TT2.3 Flux measurements for Agriculture
Report prepared by Dr. Elizabeth Pattey, Agriculture and Agri-Food Canada for TT2.3 Members

As one of the eight technical commissions of the World Meteorological Organization (WMO), the Commission for Agricultural Meteorology (CAgM) provides guidance in the field of agricultural meteorology by studying and reviewing the available science and technology. CAgM covers four Focus Areas. Task Team 2.3 on Flux Measurements for Agriculture was newly created as part of Focus Area 2 on Science and Technology for Agricultural Meteorology.

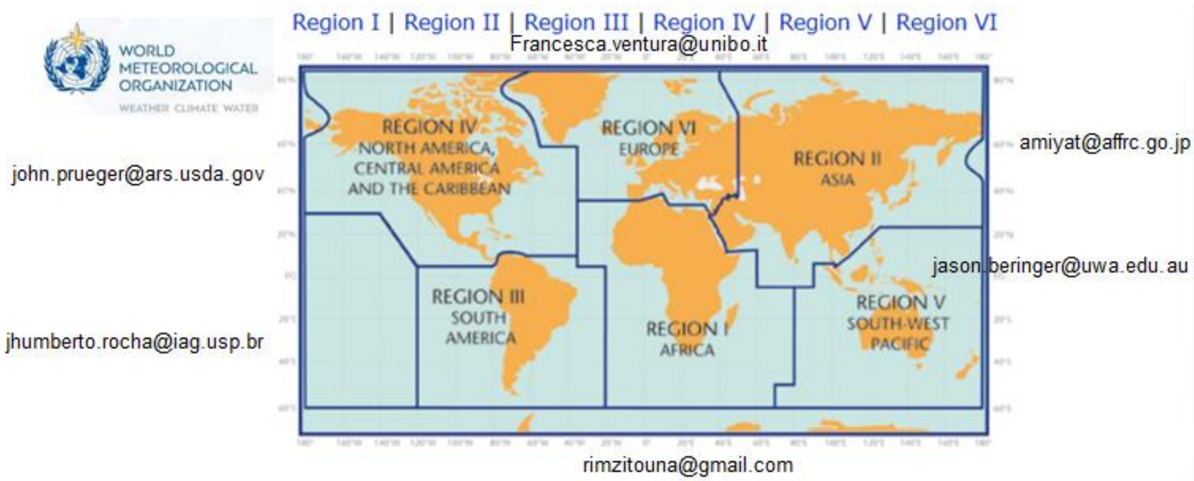
The terms of reference of Task Team 2.3 are as follows:

(a) Assemble a list of existing [long term] agricultural flux tower sites with a short description of the measured fluxes.
(b) Identify key experts for developing standards and regional guidelines of flux measurements for agriculture. Regional guidelines will account for the dominant constraints affecting flux measurements. The ad hoc experts will be invited to join the CAgM task team 2.3
(c) Provide a status report on the state of flux measurements for agriculture.

Measuring fluxes, (such as momentum, sensible heat, water vapour and carbon dioxide) in agroecosystems is usually performed close to a relatively smooth and homogeneous surface where eddies are small, with often limited fetch. Over the course of a year, substantial changes in the vegetation architecture and the processes dominating the mass and energy exchange take place. These conditions represent a challenge for setting up flux measuring systems and selecting appropriate instrumentation. Other regional constraints such as inclement weather, wildlife, dust, management practices could reduce the amount of valid flux measurements.

Task Team 2.3 will seek the input of the scientific flux community to help identifying globally 1) the flux measurement site locations relevant to agriculture 2) strategies to limit the impact of deleterious conditions on flux measurement and 3) standards and regional guidelines to be included in the mandate of a future expert team.

The task team membership was the following (Fig. 1):
Leader: Elizabeth Pattey, Agriculture and Agri-Food Canada
RA I : Rim Zitouna-Chebbi, National Researches Institute of Rural Engineering, Water and Forests, Ariana, Tunisia
RA II : Akira Miyata, Institute for Agro-Environmental Sciences, Tsukuba-shi, Japan
RA III: Humberto Ribeiro da Rocha, University of São Paulo, Brazil
RA IV: John Prueger, U.S. Department of Agriculture, ARS
RA V : Jason Beringer, University of Western Australia
RA VI: Francesca Ventura, Università di Bologna, Italy



1. Assemble a list of existing [long term] agricultural flux tower sites with a short description of the measured fluxes.

A spreadsheet template was circulated to the Task Team Members of the six regions for wider circulation through identified and referred Principal Investigators of flux tower sites measuring over crops, forage fields, improved pastures, and orchards.

The following information was collected:

Site information:

Site_ID; Site_Name; Network affiliation (if any); PI_name; PI_email; PI_Affiliation; Latitude (deg. dec.); Longitude (deg. dec.); Elevation (m); Mean Annual Temperature (oC); Mean Annual Precipitation (mm); Field/Orchard Area (m); Crop type; forage type; Improved pasture; Orchard type;

Turbulent Flux information:

Flux_data_Start_date (YYYY-MM-DD);
Flux_data_End_date (YYYY-MM-DD);
Turbulent Flux codes:
1- momentum+ sensible heat fluxes
2- 1+ latent heat flux
3- 2+ CO_2 flux
4- 3+ CH_4 flux
5- 3+ N_2O flux
6- 3+ NH_3 flux
7- 4+ N_2O flux
8- 5+ NH_3 flux
9- 8+ CH_4 flux

Weather data code:

1- weather station
2- 1+net radiation, soil heat flux
3 - 2+storage terms

Soil data code:

1- soil temperature
2- soil moisture
3- 1+2
4- soil fertility analyses
5- 3+4
6-soil respiration
7 3+6
8 5+6

Canopy data code:

1- canopy architecture
2- biomass
3- 1+2
4- plant composition analyses
5- 2+4
6- 3+4

Main management practices:

tillage
synthetic/organic fertilizers
irrigation
others

Soil texture
Drainage
Experimental objective
Environmental Challenges:

extreme temperature
heavy rainfall
flood
snow/ice
dust
hilly topography
wildlife
mesoscale circulation
others

The sources of information for assembling the listing varied by region:
RA I = expert knowledge (INRGREF; LISAH; CESBIO; UCAM);
RA II = Asiaflux;
RA III = expert knowledge (Embrapa: The Brazilian Agricultural Research Corporation);
RA IV= Ameriflux & expert knowledge (USDA; AAFC, universities);
RA V = Ozflux & expert knowledge (CSIRO; NIWA; Landcare Research; Universities);
RA VI= ICOS, CarboEurope, CarboItaly, GreenGrass.
The list is not exhaustive, but captured the main agricultural flux sites. The exact number of flux sites is not fully precise because of the annual rotation of crops, the presence of intermediate crops and the unknown numbers of flux towers measuring fields concomitantly. This would require modifying the structure of the survey to clarify these aspects.
Because a good proportion of the agricultural flux sites is not affiliated with a network, it will require advertisement to reach them. A step in this direction was made by presenting a poster introducing Task Team 2.3 on Flux measurements for agriculture at the FLUXNET Workshop, taking place in June 7-9, 2017, at Berkeley (CA). A web site accessible to flux site Principal Investigators and flux Network Managers would be very helpful to document the various agricultural flux sites and their level of activity.

The assembled list for the various regions reported the following numbers of flux site-vegetation type:
RA I = 18 (11 sites with 5 ongoing)
RA II = 32 (29 sites, with 26 ongoing)
RA III = 27 (19 sites, with 5 ongoing)
RA IV= 135 (~47 sites, with 34 ongoing)
RA V = 36 (21 sites, with 12 ongoing)
RA VI= 33 (~15 sites; with 15 ongoing).

The main crops monitored are:

-Rainfed: corn, soybean, wheat, sugarcane, canola, rapeseed, sunflower, coffee bean, fababean, barley, ryegrass, millet, hemp, chickpeas, peas, sorghum, crotalaria, Pigeon Pea, vegetables, watermelon
-Irrigated: rice (+flooding), wheat, sugarbeet, corn, soybean

The main forages monitored are: Hay meadow, alfalfa, oat, other legumes, switchgrass, sabi grass, rhodes grass

Improved pasture: Brachiaria brizantha, ryegrass-clover pasture, grass pasture, ryegrass pasture

The main orchards monitored are:
citrus (e.g., oranges), olive, apple, palm oil, Japanese pears, cassava, Eucalyptus, Cerrado, vineyard.

All the flux towers measure momentum, sensible and latent fluxes.
Turbulent CO_2 fluxes is reported in 22% of RA I; 88% of RA II; 100% in RA III & RA VI; 95% in RA IV; 89% in RA V. Turbulent methane fluxes are marginally reported 6% in RA II&VI; 4% in RA IV; 17% in RA V. The reported methane and nitrous oxide flux measurements in RA III seemed to come from enclosures and not micrometeorological towers, so they were not considered in the statistics.
Turbulent nitrous oxide fluxes are marginally reported 3% in RA II&V&VI. It is significantly measured in RA IV, reaching 34%. Turbulent ammonia flux measurements are almost non-existent.

Turbulent Flux global measured:	#Sites
1- momentum+ sensible heat fluxes	1
2- 1+ latent heat flux	19
3- 2+ CO2 flux	92
4- 3+ CH4 flux	15
5- 3+ N2O flux	6
8- 5+ NH3 flux	1
9- 8+ CH4 flux	1
Total	145

Although agriculture contribute to the release of reactive nitrogen that cascade through the environment (Galloway et al., 2003), turbulent reactive nitrogen fluxes (e.g., nitrous oxide, ammonia, nitric oxide) are marginally measured using flux towers, because they often require complex and costly laser-based instrumentation. Enclosures are preferred in site deployments because they are more accessible, although they do not properly capture the appropriate scale of measurement (i.e., the field or the canopy) and often lack the time resolution and the ability to measure from soils at high water content.
In the case of methane, the instrumentation being more accessible, turbulent flux measurements are more often implemented where large emissions are expected (e.g., rice paddies).

The most frequent environmental challenges reported are:
flood, dry summer, extreme cold, heavy rainfall, snow/ice, dust, hilly topography, wildlife

Across the regions, the main experimental objectives are related to irrigation and water use, crop rotation, management practices (fertilization, tillage, grazing intensity, etc.), quantifying greenhouse gas and other reactive nitrogen fluxes in relation to management practices, land use change (e.g., savanna to pasture) , impact of climate variations. Although the information we have so far is not complete, the tendency is to run almost year round. About one third of the sites (Fig. 2) are not part of a network. This proportion might even be higher because the flux sites belonging to networks being easy to track could be overrepresented.

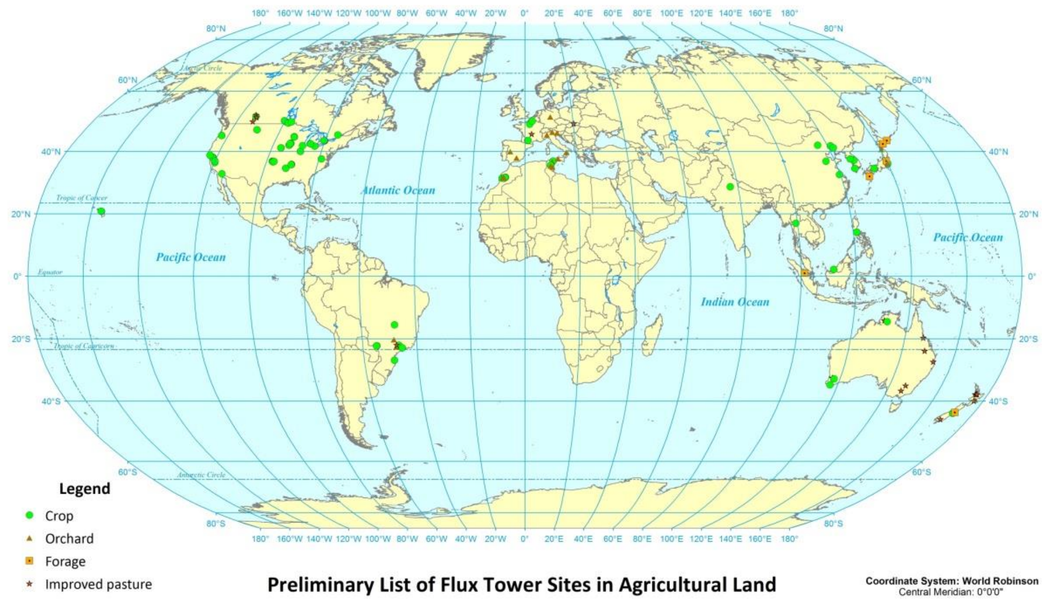


Figure 2. Preliminary inventory of the flux towers (~149) in crop (97) and forage fields (8), improved pastures (22) and orchards (22).

Referring to Fig. 3, more tower flux sites could be added in agricultural areas important for ensuring global food security.

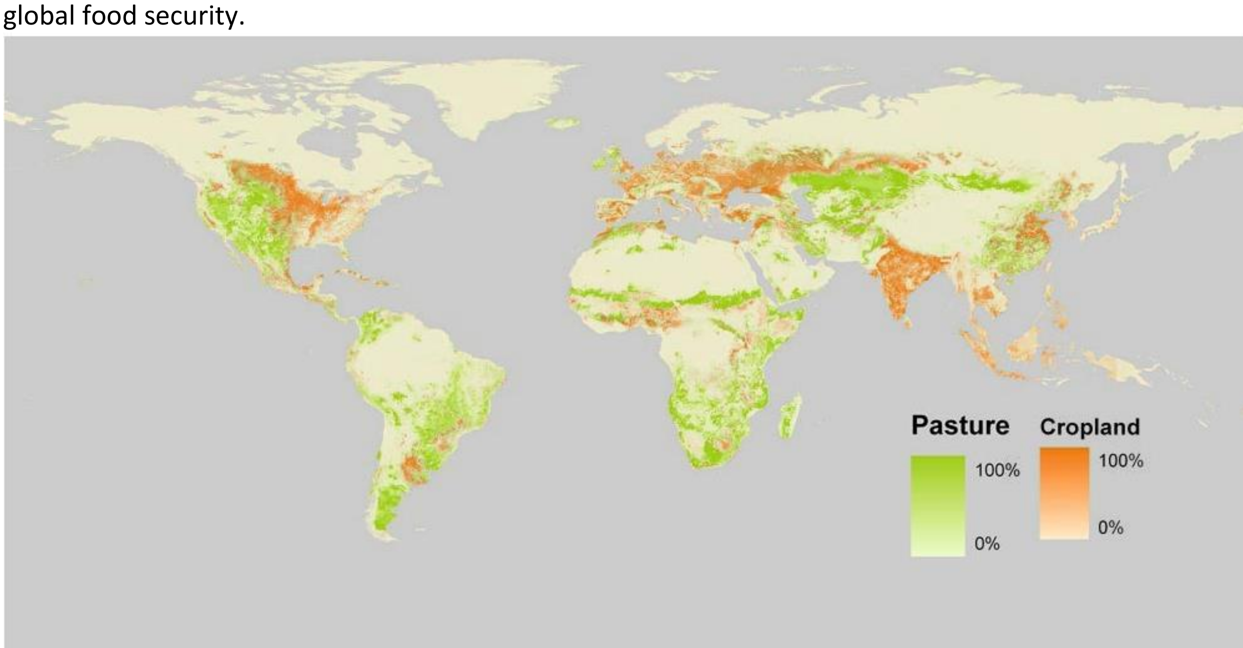


Figure 3. World map of cropland and pastureland established by the Center for Sustainability and the Global Environment (SAGE) at the University of Wisconsin-Madison in 2005.

Assembling a list of existing agricultural flux tower sites with a short description of the measured fluxes is a work in progress. The initiative needs to be continued to get a more accurate picture of the effort devoted by region; for example, India is installing ~40 flux towers that are not included in the database yet.

It is recommended that WMO CAgM establishes and promotes a Web portal for collecting the flux tower sites in agriculture that could be populated and edited directly by either the Principal Investigators or the flux Network Managers. The requested information takes about 15 min per site to fill, so this is not too demanding, compare to the pay back of being able to identify the lack of coverage of certain vegetation types and agroclimatic regions. A detailed documentation should be prepared in support of flux site information collection.

2. Identify key experts for developing standards and regional guidelines of flux measurements for agriculture.

Dr. Thomas Foken, recently retired from University of Bayreuth, was approached during the 2017 Fluxnet meeting (Berkeley, CA) and accepted to join task team 2.3 for contributing to developing standards and regional guidelines of flux measurements for agriculture. In addition to its very productive contribution to scientific papers and books in micrometeorology (https://www.bayceer.uni-bayreuth.de/mm/en/pub/pub/pub_alle.php), Dr. Foken led the development of guidelines for Meteorological measurements for the Federal Republic of Germany (VDI 3786, 2006).

Recruiting experts to develop standards and regional guidelines of flux measurements for agriculture would be more effective if a few meetings were planned to set the stage, realign and resolve issues during the development, and finalize the standards and regional guidelines.

We recommend that WMO CAgM considers upgraded the Task team 2.3 status to thus of an Expert Team in order to establish a meetings and deliverables calendar in support of developing standards and regional guidelines of flux measurements for agriculture.

3. Provide a status report on the state of flux measurements for agriculture.

This report constitutes the fulfillment of the term of reference.

The development of standards and regional guidelines of flux measurements for agriculture will build on on-going initiatives such as:

NEON (http://www.neonscience.org/observatory/about),

ICOS RI (Integrated Carbon Observation System Research Infrastructure, https://www.icos-ri.eu/about-us),

and liaise with the:

WMO Commission for Atmospheric Sciences (https://public.wmo.int/en/our-mandate/how-we-do-it/technical-commissions/commission-atmospheric-sciences-cas) and

WMO Commission for Instruments and Methods of Observation (https://public.wmo.int/en/our-mandate/how-we-do-it/technical-commissions/commission-instruments-and-methods-of-observation-cimo).

The initiative will contribute to develop, share and report innovative solutions to address and overcome environmental challenges and provide regional guidelines to account for the dominant constraints affecting flux measurements from agroecosystems and to establish standards for measuring fluxes often close to the surface and with limited fetch. The standards are particularly needed for trace gas fluxes such as methane, nitrous oxide and ammonia, which involves laser-based equipment and sophisticated instrumentation setup.