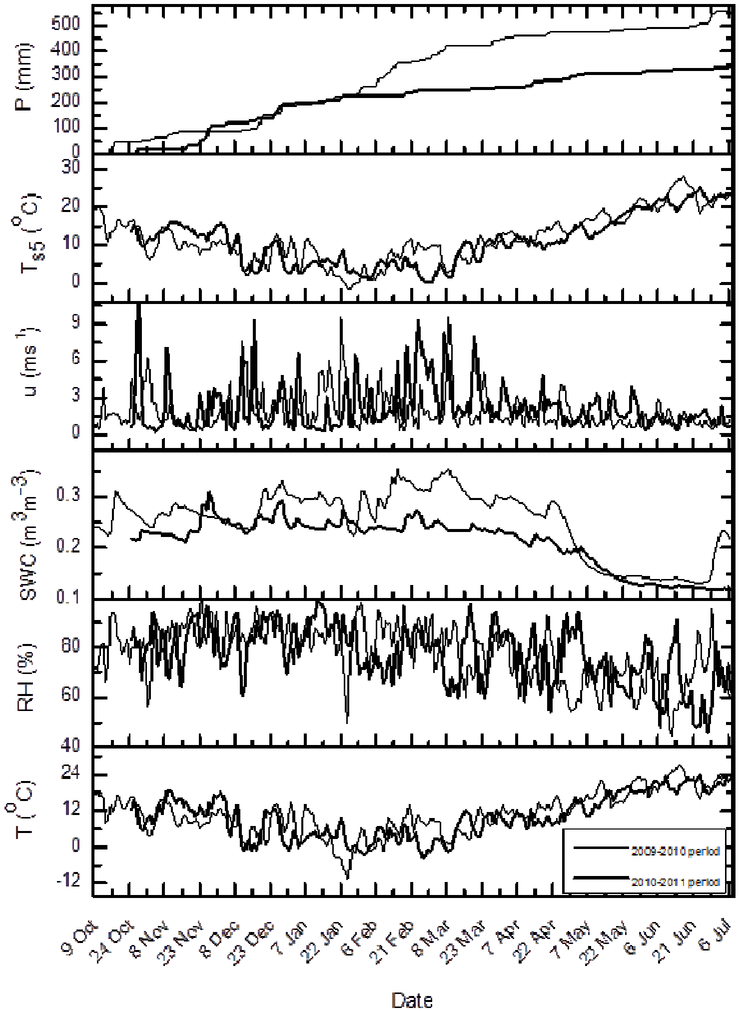
$$\mathbf{NEE = R_{eco} - GPP}$$

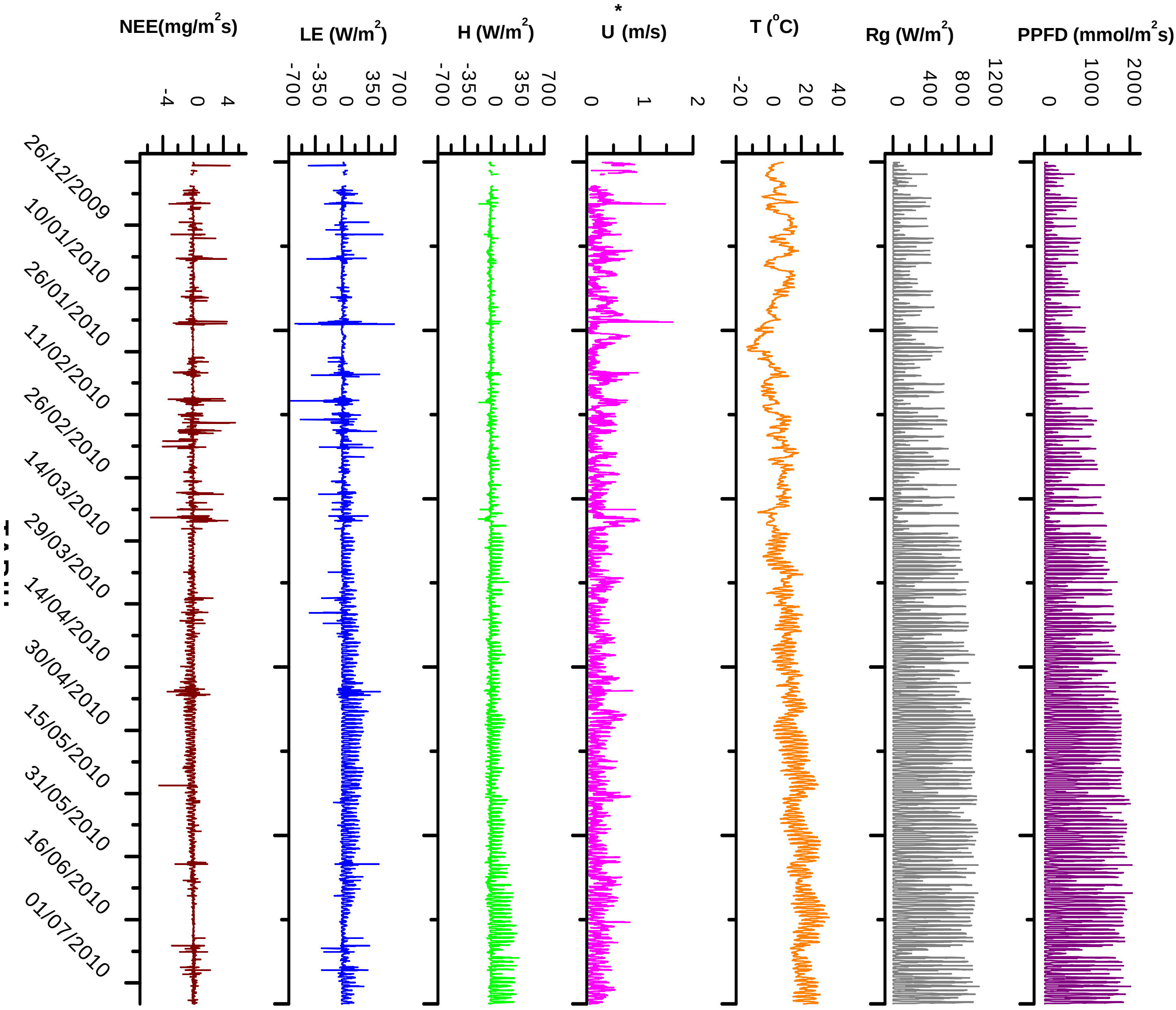
Gap filling and flux partitioning of EC data have been done according to the methods which are explained by Reichstein et al. (2005) and Falge (2001).

RESULTS&DISCUSSION

Table 3. Statistics of meteorological variables for two growing seasons of winter wheat.

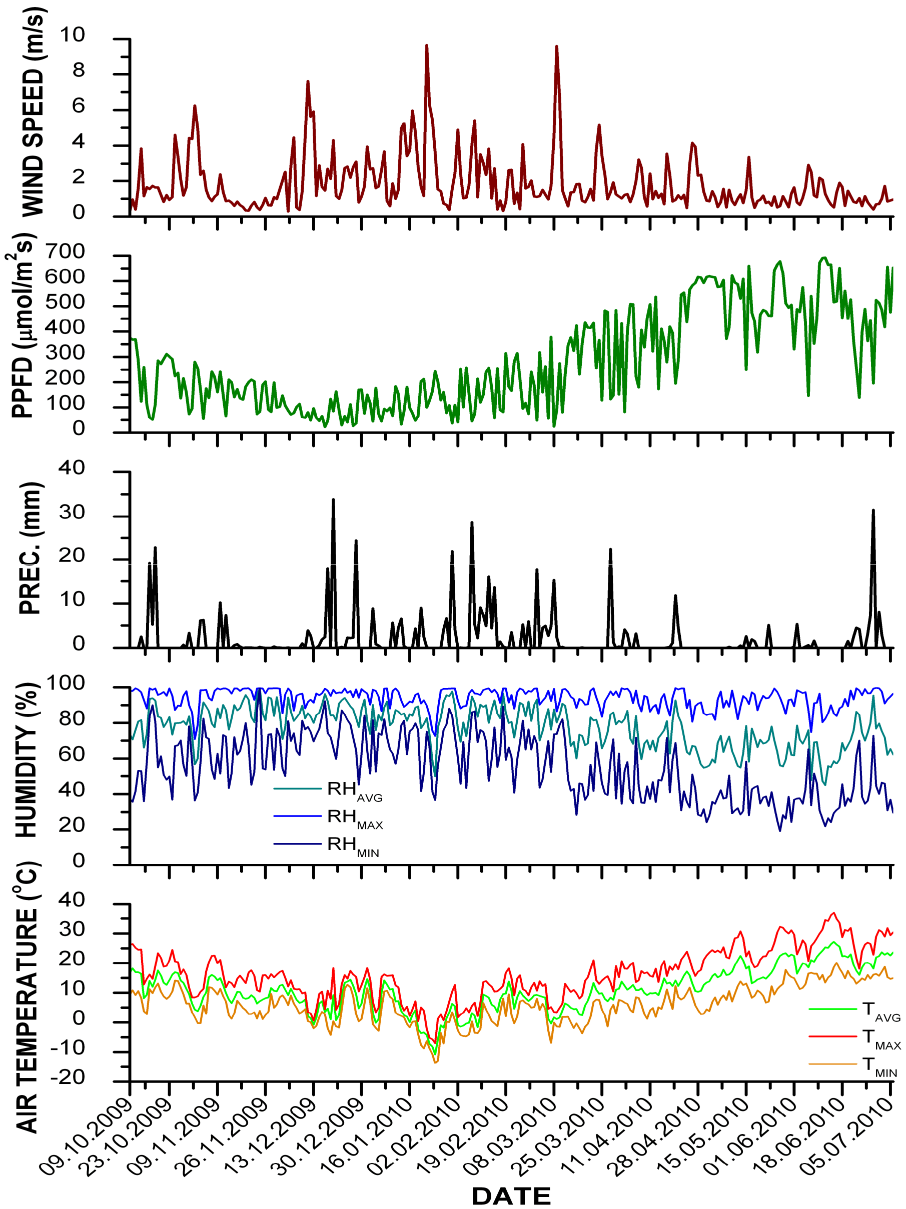
Meteorological variables	Growing period of 2009-2010			Growing period of 2010-2011		
	Daily Ave.	Max	Min	Daily Ave.	Max	Min
Air Temperature at 2 m (°C)	11.0	27.2	-10.8	10.0	23.6	-3.8
Maximum air temperature at 2 m (°C)	16.4	37.1	-7.0	15.5	33.02	-2.4
Minimum air temperature at 2 m (°C)	6.0	20.2	-13.7	5.0	16.6	-7.7
Global solar radiation (W m^{-2})	148.5	357.0	10.8	156.6	367.0	13.6
Net Radiation (W m^{-2})	61.7	207.2	-32.7	65.7	211.4	-21.73
Photosynthetic Photon Flux Density (μmol $m^{-2}s^{-1}$)	279.2	692.3	22.8	284.2	688.4	28.7
Soil heat flux (G) (W m^{-2})	-1.35	26.15	-29.05	-2.5	14.5	-39.1
Volumetric soil water content (SWC) at 0-30 cm (m^3 m^{-3})	0.25	0.36	0.13	0.21	0.31	0.12
Volumetric soil water content (SWC) at 30-60 cm (m^3 m^{-3})	0.27	0.40	0.14	0.24	0.34	0.15
Volumetric soil water content (SWC) at 60-90 cm (m^3 m^{-3})	0.31	0.42	0.18	0.31	0.39	0.24
Wind speed at 2 m (m s^{-1})	1.8	9.7	0.3	2.2	11.1	0.2
Soil temperature at 2 cm (°C) (T_{s2cm})	12.0	28.4	-2.4	11.1	25.7	0.2
Soil temperature at 5 cm (°C) (T_{s5cm})	11.9	27.9	-1.5	11.1	25.2	0.5

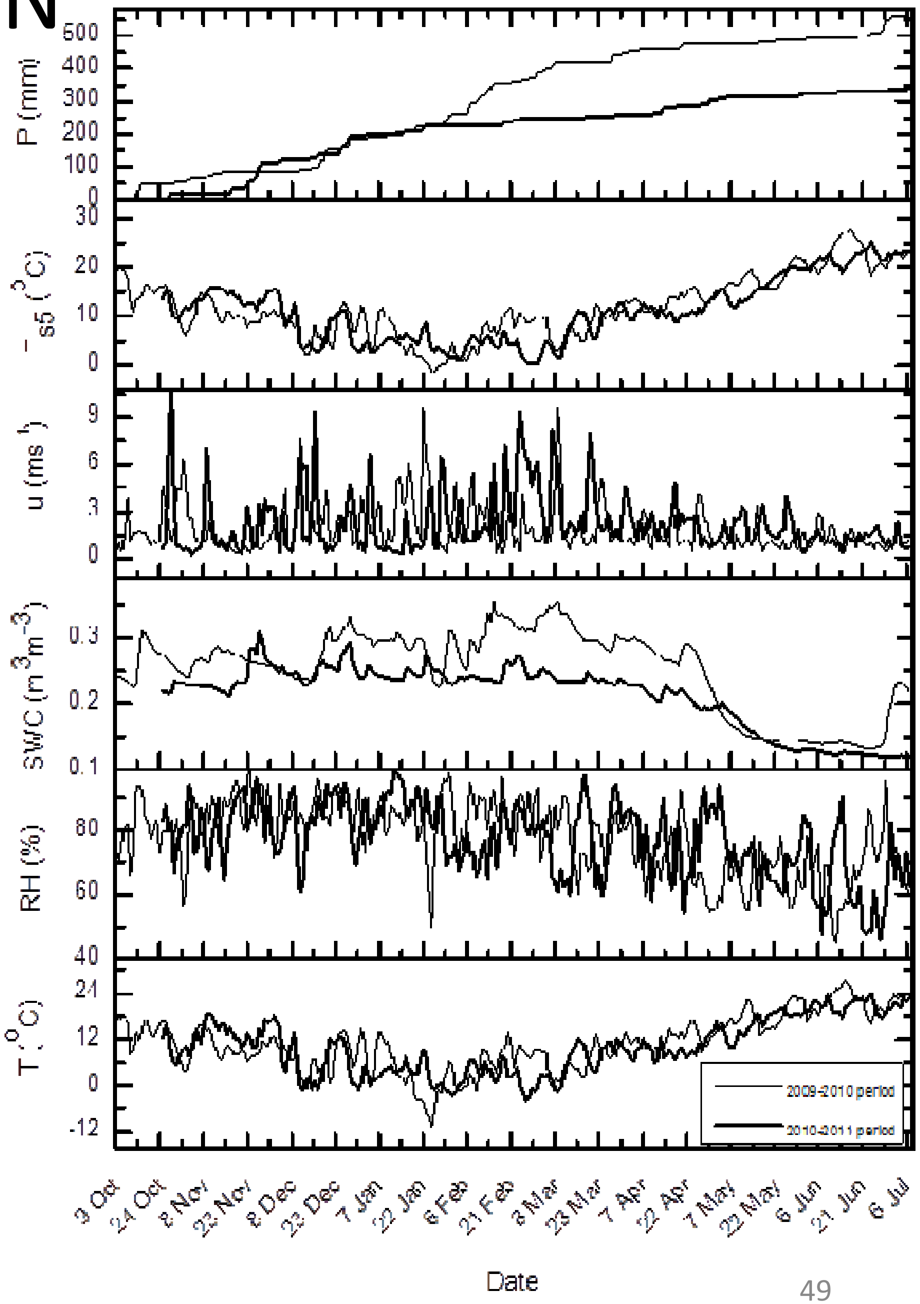


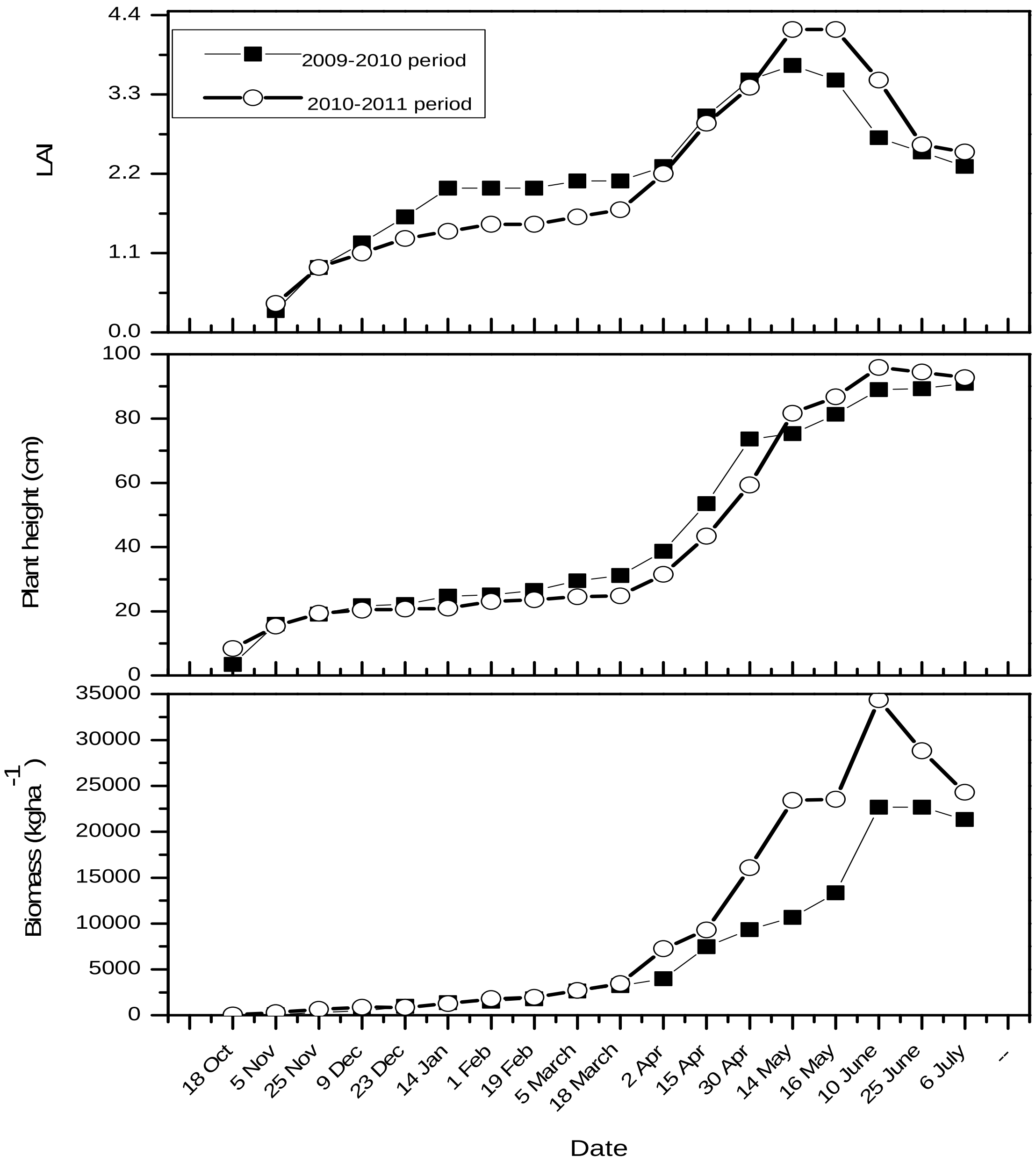


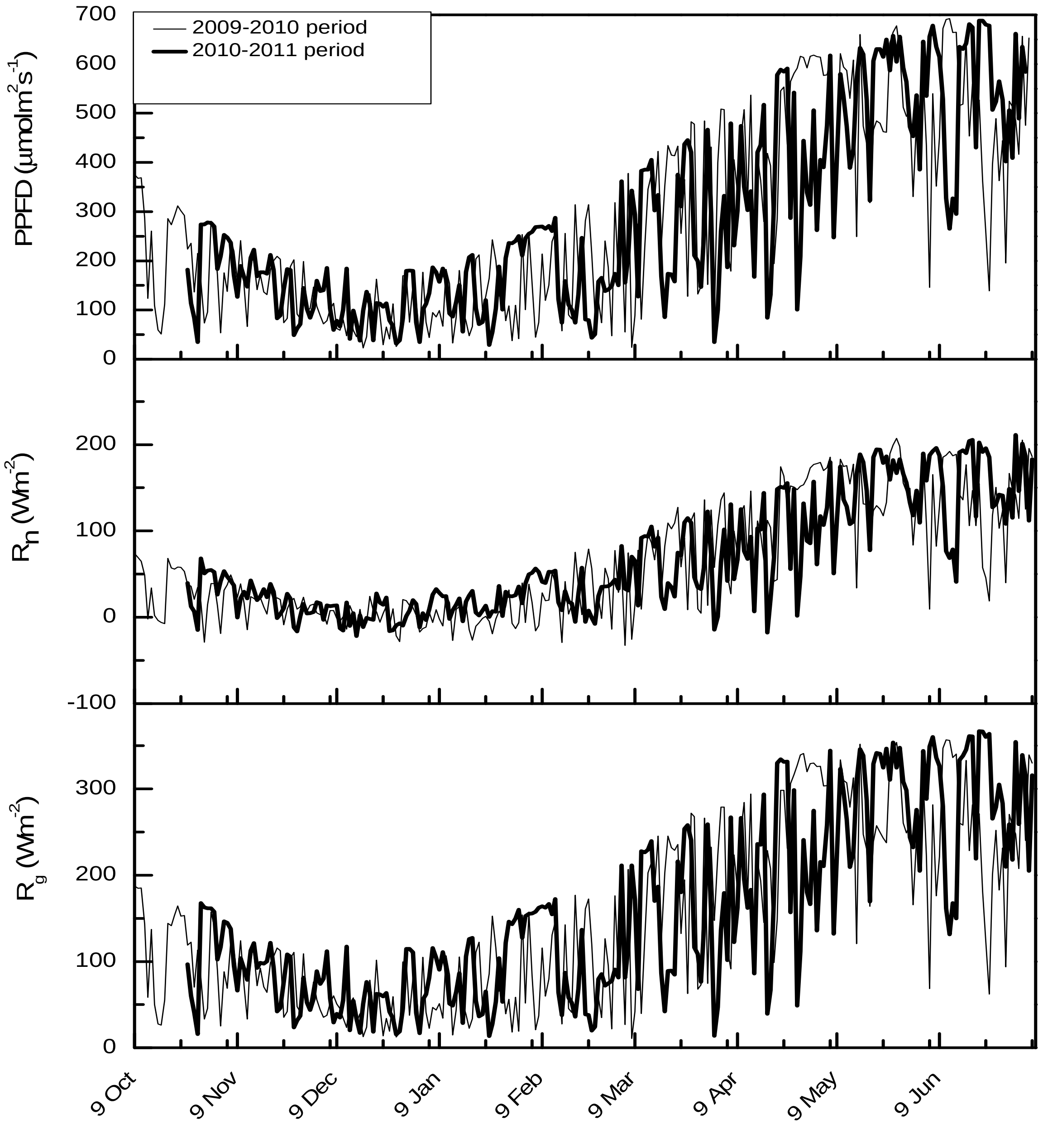
NEE(mg/m2s)
LE (W/m2)
H (W/m2)
U* (m/s)
T (oC)
Rg (W/m2)
PPFD (mmol/m2s)
26/12/2009
10/01/2010
26/01/2010
11/02/2010
26/02/2010
14/03/2010
29/03/2010
14/04/2010
30/04/2010
15/05/2010
31/05/2010
16/06/2010
01/07/2010

RESULTS&DISCUSSION



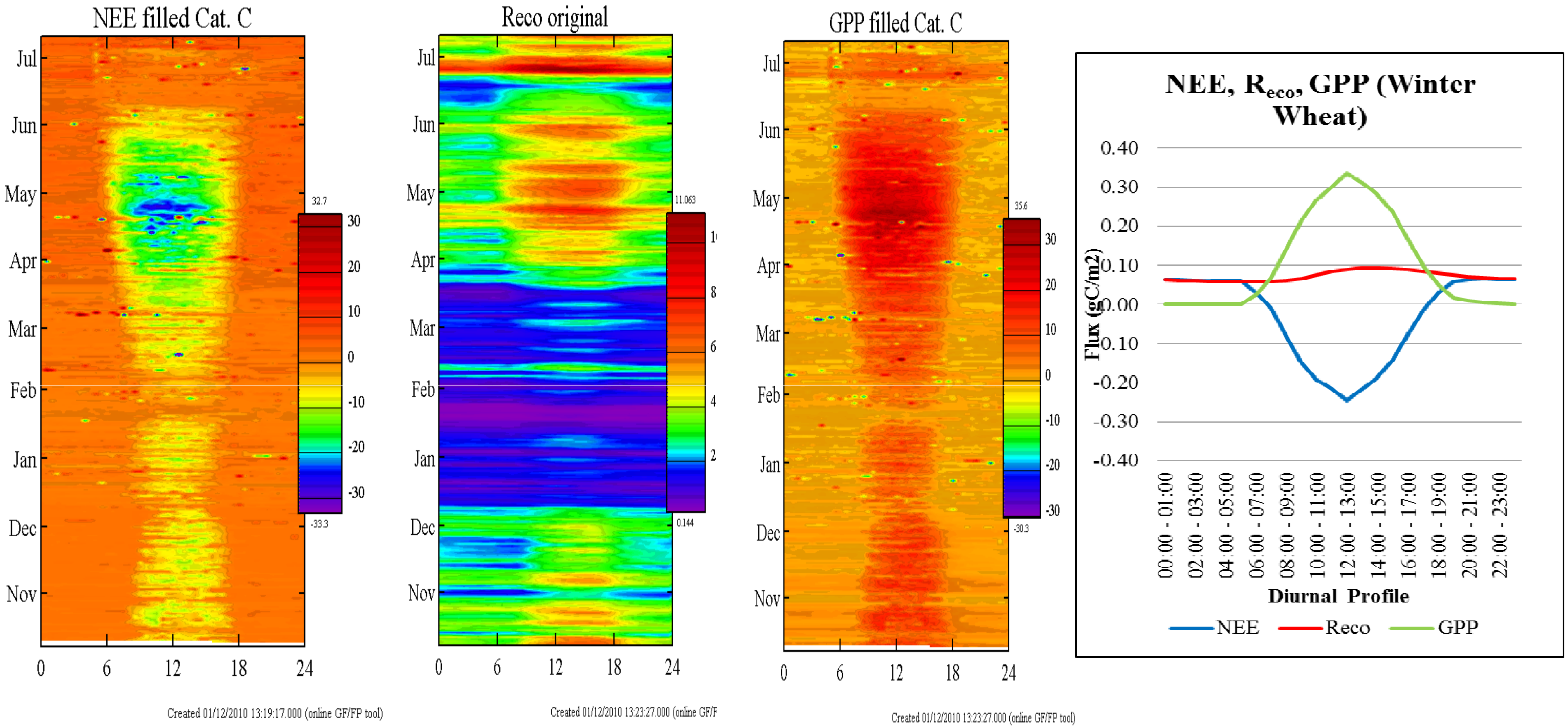



2009-2010 period
2010-2011 period
LAI
4.4
3.3
2.2
1.1
0.0
Plant height (cm)
100
80
60
40
20
0
Biomass (kgha^{-1})
35000
30000
25000
20000
15000
10000
5000
0
18 Oct
5 Nov
25 Nov
9 Dec
23 Dec
14 Jan
1 Feb
19 Feb
5 March
18 March
2 Apr
15 Apr
30 Apr
14 May
16 May
10 June
25 June
6 July
Date

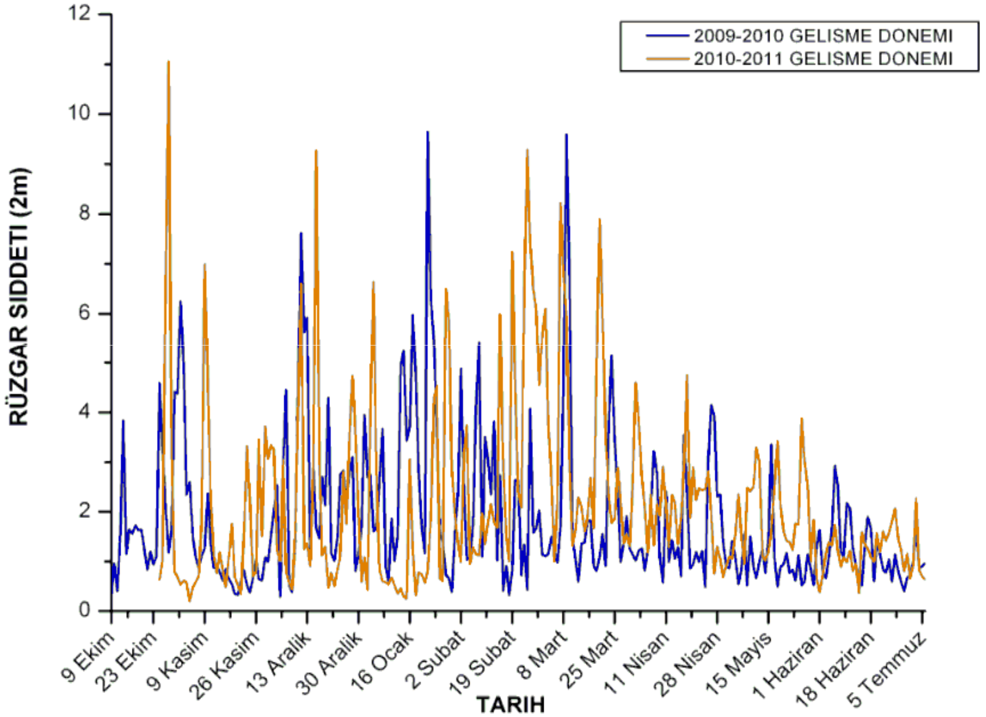


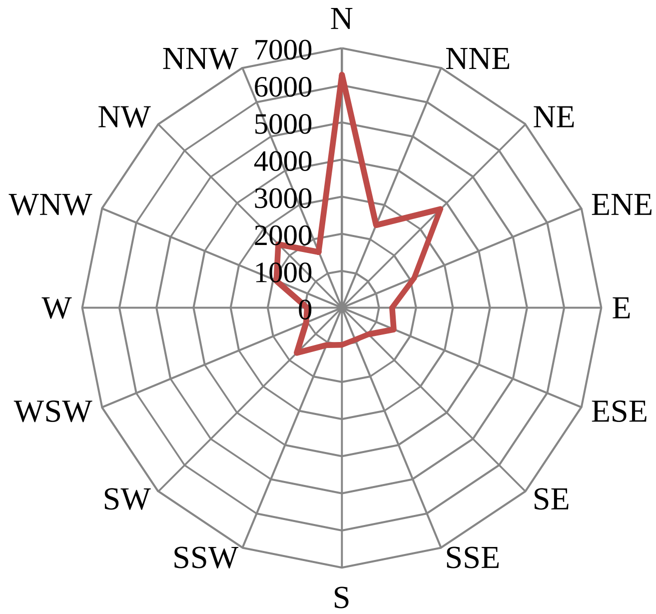
2009-2010 period
2010-2011 period
PPFD (µmolm-2s-1)
700
600
500
400
300
200
100
0
Rn (Wm-2)
200
100
0
-100
Rg (Wm-2)
300
200
100
0
9 Oct
9 Nov
9 Dec
9 Jan
9 Feb
9 Mar
9 Apr
9 May
9 Jun

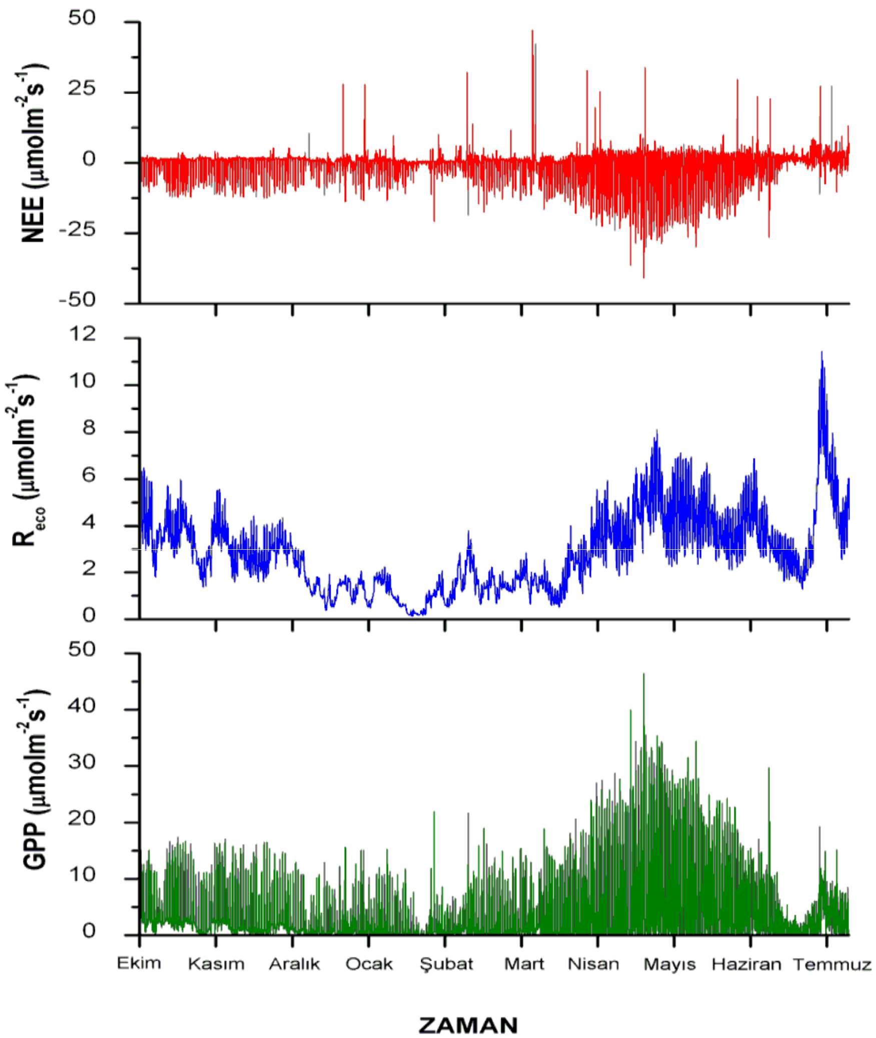
1st Growing Season of Winter Wheat



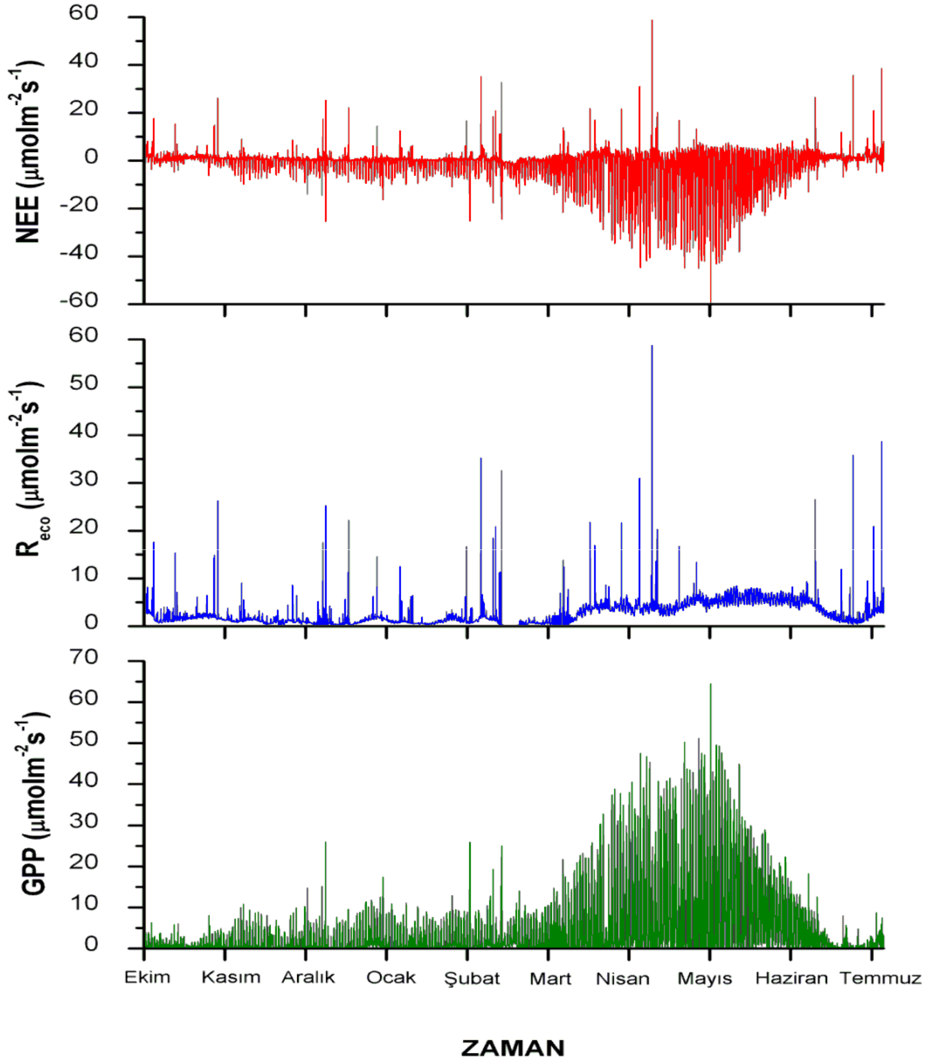
Wind speed and direction





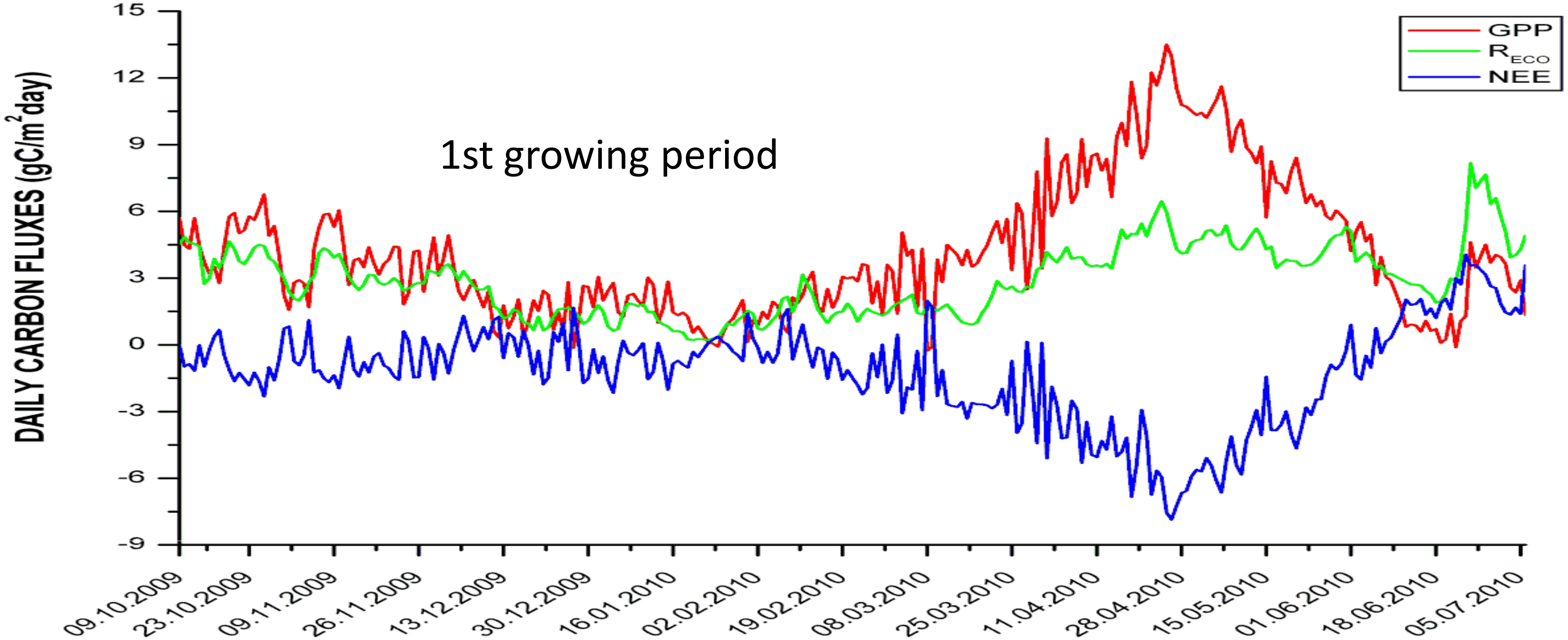


1st growing period



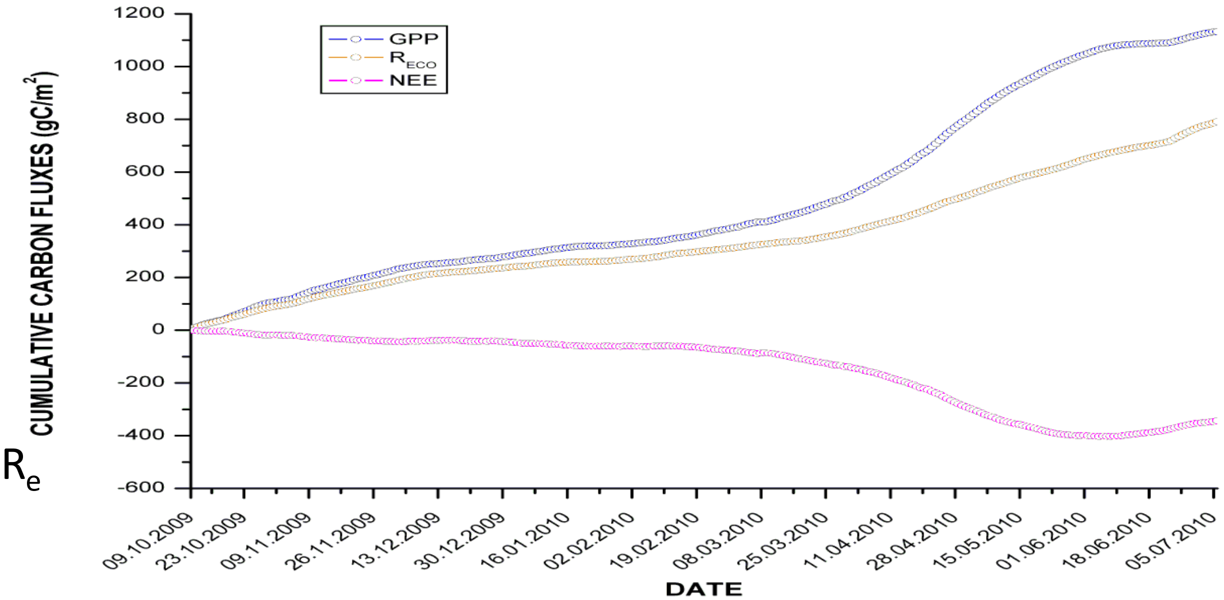
2nd growing period

RESULTS & DISCUSSION

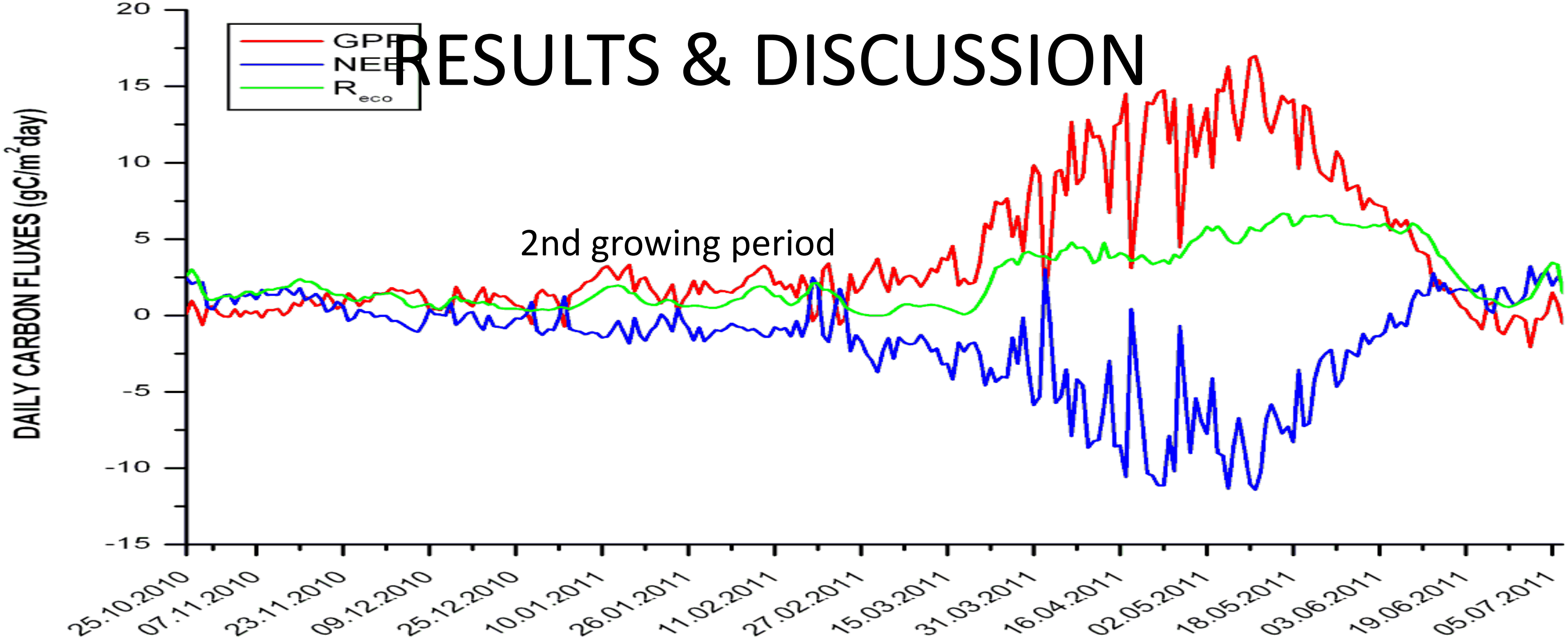


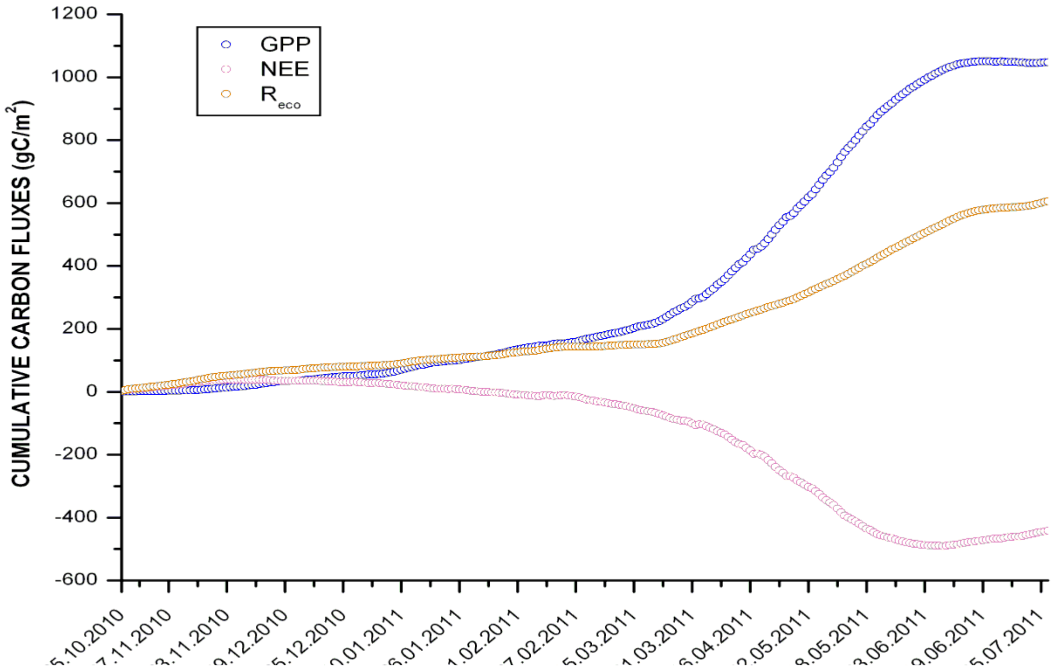
NEE (gC/m²)	GPP (gC/m²)	Reco (gC/m²)
-359.9	**1142.2**	**787.3**

Daily averages of NEE, GPP and R_e -1.31, 4.21 and 2.91 gC m^{-2},



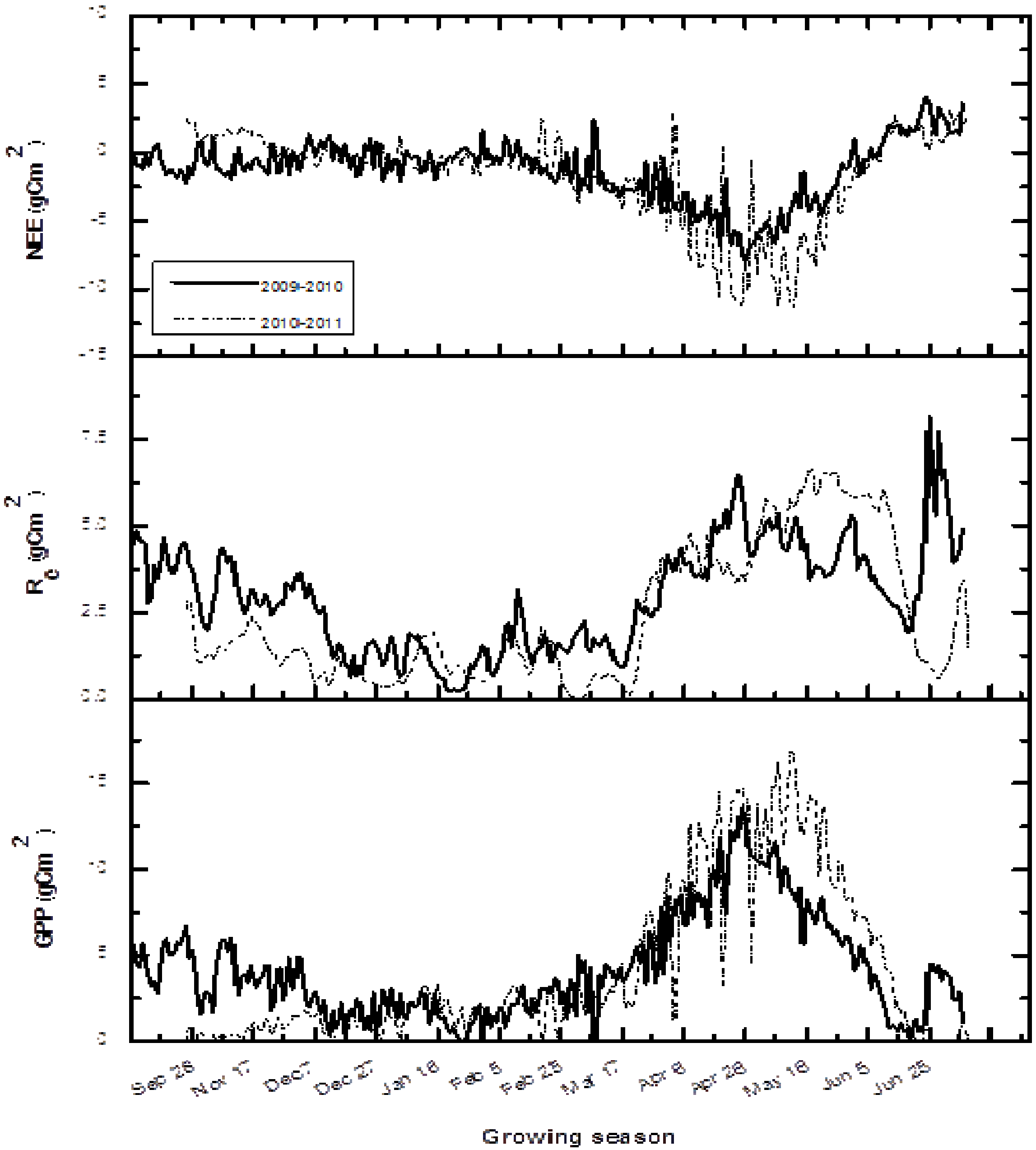
RESULTS & DISCUSSION





NEE (gC/m²)	GPP (gC/m²)	Reco (gC/m²)
-441.3	**1046.8**	**605.5**

NEE, GPP and R_e
-1.72, 4.09 and 2.37 gC m^{-2}.



NEE (gCm
2
)
2009-2010
2010-2011
R
e
(gCm
2
)
GPP (gCm
2
)
Sep 28
Nov 17
Dec7
Dec 27
Jan 16
Feb 5
Feb 25
Mar 17
Apr 8
Apr 28
May 18
Jun 5
Jun 25
Growing season

Table 4. Variation of cumulative (∑) GPP, R_e and NEE during the phenological stages of the first growing period.

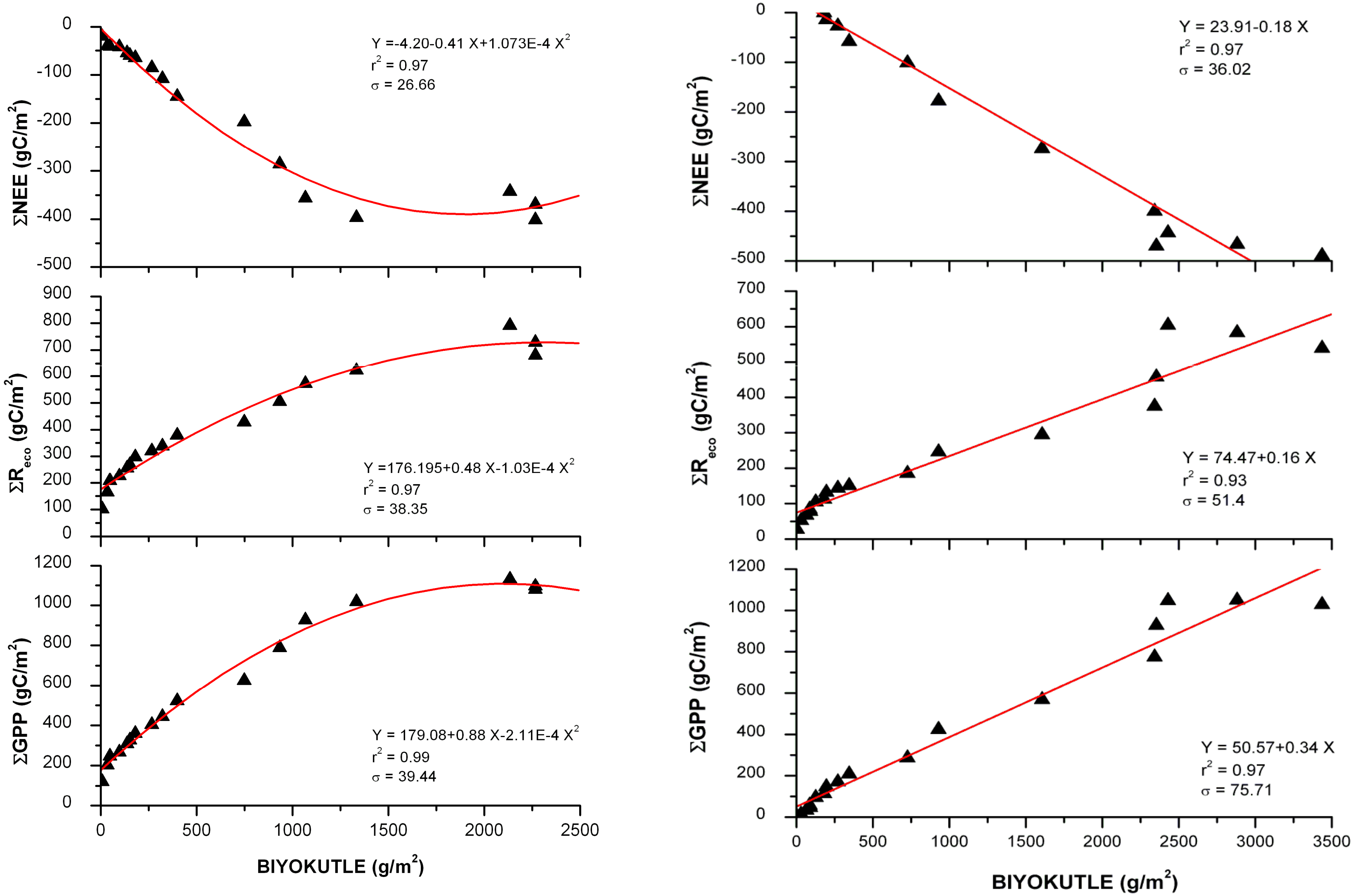
Phenological stages	**∑GPP ($gC\ m^{-2}$)***	**∑R_e ($gC\ m^{-2}$)***	**∑NEE ($gC\ m^{-2}$)***
Sowing-Emergence	35.05 (3.1%)	32.47 (4.1%)	-3.90 (0.8%)
Emergence-3rd leaf	46.61 (4.1%)	36.54 (4.6%)	-10.07 (2.2%)
3rd leaf-Tillering	117.65 (10.3%)	93.67 (11.9%)	-23.99 (5.2%)
Beginning of Tillering-Beginning of Stem Elongation	310.39 (27.2%)	205.04 (26.0%)	-105.35 (22.7%)
Beginning of Stem Elongation-Earing	230.51 (20.2%)	115.21 (14.6%)	-115.31 (24.9%)
Earing-Flowering	150.12 (13.1%)	66.15 (8.4%)	-83.97 (18.1%)
Flowering-Grain Filling	110.59 (9.7%)	58.20 (7.4%)	-52.39 (11.3%)
Grain Filling-Maturity	62.76 (5.5%)	48.54 (6.2%)	-14.21 (3.1%)
Maturity-Harvest	78.50 (6.9%)	132.83 (16.7%)	54.33 (11.7%)**

*Percentages given in brackets show the ratios of the cumulative fluxes in each corresponding phenological stage to their totals in the corresponding growing season.
**In this phenological stage, ∑R_e is greater than ∑GPP, so ∑NEE is positive (release).

Table 5. Variation of cumulative (∑) GPP, R_e and NEE during phenological stages of the second growing period.

Phenological stages	**∑GPP ($gC\ m^{-2}$)***	**∑R_e ($gC\ m^{-2}$)***	**∑NEE ($gC\ m^{-2}$)***
Sowing-Emergence	2.23 (0.2%)	17.92 (3.0%)	15.68 (2.6%)
Emergence-3rd leaf	2.78 (0.3%)	17.07 (2.8%)	14.29 (2.4%)
3rd leaf-Tillering	25.29 (2.4%)	30.92 (5.1%)	5.64 (0.9%)
Beginning of Tillering-Beginning of Stem Elongation	234.48 (22.4%)	107.12 (17.7%)	-127.35 (21.2%)
Beginning of stem Elongation-Earing	447.63 (42.8%)	179.05 (29.6%)	-268.58 (44.8%)
Earing-Flowering	129.89 (12.4%)	54.55 (9%)	-75.34 (12.6%)
Flowering-Grain Filling	127.88 (12.2%)	80.70 (13.3%)	-47.18 (7.9%)
Grain Filling-Maturity	70.54 (6.7%)	68.31 (11.3%)	-2.24 (0.4%)
Maturity-Harvest	6.06 (0.6%)	49.87 (8.2%)	43.81(7.3%)**

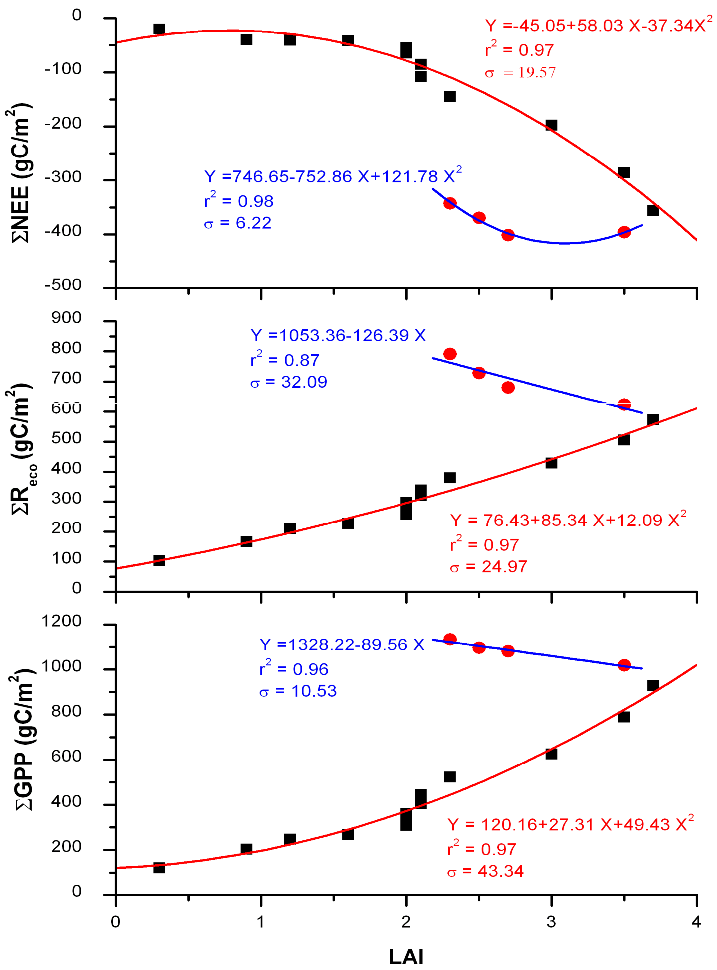
Biomass & Flux (NEE, GPP, Re)

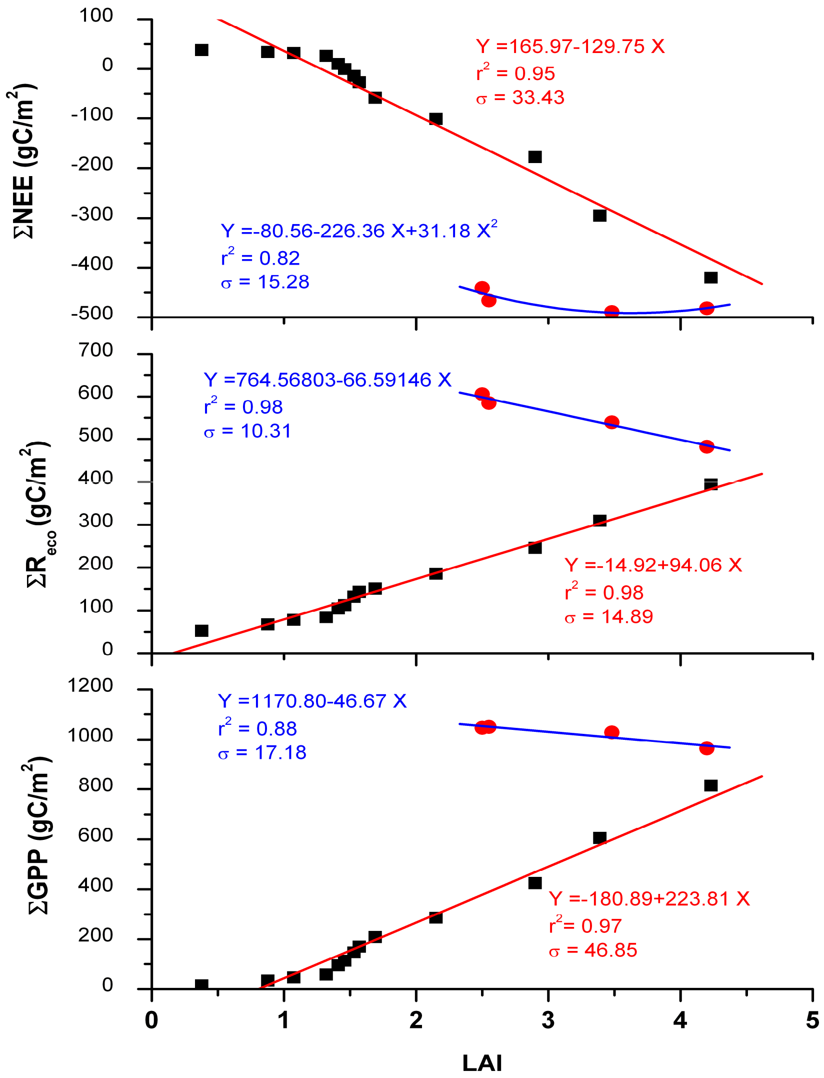


2009-2010

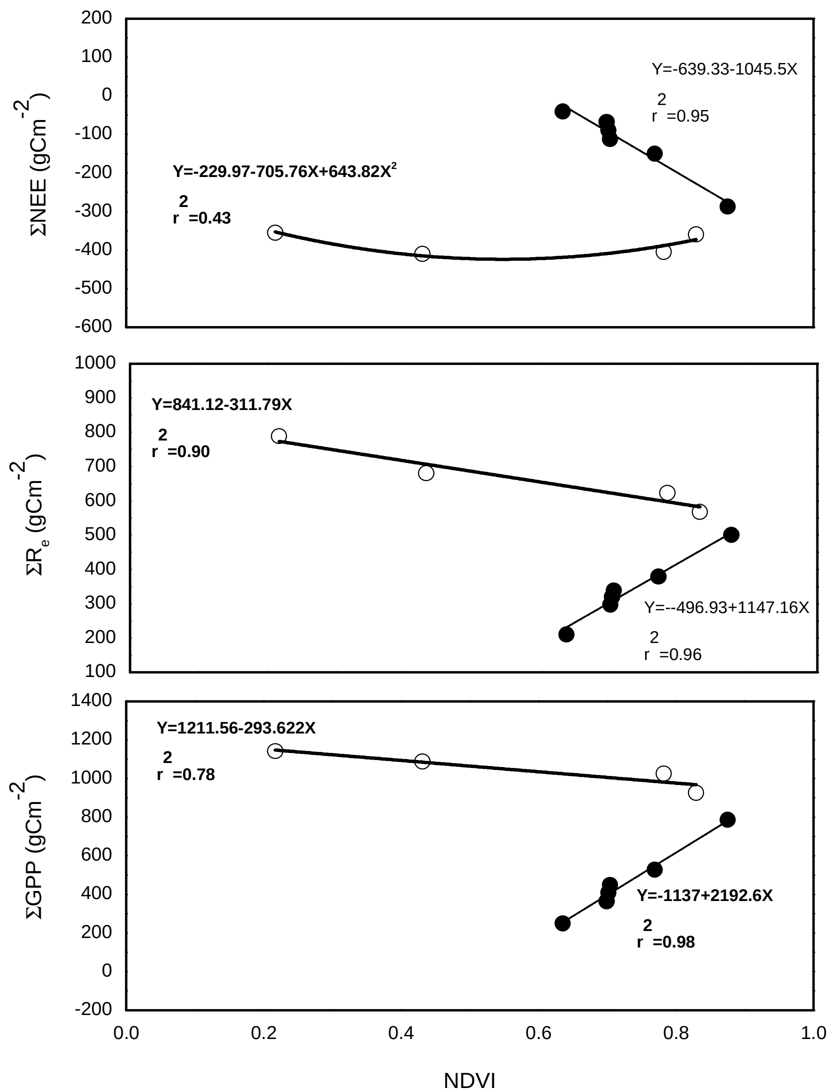
2010-2011

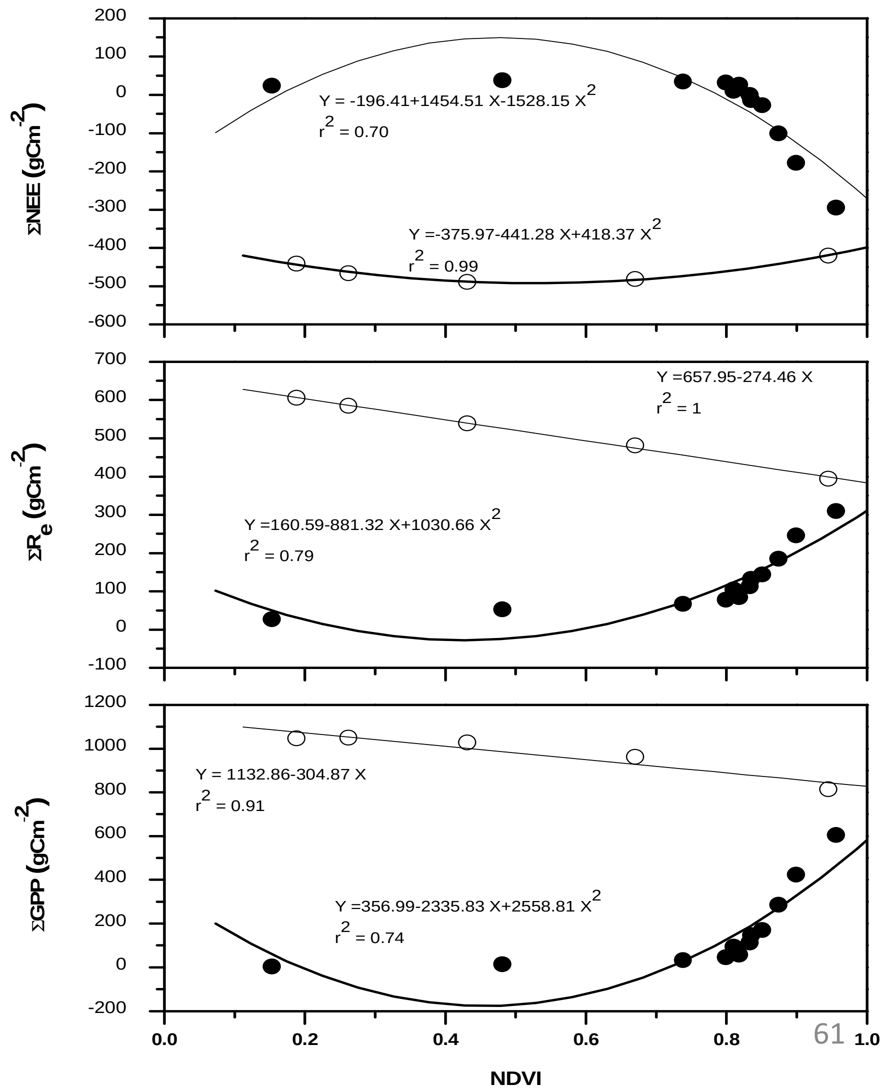
LAI & CO2 Flux


Y =-45.05+58.03 X-37.34X²
r² = 0.97
σ = 19.57
Y =746.65-752.86 X+121.78 X²
r² = 0.98
σ = 6.22
ΣNEE (gC/m²)
Y =1053.36-126.39 X
r² = 0.87
σ = 32.09
Y = 76.43+85.34 X+12.09 X²
r² = 0.97
σ = 24.97
ΣR_eco (gC/m²)
Y =1328.22-89.56 X
r² = 0.96
σ = 10.53
Y = 120.16+27.31 X+49.43 X²
r² = 0.97
σ = 43.34
ΣGPP (gC/m²)
LAI


Y =165.97-129.75 X
r² = 0.95
σ = 33.43
Y =-80.56-226.36 X+31.18 X²
r² = 0.82
σ = 15.28
ΣNEE (gC/m²)
Y =764.56803-66.59146 X
r² = 0.98
σ = 10.31
Y =-14.92+94.06 X
r² = 0.98
σ = 14.89
ΣR_eco (gC/m²)
Y =1170.80-46.67 X
r² = 0.88
σ = 17.18
Y =-180.89+223.81 X
r²= 0.97
σ = 46.85
ΣGPP (gC/m²)
LAI

NDVI & CO2 Flux





CONCLUSION

DATA SETS	NEE (gC/m²)	GPP (gC/m²)	Re (gC/m²)	GPP/Re
Kırklareli, Turkey (Saylan et al., 2011)	-398.0	1094.5	696.4	1.57
South West France (Beziat, 2009)	-369±33	-1310	982	1.34
Thuringia, Germany (Anthoni, 2004)	-185 & -245			

The difference between our average cumulative NEE and the estimated **NEE (-369±33 gC m^{-2}) by Beziat *et al*. [7] for Lamasquere/France is about 8 %**. The differences might be resulted from the crop genetic characteristics and crop management (e.g., fertilizers) and site specifications such as meteorological and soil properties, as Li et. al. [39] mentioned.

Generally, strong linear and nonlinear relations ($0.70 \leq r^2 \leq 0.95$) between NEE and vegetation dynamics during the first and the second growing seasons were obtained.

This study reveals that the major indicators of vegetation dynamics such as LAI, biomass, NDVI are strongly related to CO_2 fluxes of winter wheat.

For this reason, these variables are considered as significant predictors for the carbon exchange above winter wheat.

The results of this study pointed that the CO_2 fluxes between winter wheat canopy and atmosphere are under the influence of both meteorological and environmental factors.

Evaluation of long term EC measurements is necessary for testing the reliability of the relevant model results. Thus, carbon budget of winter wheat can be estimated for wide areas only depending on the long-term measurements.

In addition to these, there is an obvious need to measure, record and pursue fluxes, meteorological factors, vegetation dynamics such as NDVI, LAI and biomass continuously for different crop types. Measuring CO_2 fluxes together with observations and measurements on vegetation dynamics would give a chance to apply the results for larger areas by using available modeling approaches.

acknowledgement

- We thank «THE SCIENTIFIC AND TECHNOLOGICAL RESEARCH COUNCIL OF TURKEY for their continued support throughout the project named «Determination of carbon dioxide, water vapor and energy fluxes for winter wheat» and Istanbul Technical University (Scientific Research Projects Coordination Unit) and Atatürk Soil Water and Agricultural Meteorology Research Institute Directorate

Thank you for your concern…

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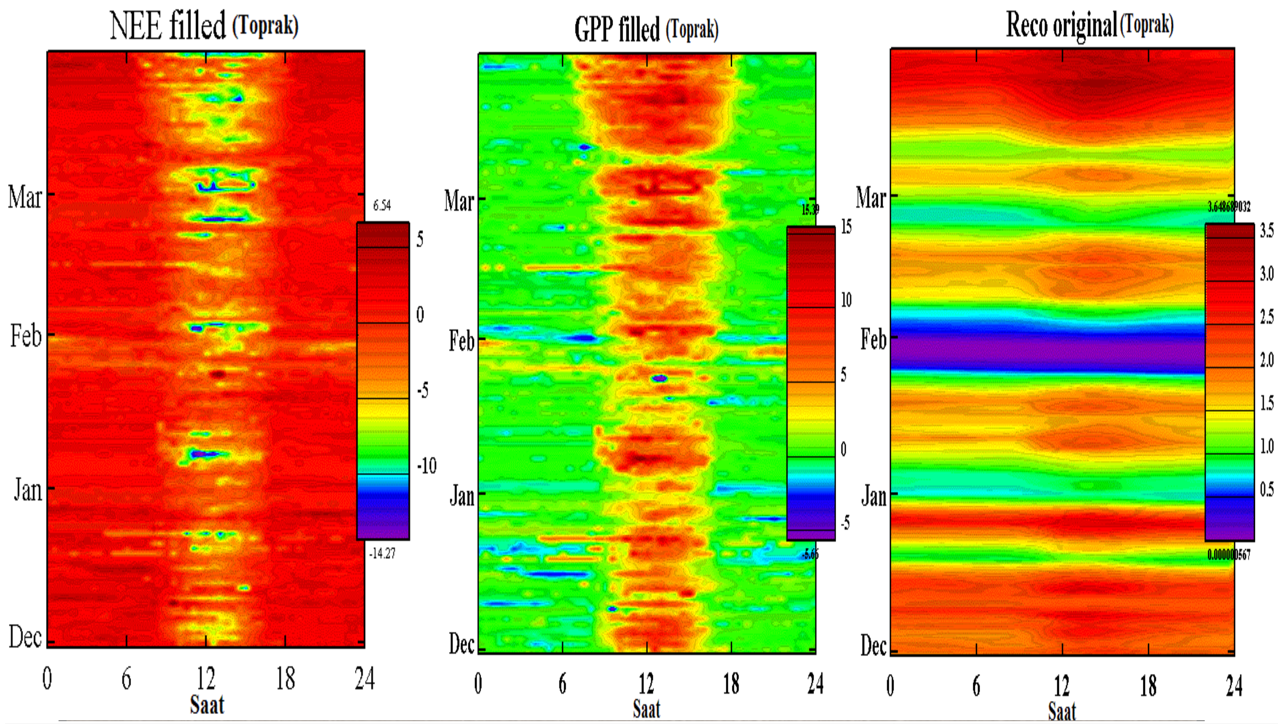
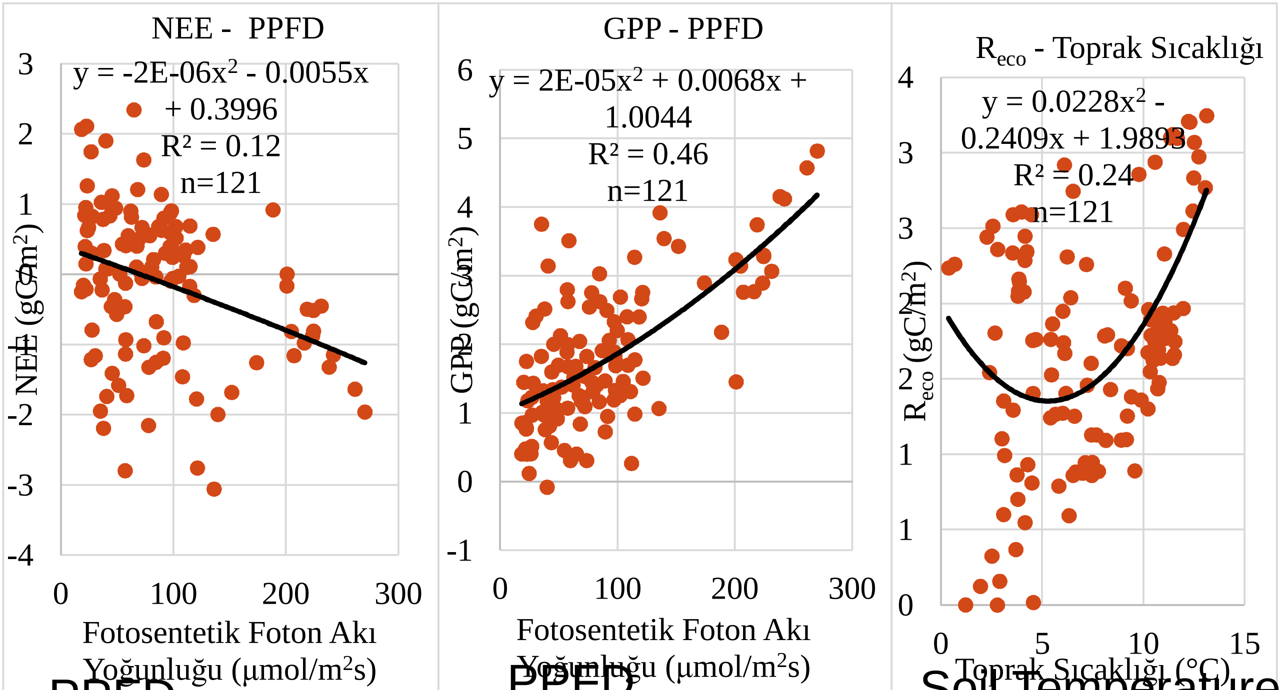
Meteorological Engineering Department
saylan@itu.edu.tr

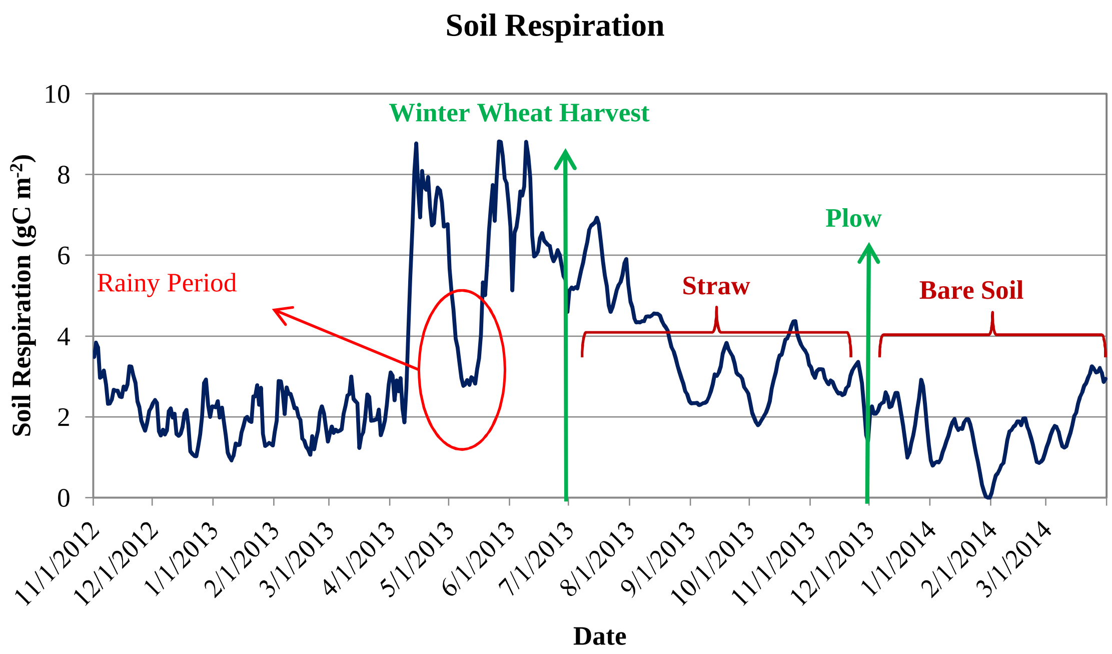
Results
Bare soil

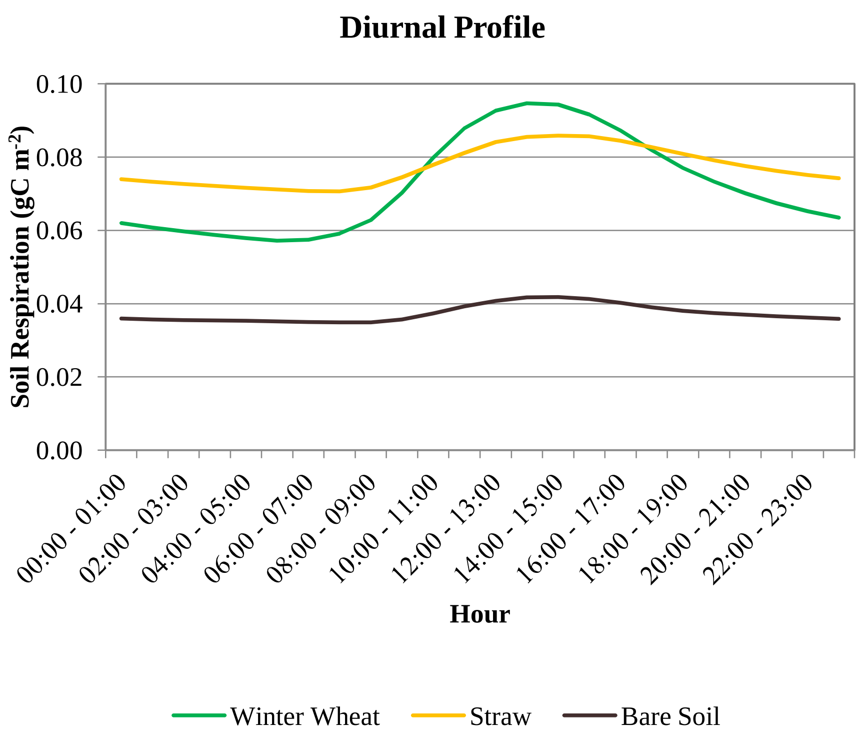




PPFD PPFD Soil Temperature (oC)

Results
Diurnal Profile





Results

Relationship between soil temperature and soil respiration below 10°C is much higher than above 10°C. In straw period, photosynthetic photon flux density (PPFD) has the best correlation (R^2= 0.48) with soil respiration. Soil temperature is not dominant in this period due to there is not any crop to cultivate.