FCN-LCF Pilot Project
Our search for suitable Gas Analysis

A short semi-technical summary of estimating Greenhouse gases (GHG) from cropland gas samples

The Low Carbon Farming (LCF) initiative of the Fair Climate Network (FCN) is setting up GHG monitoring experimental plots (also called Reference Plots) in 4 Agro Ecological Zone Sub-Regions (AEZ SR) representing major crops and major soil types of the region. The experimental plots will have a single parameter test for GHG emissions: a) Mainstream Agriculture and b) improved or log GHG agriculture.

Hypothesis Under Test

"Optimized and low external input agriculture emits less GHGs than current Mainstream Agriculture"

Mainstream Agriculture refers to the complete system of general/common management of a particular crop especially characterized by inefficient management of mineral nitrogen. The high dosage of inorganic (synthetic) fertilizer and improper timing of applications or dosages lead to very low Nitrogen uptake by the plants and on the other hand, volatization and losses in the form of Nitrous Oxide (N_2O) increases.

Sustainable Low GHG Agriculture on the contrary addresses these issues and optimizes the system of crop management such that there is increase in the uptake of Nitrogen by the crops and altered management ensures least N_2O emissions thereby increasing the Nitrogen uptake by the crop and hence the yields.

The experimental plots have a single agenda of comparing mainstream 'system' of agriculture with the optimized and low GHG system of Sustainable Agriculture.

What do the Reference Plots represent?

The Reference Plots being set up are unique and first of its kind in India (or at least not a common thing!) where the crop is managed by actual farmers and not scientists. These plots truly and fully represent the real situation as there is no alteration or change or deviation in the practice from the ones in the experimental plots to what any random farmer actually does in his small piece of land. This is especially true for the Mainstream Plots. Even the SA Plots are not the best optimum practice which a very highly skilled agronomist can achieve, but the farmers' interpretation of the recommended SA package of practices. Hence the GHG emission difference between these two systems will be the real actual than an exaggerated high optimum. This makes the experiment extremely conservative, real and not a desired projection.

PURPOSE OF SETTING UP REFERENCE PLOTS

Reference Plots are aimed to serve as test points where all technical rigorous parameters of the crop management system will be studied and continuously monitored. Technically these are experimental plots where agronomic parameters will be monitored with very high rigor. These Reference Plots are to study the response of different cropping systems in terms of crop development, yields and very importantly GHG emissions to altered and optimized crop management systems. Hence there will be two set of plots for each crop:

a) Mainstream Agricultural (MA) system and
b) Altered, optimised and low GHG agricultural system (Sustainable Agricultural system)

The set of alterations and improvements in the crop management is referred as "Package of Sustainable Agricultural (SA) Practices". The Reference Plots will serve two purposes:

c) Site for rigorous calibration of process based model DNDC for emission assessment, and
d) Validating the DNDC model emission projections and comparing with the field actual

The long-term objective is to make emission assessment in semi-arid small holding agricultural systems simpler. Hence all these exercises have been carefully designed to incorporate aspects to understand the most important set of parameters that affect GHG emissions. The relationship between type and quality of agricultural inputs (fertilizers/manure and nitrogen content for example) and their contribution to GHG emissions under different agricultural systems (MA and SA) will be established, leading to elucidation of 'Emission factors'. Further, the whole set of parameters such as AEZ, soil type, rainfall pattern, will provide us with a test bed to understand and derive the those relationships which affect the GHG emissions most in this semi-arid region. For example, paddy fields in Anantapur, Pudukkottai and Tirunelveli provide us with a test as to how soil type, rainfall and temperature affects GHG emissions. Also the test for effect of management on emissions will be done as there will be enough of variation from one set of plots to other (MA and SA management in those 3 districts differ).

Determination of a 'general' System of Crop Management

A sample questionnaire survey was conducted to understand all aspects of crop management. Data from questionnaire survey was compiled to arrive at a descriptive representation of the crop management and average values for farm inputs. Experienced and knowledgeable farmers were interviewed to reflect on the common general method of management for a particular crop-season in a given standard condition (soil type, irrigation source and other parameters) of the region. Parameters such as major variety cultivated, major soil type, general sowing date, irrigation method etc., were determined. This whole crop management as practiced by a mainstream farmer is referred as system of Mainstream Agriculture (the word "system" is used to represent crop + crop management). This is not a precise description of any one particular farmer but a general average situation of all mainstream farmers in the region. The most important parameters considered, apart from all finer parameters, are listed below. These parameters are crucial as they are the ones which are altered or improved in the low GHG agricultural system being promoted.

- *Sowing and crop mix*: time and method of sowing; crop mixes
- *Chemical fertilizer application*: type, dosages, application method
- *Manure application*: type, level of composting, method of application, dosage and timing
- In case of paddy, water regimes: flooding events

Package of SA Practices

This has been worked out with rigorous rounds of discussion and design, coupled with brainstorming with different stakeholders such as farmers, lead farmers, partner NGO expertise and agricultural scientists. Aspects to reduce GHG emissions from croplands without affecting yields have been built in to the package of practices. These practices have been simplified and reduced to few descriptive lines of recommendations so that both, field staff as well as farmers who actually implement, will find it easy.

Reference Plots

Each crop system (Crop + MA or SA) will be represented in triplicate plots in the respective regions. For example, BEST for Pudukkottai region has selected Groundnut and Paddy as the 2 crops which they will deal with in the pilot phase. For each of these, a single Package of Practices has been finalized. Hence there will be 2 crops x 2 system of management (1 MA and 1 SA) x 3 replicates which is 12 plots. 12 plots will be set up on the lands of identified farmers, considering soil type and accessibility. A schematic representation of the Reference Plots for Pudukkottai (BEST) is given below (Figure 1).

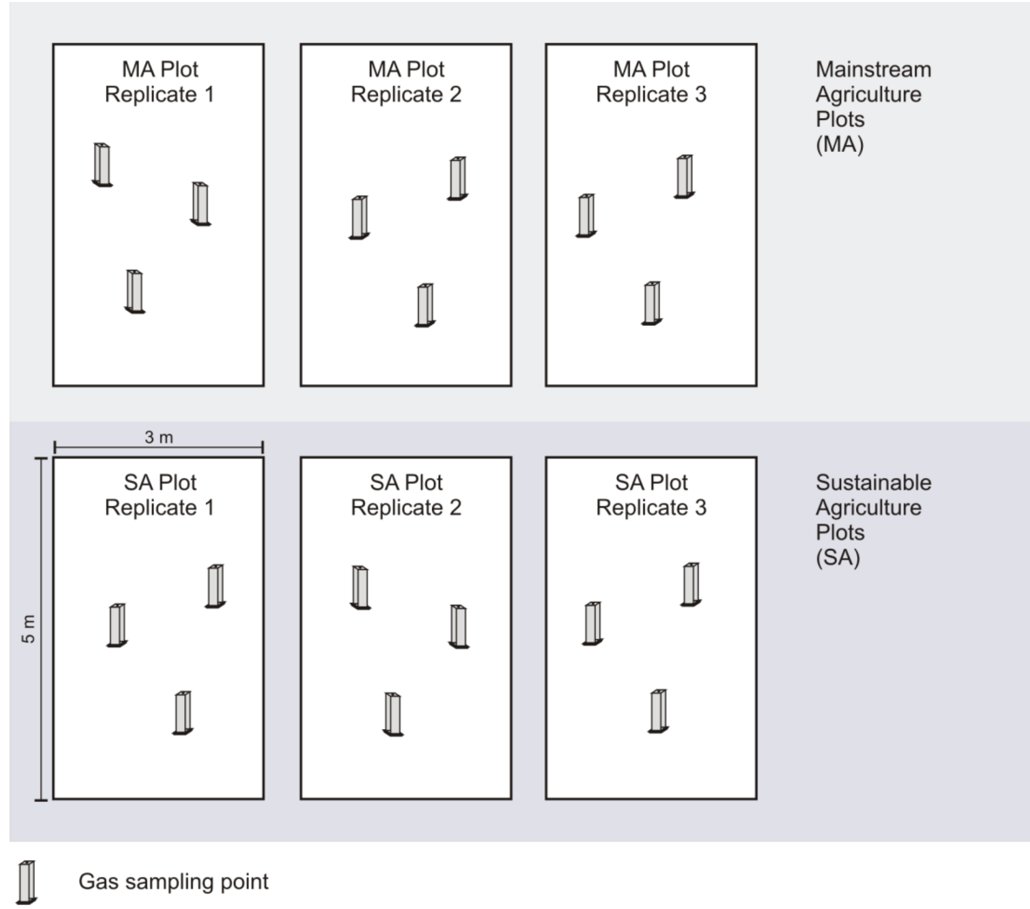

Figure 1: Schematic representation of the experimental plots for GHG monitoring.

GAS SAMPLING

In each Reference Plot, as detailed in the previous section, gas samples will be drawn using closed Perspex (acrylic glass) boxes of fixed dimensions. Gas samples will be collected once a week, during the peak photosynthesis periods (10:00 to 12:00 hours) of the day. Gas sampling is a time and volume constrained procedure. A known area of cropland (0.25 x 0.25 m) is isolated for a fixed period (60 minutes) to draw a fixed volume of gas sample (20 ml) from the saturated chamber using a gas sampling syringe at 0th minute, 30th minute and 60th minute.[1]

The procedure involved in gas sampling is detailed in Box 1. The tools/equipments mentioned below have been described in Figure 2. In addition to these main monitoring, there will be series of experiments to understand spatial variability, daily fluxes, diurnal changes and other parameters. These plots will therefore serve as very rigorous research plots to enhance the understanding GHG emissions from semi-arid croplands.

[1] Ideally, replicate samples for a given time point has to be taken from each box. However this step has been avoided to reduce the sample number and complexity involved in designing the sampling plan.

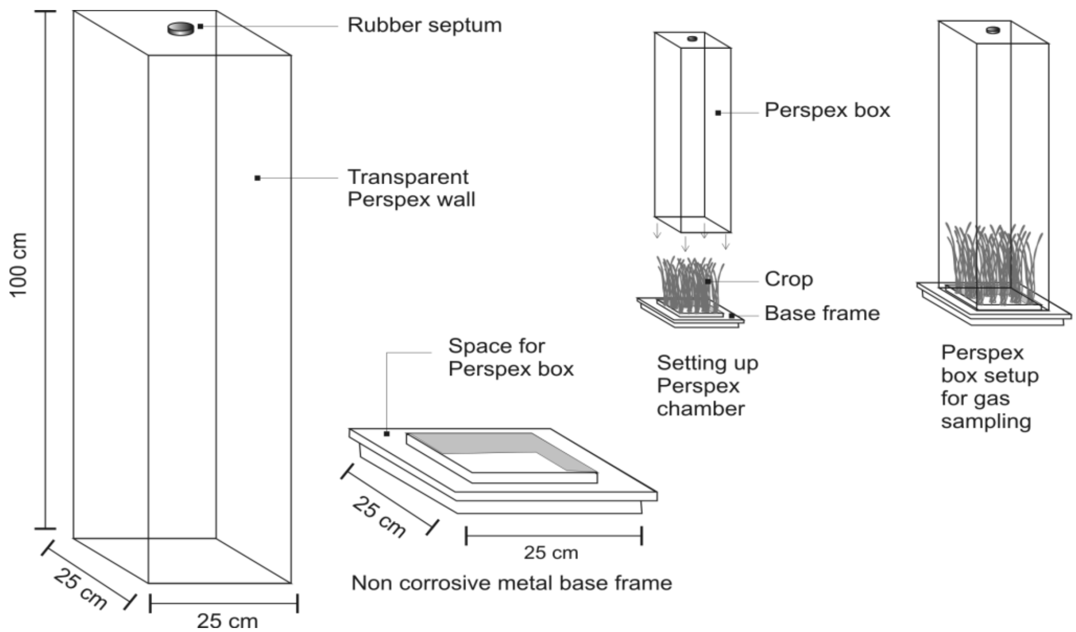

Figure 2: The Perspex chamber and base frame: dimensions and assembly

Box 1: Steps involved in drawing gas samples from closed chambers

Step 1: Fix the non corrosive metal frame in the plot to be sampled; cover the basal portion with a little soil for isolation

Step 2: Put the Perspex box on the metal frame and isolate it from the external atmosphere by pouring a little water in the space provided in the metal frame

Step 3: 0^{th} minute gas sample: Using a 20 ml syringe with a three way stop cock draw the 0^{th} minute gas sample (Immediately after setting up). First push out the air in the syringe and make sure the stopper is open. Inject the needle into the rubber nozzle on the top of the Perspex box. Pull the piston of the syringe to draw the gas inside the Perspex box. Close the stop cock and remove the needle from the rubber.

Step 4: Transfer the sample to Vacutainer: evacuate a vacutainer by repeatedly drawing the air in the tube with a separate syringe. Once certain that a vacuum is created, inject the needle of the syring with 0^{th} minute gas sample and release the stopper. Transfer the entire gas sample to the vacutainer and carefully remove the needle.

Step 5: Follow Step 3 and 4 again at 30^{th} minute and 60^{th} minute after setting up the Perspex box and transfer them into respective pre labelled Vacutainers.

The procedure in Box 1 is to draw time staggered gas samples from a ‘single’ Perspex chamber. On each Reference Plot, 3 chambers will be set up, and 3 time point gas samples will be drawn from each of them. There can be a difference of 10 minute in setting up the next box for practical purpose, but a stop clock has to be used to make sure that time is precisely maintained. Ideally samples have to be drawn parallel.

Hence from a single plot, there will be 9 gas sample drawn every single week for the whole crop cycle. MA and SA plots and their replicates (3 replicate Reference Plots) have to be sampled on the same day within a comfortable/practical time-frame. This needs rigorous and systematic site specific planning. For the BEST region, for one crop, there will be totally 54 samples drawn from the experimental plots every week. We can sample one crop per day so that sample load is minimum or manageable. Before sampling next crop, a day's gap is advisable.[2]

Every week, the samples have to be taken with an exact gap of 7 days.

Gas Analysis

The collected gas samples have to be analyzed immediately, or within 24 hours. Temperature difference and handling are very difficult and it is best to immediately analyze the gas samples. To analyze gas samples, a Gas Chromatography (GC) is used where a known quantity (few µl of gas sample) is fed with a carrier gas in a particular temperature through a specialized coil which propels it to sensors. Sensors adopt different technologies to quantify the component gases and electric signals are plotted as chromatogram peaks. The location of these peaks represents the individual gas and the area and width of each peak represent the concentration.

For Nitrous Oxide (N_2O), Electro Capture Detector (ECD) is required whereas for Methane (CH_4), Flame Ionization Detectors (FID) is needed. There are chromatographs with multiple detectors and depending on these detectors, the Gas Chromatographs can analyze different samples.

There are another set of devices available in the market which are commonly referred to as portable analyzers. These are mostly Combustion Analyzers and most of them do not have ECD which makes it useless for N_2O analysis. Furthermore, there are Combustion Analyzers which use a probe method, used to detect leakage in industries or refineries. These devices have probes that can detect and provide an estimate of combustion emission gases. However, these are not useful for our purpose for the following reasons:

[2] Analysis of one gas sample for one gas need 6-10 minutes. Hence 54 samples means a whole day's work which may stretch till late evening. Hence a day's gap in sampling next crop is advisable – see the next sections below for the gas analysis details

- They normally do not have ECD detectors.
- They do not have an option for sample injection/input which is crucial for estimating a particular gas in a known volume of sample. Detector probes are inaccurate in analysing gas concentrations.
- Detection range is much coarser than what we need to detect.

There are portable Gas Chromatographs, but with ECD (needed for N_2O), they are bulky. Again the concentration ranges that portable ECD can handle is too coarse for our purpose. These detectors are usually of >1000 ppmv[3] concentration sensitive whereas our cropland gas samples would be just a few ppmv concentration. Hence we need high precision detectors which makes the portable Gas Chromatograph option non practical.

There are portable methane analyzers with FID. Since N_2O is the major gas of concern in ALL our experiments, with CH_4 only for paddy, the Gas Chromatographs we are procuring would be much more efficient to handle FID in addition to ECD. Separate FID is a costly option and there are no Indian manufacturers of such portable devices (the detection of very low concentration is very important for us). Hence the option of Gas Chromatograph was decided.

Gas Chromatographs

All possible Gas Chromatograph manufacturers, global and national, were contacted. Although there were a lot of dealers and assemblers, there were very few manufacturers who are into custom made Gas Chromatograph suiting our purpose. The major companies manufacturing GCs include Agilent, LGR, ALM, SRI, Shimadzu, Thermo Fisher and Parkin Elmer. Out of this, Thermo Fisher was the cheapest. SRI did not send a formal quote but the prices are displayed online. Each instrument is priced at US$ 20,000 (accessories, carrier gas and other fixtures not included). In addition to taxes, we also have to bear import duty. This was ruled out at the first instance. Another International Company sent the technical description which suited out purpose very well (going up to the precision of ppbv[4]) but did not send a formal quote. Informal telephonic conversation with the contact person quoted a price of ₹ 60,00,000 plus taxes and duty. This again was an impossible option. There were several other International companies which were dropped due sky high price.

Thermo Fisher provided a decent option. The technical requirement was met with a full fledged FID-ECD Gas Chromatographs with options to inject sample with split valve. The Gas

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[3] ppmv = parts per million by volume

[4] ppbv = parts per billion by volume

Chromatographs system with the unit, methanizer, calibration gas and software has been quoted at ₹ 8,94,840 (+ 12.5% VAT + 10.3% Excise Duty). This includes Carrier gas cylinders which are sufficient for one year worth samples (calculated on the earlier described plot setup and design).

SUMMARY

The search from scrap to detectors to portable analyzers ended in Gas Chromatographs. Apart from budgetary constraints, Gas Chromatograph with FID and ECD is the best and only practical option for us. Especially considering the number of samples we are handling. All other options do not confer/suit our requirement. We know even outsourcing is an impossible option due to the distance factor and need to analyse gas samples within 24 hours, on an every day basis, apart from high cost.

A detailed discussion with Prof. Param (UAS, GKVK) affirmed that this option is the only workable one. He also explained the age old Gas Chromatographs instrument in his lab from company Chemito. Chemito which is now merged with Thermo Fisher. He also came up with the same set of companies who manufacture Gas Chromatographs whom we had already contacted.

The video of Prof Param explaining the Gas Chromatographs in his lab have been uploaded to YouTube at http://www.youtube.com/playlist?p=7977EEFF4BF44C36

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