Introduction

According to the Gaia theory, earth’s physical and biological processes are linked to form a self-regulating and self-aware system. The regulating processes are often slow and continue over decades or even centuries. With the increasing human interventions; appropriation of most of the natural resources in a hasty manner to fulfill the need and greed of human desires, ultimately causes huge strain on the entire earth’s natural resources and its synergic eco-systems. These man-made interventions force the natural eco-system to act impetuously to adopt the exterior interference. This is reflecting as increase in temperature, increase in the intensity of heavy storms, flood, longer drought periods, unseasonal rain events etc. All summed as the effect of climate change. Scientists from different corners of the world echo for the timely need to protect life on planet Earth from possible adverse effects of climate change.

On 2nd Oct. 2016, India has ratified the Paris Agreement on Climate Change and has pledged to improve the emissions intensity of its GDP by 33 to 35% by 2030 from 2005 levels. While per capita emissions are only 1/3rd of the global average, India is the 4th largest Greenhouse gas emitter in the world. Indian agriculture sector ranks 3rd in contribution of the country’s total greenhouse gas emissions.

To meet the demand for food for the growing Indian population, agricultural productivity has to be increased. Uses of chemical fertilizers, high yielding crop varieties and adoption of farm mechanization have proven to be effective ways to increase agricultural productivity. Studies have shown that the excessive use of nitrogen based chemical fertilizers deteriorate the soil health and became the major cause for greenhouse gas emissions (especially N₂O) from agricultural soils. Nitrous Oxide (N₂O) has a global warming potential equivalent to 298 times as that of CO₂ for a 100-year timescale.

WOTR is always promoting the sustainable agricultural practices in the region. The package of practices are developed and promoted among the farmers to attain better soil health, use of local/organic resources as agricultural inputs and achieve higher yield. Thus, we found it necessary to quantify GHG emissions from agricultural production systems with various ongoing agricultural practices. In collaboration with GIZ and CIAT, WOTR had undertaken the study to assess the impact of various soil conservation practices on Greenhouse Gas (GHG) Emissions from agricultural soils.
Study area

The study area was located in Parner block of Ahmednagar district, Maharashtra. The experimental project site was located near Bhalwani village (19.113157°N and 74.550047 °E). The villages in Parner block are characterized by hot summers and a generally dry climate except during the south-west monsoon season. The study area falls in the semi-arid region of Ahmednagar district. The south-west monsoon is the major source of annual precipitation which generally starts the 2nd-3rd week of June and last until October – the kharif season. The region also receives some (return monsoon) rainfall from mid-October to November during the rabi season. The annual rainfall is less than 450 mm.

The experimental plots were located in ‘hot semi-arid eco region with shallow and medium (dominant) black soils’. A detailed analysis of the soil from the experimental plots showed that the soil texture is clay (67% clay, 16% sand and 17% silt), with a bulk density of about 1.26 g/cm$^3$ and a particle density of 2.72 g/cm$^3$. Detailed information on soil properties from the experimental plots are given below (Table 1).

<table>
<thead>
<tr>
<th>pH (°)</th>
<th>EC (dS/m)</th>
<th>OC (%)</th>
<th>Available N (kg/ha)</th>
<th>Available P$_2$O$_5$ (kg/ha)</th>
<th>Available K$_2$O (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.53</td>
<td>0.28</td>
<td>0.87</td>
<td>243</td>
<td>10</td>
<td>321</td>
</tr>
</tbody>
</table>

Green gram (*Vigna radiata*) was selected for the GHG emission study as it is grown by most of the farmers in the area. Being a leguminous crop it has the ability to fix the nitrogen from air to soil. In total, 5 main treatments and 2 sub-treatments with 3 replications (30 plots) were designed to assess the impact of different agricultural practices on agronomic performance and GHG emissions.
Objectives of the Study

a. Compare agronomic performance of different nutrient/fertilizer (organic and in-organic) combinations
b. Assess the impact of various nutrient management practices on Greenhouse Gas (GHG) emissions from agricultural soils

Main Treatments

1) Farmer’s Practice – The plots under this treatment were managed as per the current farmer’s practice in the region, with the same fertilizer source and crop protection treatments as being applied by local farmers.
2) Chemical Fertilizer – The plots under this treatment received 100% of the recommended dose of chemical fertilizer.
3) Integrated Nutrient Management (INM) – the plots under this treatment received 50% of the recommended amount of chemical fertilizer and remaining 50% were added in the form of vermi-compost.
4) Organic – The plots under this treatment received 100% of the recommended dose of nutrients in the form of vermi-compost.
5) Controlled Treatment – No fertilizer was added to the plots under this treatment.

Sub Treatments

A) Seeds without treatment – Good quality seeds were used for sowing and standard sowing practices were followed.
B) Seeds with treatment – Seeds were treated with bio-fertilizers/inoculants (Rhizobium and Phosphate Solubilizing Bacteria-PSB) prior to sowing.
### Table 2: Amount of elemental nitrogen (kg/ha) applied to the various main treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fertilizer</th>
<th>20:20:0</th>
<th>DAP</th>
<th>Urea</th>
<th>Vermi-compost</th>
<th>SUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (Farmer Practice)</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>T2 (Chemical Fertilizer)</td>
<td>0</td>
<td>15.6</td>
<td>9.4</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>T3 (50% Chem., 50% Organic)</td>
<td>0</td>
<td>7.8</td>
<td>4.7</td>
<td>12.5</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>T4 (100% organic Fertilizer)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>T5 (No Fertilizer)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Methodology for N\textsubscript{2}O measurements

A low cost static chamber method was used to measure the GHG fluxes from the agricultural field. Using a syringe, gas samples were collected 14 times during the season from all experimental plots. Samples were collected in evacuated glass vials at 0, 15, 30 and 45 minutes after the top chamber was mounted on the base ring. To avoid diurnal variations, the sampling start time was fixed to 10:30 a.m. Along with the GHG gas sample collection, some environmental parameters, namely soil temperature, ambient air temperature and the temperature of air inside the static chamber were recorded, while the daily weather data was recorded from an automatic weather station installed by WOTR within the vicinity of the site.
Farmers’ Exposure Visits

- WOTR organized farmer field schools and exposure visits to the GHG experimental plots to build awareness on the crucial issue of greenhouse gas emission and climate change.

- As the experimental design included various nutrient treatments which were demonstrated next to each other, farmers could easily identify the difference in the plant growth parameters and experience the difference among various chemical and organic nutrient treatments.

- The positive response of Green gram to the application of vermi-compost either alone or in addition to mineral fertilizer was very encouraging.

As most farmers in the region are mixed crop-livestock enterprises and therefore manure is readily available, the production of vermi-compost is a viable strategy to significantly reduce production costs by either completely eliminating the financial expenses for mineral fertilizer, or reducing these expenses significantly (50% in our case).
Results and Discussion

• Green gram yields ranged between 0.72 & 1.20 t/ha. Results showed that, Green gram production can be increased by following INM practices with bio-fertilizer seed inoculation in climate smart agriculture management practices.

• Seed treatment with *rhizobium* and *PSB* produced about 15% higher grain yield than the seed without any treatment.

• The fully organic fertilizer application recorded highest grain yield over other treatments.

• The studied soil turned out to be a net sinks for $N_2O$, even though altogether very little.

Conclusions

• The observed significant yield increase (+~50%) of Green gram in response to the application of vermi-compost underlines that such agronomic management strategy merits promotion by WOTR in Pro-soil project, and that this technology should also be tested in other countries.

• As, the study showed negative fluxes of $N_2O$, the Green gram production in Maharashtra with vermi-compost and inoculation is a climate smart management practice.

• Further studies should investigate the long-term trends of these improved practices on soil organic carbon contents and carbon dynamics, with the aim to answer the question whether these soils are losing or sequestering carbon and what the importance of such losses or gains are.
Grain Yield (t/ha) and the better availability of phosphate to plants by PSB, which only becomes visible when plant growth and nutrient uptake surpasses a level where the added amounts of N and P, or those residual in the soil from the application of mineral fertilizer in the past, are no longer sufficient to satisfy crop demand. Therefore, rhizobia and PSB inoculations constitute a smart way of improving agricultural productivity of green gram without increasing the risk of eutrophication of water bodies by excessive use of chemical fertilizers.

\( \text{N}_2\text{O} \) fluxes measured in situ in most of the cases were negative (Figure 3). In other words, the soil in this experiment largely constituted a sink for \( \text{N}_2\text{O} \). Only in one occasion, 11 days after planting (7 July), were the majority of fluxes (8 out of 10) positive. There was no clear seasonable trend visible in any of the treatments.

Figure 3: Seasonal measured \( \text{N}_2\text{O} \) fluxes of the various fertilizer treatments. Significant fluxes were detected only in 13 instances, and in all of the cases these were negative (Table 3).

A detailed report of this study is available at: https://hdl.handle.net/10568/89840

Yield of Green gram in response to the application of various levels of inorganic and organic fertilizer and inoculation with \textit{rhizobium} and \textit{phosphate solubilizing bacteria (PSB)}. Different letters (top of the graph) indicate significant differences between yields owing to fertilizer application, while asterisks directly above bars denote a significant impact of inoculation. (Source: Sommer \textit{et al.}, 2017)

Seasonal measured \( \text{N}_2\text{O} \) fluxes of the various fertilizer treatments in Green gram experimental plots (Source: Sommer \textit{et al.}, 2017)
About Us

Watershed Organisation Trust, (WOTR) is a non profit that engages at the intersection of practice, knowledge and policy across scales and in collaboration with stakeholders from across sectors. Headquatered in Pune, WOTR has supported and carried out developmental work in over 4522 villages across 7 states of India.

WOTR assists rural communities to assess their vulnerability to climate and non climatic risks. It organizes them in a socially and gender inclusive manner to help themselves out of poverty by regenerating their ecosystems in a holistic and integrated manner, conserving and optimising resource use, especially water and undertaking climate smart sustainable livelihoods.

Being a Learning Organisation, WOTR undertakes applied research and closely engages with institutions and governance actors so that insights and good practices derived from ground experience contribute to shaping enabling policies and effective programs. With a view to upscale successful interventions, WOTR develops pedagogies for implementation and organizes a variety of knowledge sharing and capacity building events for stakeholders across the civil society, developmental and governance spaces, from India and other countries.

This publication has built on experiences from the project “Soil protection and rehabilitation of degraded soils for food security in India” funded by GiZ and implemented by WOTR.