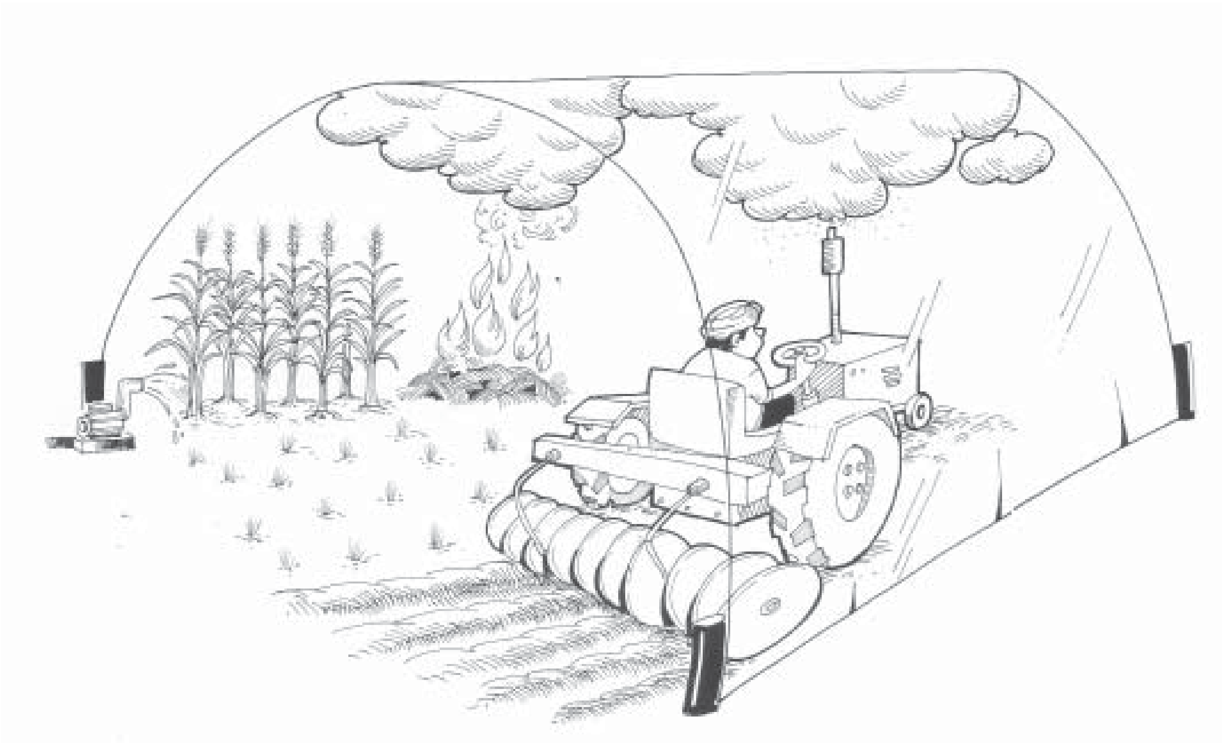
Rice-Wheat Systems and Climate Change



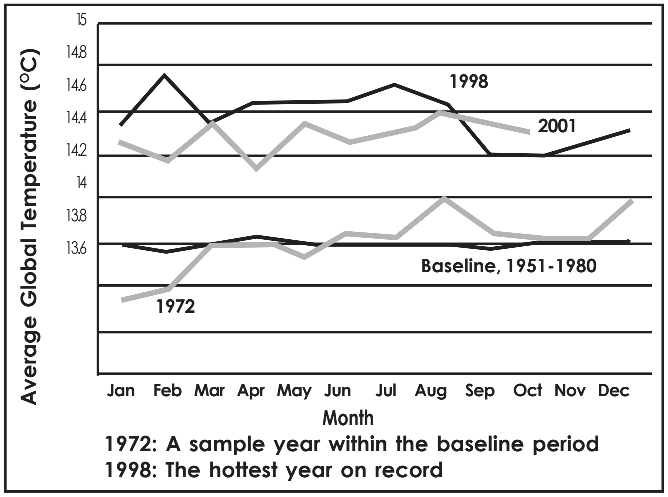
The effect of climatic changes on productivity and production in a rice-wheat system is generally accepted. What has not received sufficient attention is the effect of the rice-wheat system on local and global climate changes. A shift to, or intensification of, rice-wheat systems in the Indo-Gangetic Plains has resulted in seasonal wet and dry crop cycles, a heavy reliance on irrigation and an increased fertilizer usage accompanied by indiscriminate burning of crop residues. The emission of greenhouse gases CO_2, CH_4 and N_2O in rice-wheat systems and other environmental concerns associated with foodgrain production now beg for attention.

One Degree

An increase of temperature by 1^0C in the Indo-Gangetic Plains would be equivalent to a 150 km Northward shift of isotherms (lines joining places with similar temperature) or about 150m lower altitude. There is a 5% decrease in rice yield for every ^{0}C rise above 32^0C.

Inter-relationship of CO_2, Temperature and Yields

Long-term experiments in the region have shown that degradation of soil fertility has led to decline in yields of rice and stagnation in wheat production. In particular, soil organic matter decline has been of importance because it impacts on both soil fertility and soil structural stability. However, soil organic matter decline seems inevitable given the farmers' practices of burning virtually all crop residues and manure generated by livestock, fed thereon. Decline in soil structure compounds yield decline due to nutrient deficiencies. Addition of 15t/ha/annum of organic inputs (farmyard and green manure) in conjunction with NPK fertilizers consistently increased yields of wheat compared to NPK fertilizers alone in a 20-year experiment, but rice yields declined regardless. The role of tillage under warm, wet conditions in fostering rapid soil organic matter loss and the consequences for CO_2 emissions into the atmosphere also needs to be taken into account.



Higher atmospheric CO_2 content increases grain yields. However, wheat yields are unlikely to increase by more than 10% for double pre-industrial CO_2 levels, even under optimal field conditions, because of decreased crop duration (and hence yield) as a consequence of warming. A 5% to 7% increase in wheat yields is more likely under average management conditions. The prognosis for rice is even worse. Spikelet sterility is caused when temperature exceeds 32^0C at flowering. There is a reduction in yield of about 5% per ^{0}C rise above 32^0C. This is unaffected by, and may even offset the benefits of, an elevated CO_2 level.

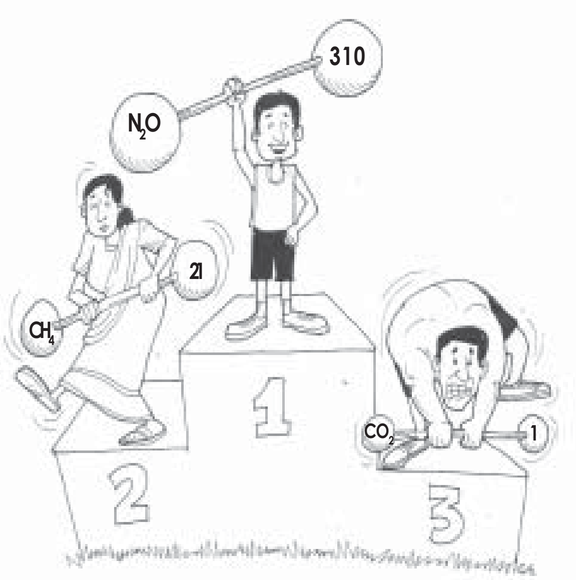
Global Warming Potential

Global Warming Potential (GWP) is used to compare with CO_2 the relative effectiveness of each greenhouse gas (GHG) to trap heat in the atmosphere.

GWP of common GHGs.

CO_2	Carbon dioxide	1
CH_4	Methane	21
N_2O	Nitrous oxide	310

Different gases last for different lengths of time in the atmosphere. GWP is based on a 100-year time horizon. Although present in lower concentrations, N_2O is a very potent GHG as 1kg N_2O is equivalent to 310 kg CO_2.



Sources of Greenhouse Gases

Rice-wheat systems produce greenhouse gases through both biological processes and burning of fuel by farm machinery.

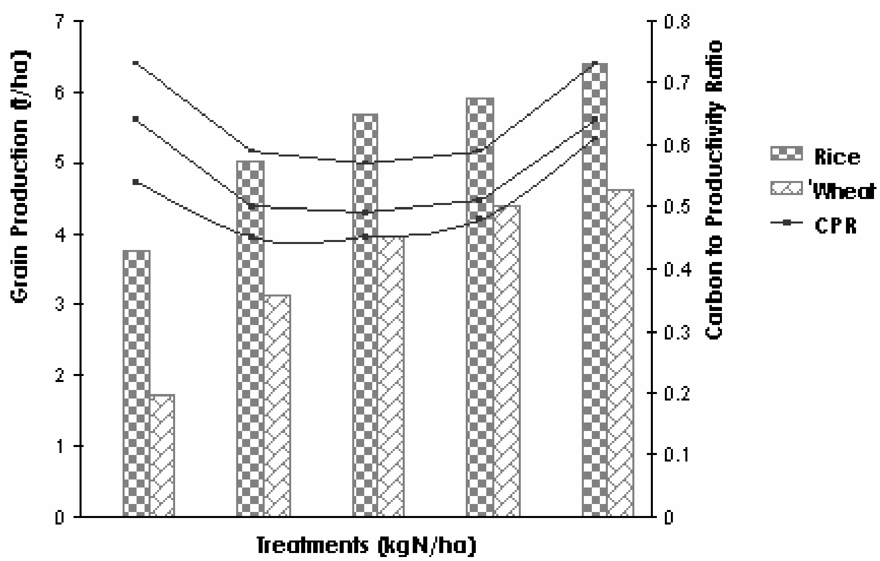
Carbon Dioxide

Tillage operations contribute CO_2 through the rapid organic matter decomposition due to exposure of larger surface area to increased oxygen supply. Experiments in Mexico have shown that tillage almost doubles the rate of decline in soil organic carbon levels in the top 20cm of soil. Every liter of diesel fuel used by tillage machinery and irrigation pumps also contribute 2.6kg CO_2 to the atmosphere. Thus, nearly 400kg CO_2 would be generated per hectare assuming an annual use of 150 litres diesel in the conventional rice-wheat system. For the 12 million ha, this would amount to 4.8 Mt CO_2 per annum or 1.3 MMTCE. This is one third the value (4 MMTCE) of CH_4 from ricefields. Diesel use remains greatly an underestimated source of GHG.

The presence of nitrogen (N) enhances microbial decomposition and release of CO_2. An important off-site source of CO_2 is the production of N fertilizers. For every kilogram of N fixed in fertilizer 1.8 kg CO_2 is the by-product. It is presumed that CO_2 generated by burning crop residues will be taken up by the following crop.

Carbon to Productivity Ratio

To assess how environmentally efficient the various productions systems are with respect to GHG emission and how much food is actually placed on the table, a Carbon to Productivity Ratio (CPR) is an ideal measure. CPR the value obtained by dividing the total annual on-site GHG emissions stated as Carbon Equivalents (CE) by the total annual food production in that area. Yield data of a long-term experiment at Pantnagar with NPK fertilizers at 50, 100 and 150% of the recommended dose when analyzed after constructing annual GHG budgets individually for CO_2, CH_4 and N_2O indicated that CPR values of 0.45 to 0.48 were possible with zero tillage and retention of crop residues at all three levels of N fertilizer use as against 0.54 for control, i.e., without fertilizer. However, with conventional tillage practices and burning of crop residue the CPR values were between 0.57 to 0.73 showing a higher level of ineffectiveness in the production system. The lower the CPR, the more efficient the system is at producing food with respect to the health of the global environment.



Carbon to Productivity Ratio at Various Levels of Nitogen and Production of Rice and Wheat Over 20 Years

Treatment N Fert/Crop Kg/ha	Production			Carbon Equivalents (CE) Kg C emitted			Carbon to productivity ratio		
	Rice (t/ha)	Wheat (t/ha)	Fodder (t/ha)	C/RR	C/BR	Z/RR	C/RR	C/BR	Z/RR
0	3.74	1.71	1.86	3496	3953	2966	0.64	0.73	0.54
60	5.02	3.13	1.93	4103	4774	3646	0.50	0.59	0.45
120	5.67	3.97	2.36	4721	5510	4362	0.49	0.57	0.45
180	5.92	4.38	2.32	5232	6086	4981	0.51	0.59	0.48
120+	6.41	4.60	2.47	7137	8032	6724	0.64	0.73	0.61

120+ - 120 kg N + 15 + FYM
C - Conventional tillage
RR - Retained residues of crop
Z - Zero tillage
CPR - Carbon to productivity ratio
BR - Burn residues

Methane

Methane is produced by fermentation, i.e., anaerobic decomposition of organic matter reducing CO_2 to CH_4. The continuously flooded rice fields produce CH_4 due to their anoxic conditions and rice plants serve as conduit for its release to atmosphere. Multilocational experiments in five countries studied CH_4 production in irrigated, deepwater and rainfed rice ecosystems. Irrigated rice fields had the highest CH_4 emission rates that also showed seasonal variations. Rainfed rice showed less than half of the emission from irrigated fields. The CH_4 emission rate can be greatly reduced by single or multitude aeration of fields instead of continuous flooding. In 12 million ha of rice-wheat in the Indo-Gangetic Plains about 0.7 Mt of CH_4 per year (or 4 MMTCE/annum) is produced by rice cultivation. This is primarily due to low organic carbon levels in this region.

The burning of crop residues contributes about 0.14 Mt of CH_4 (0.8 MMTCE/annum) assuming that half of the crop residues produced at the rate of 10t/ha (rice and wheat) in the 12 million ha are burnt. This is equivalent to 20% of the total CH_4 emitted from paddy fields in the same area.

IGP A-L-E-R-T

- The Indo-Gangetic Plains (IGP) occupy one-sixth of South Asia's geographical area, hold nearly 42% of its population and produce more than 45% of its food.
- Rice-wheat is grown on more than 12 million ha and provides livelihood for millions in the IGP.
- Observations suggest that during the 1990s the atmospheric abundance of almost all greenhouse gases (GHG) reached their highest values in recorded history. According to recent estimates by IPCC, by 2100 A.D., the average global surface temperature is projected to increase by 1.4 to 3^{0}C above 1990 levels for low emission scenario of GHG and between 2.5 to 5.8^{o}C for higher emissions.
- By using no-till (zero-tillage) and other soil conservation practices that preserve crop residue, farmers can help reduce GHG emission and curb global warming.
- Water and agriculture sectors are likely to be most sensitive to climate change in South Asia.
- Increasing demand for waters by competing sectors may limit the viability of irrigation as a sustainable adoption to climate change.

Source M.Lal, IIT, New Delhi

Nitrous Oxide

This gas is released even from soils to which no nitrogen containing fertilizer has been applied. Destruction of the ozone layer due to N_2O is an important consideration beyond the concern for nitrogen losses from applied fertilizers and manures. Experiments have shown that both the processes of nitrification and denitrification contribute to the release of N_2O from the soils into the atmosphere.

The N_2O production is greatly affected by soil water content. Water creates anaerobic conditions by slowing down the diffusion rate of oxygen by ten thousand times. Generally, an increase in denitrification and potential N_2O losses is observed following irrigation or rain in aerobic or partially aerobic soils. Rice paddies are not considered to be an important source of atmospheric N_2O because it is further reduced to N_2 under strong anaerobic conditions due to standing water. N_2O flux increases sharply due to draining of the fields at mid-tillering stage.

The burning of crop residue produces 40g N_2O/t. Assuming as before that half of the 10t/ha crop residue produced on 12 million ha is burnt, then 2000 tons of N_2O (about 0.2 MMTCE/annum) is released into the atmosphere. This is almost a quarter of the value derived in terms of CH_4 from the same process.

Reducing Greenhouse Gases

Positive changes in agronomic practices like tillage, manuring and irrigation can help reduce greatly the release of greenhouse gases into the atmosphere. Adoption of zero tillage and controlled irrigation can drastically reduce the evolution of CO_2 and N_2O. Reduction in burning of crop residues reduces the generation of CO_2, N_2O and CH_4 to a significant extent. Saving on diesel by reduced tillage and judicious use of water pumps can have a major role to play. Changing to zero tillage would save 98 liters diesel per hectare. With each liter of diesel generating 2.6 kg, about 3.2 Mt CO_2/annum (about 0.8 MMTCE) can be reduced by zero-tillage in the 12 million ha under rice-wheat systems in the Indo-Gangetic Plains alone. Intermittent irrigation and drainage will further reduce CH_4 emission from rice paddies by 28% to 30% as per the findings at IARI (Delhi) and at Pantnagar.

Use of calcium nitrate or urea instead of ammonium sulphate and deep placement instead of surface application of nitrogenous fertilizers can increase its efficiency and plant uptake thereby reducing N_2O emission.

Reference

Lal M., IIT, New Delhi, India (unpublished).

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