Sustainability of Rice production; Is Aerobic rice the way forward

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Presentation Outline

- Sustainability in relation to global challenges
- GHG emission from agriculture Global Scenario (AR5-FAO, 2014)
- GHG emission from agriculture Malaysian Scenario (NC2, year 2000)
- Carbon foot print – Case study
- Aerobic rice – mitigating GHG emission

Global Challenges

Food Security

Climate change

Agri-Food System

Stewardship

Food & Health

Biobased Economy

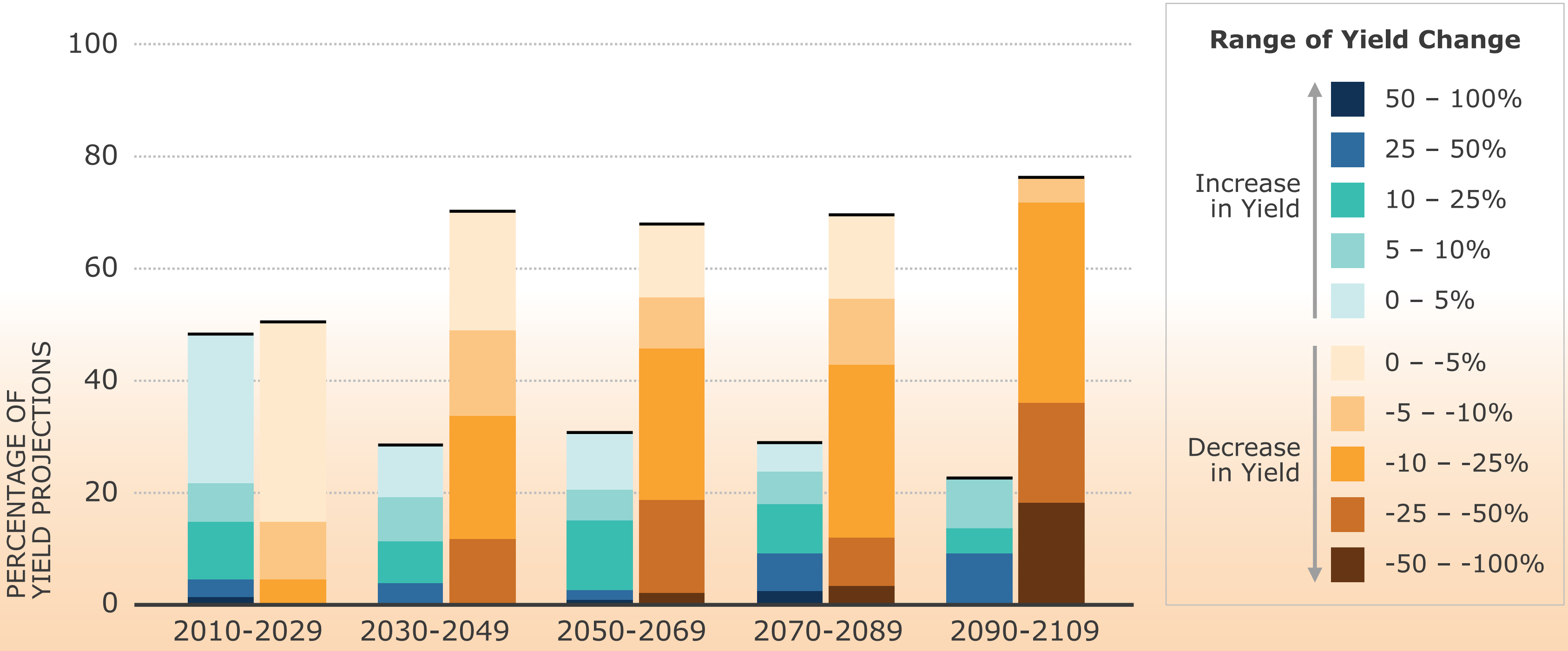
Agriculture & Climate Change

- Agriculture plays a dual role in global efforts to reduce the greenhouse gas (GHG) emissions that contribute to climate change.
- First, the agriculture is a major source of GHG emissions.
- Second, the agricultural sector provides major opportunities for the mitigation of GHGs.

Agriculture's GHG emissions on the rise

- FAO global estimates of GHG data show that emissions from agriculture, forestry and fisheries have nearly doubled over the past fifty years and could increase an additional 30 percent by 2050, without proper mitigation. (IPCC-AR5)
- Agricultural emissions from crop and livestock production grew from 4.7 billion tonnes of CO_2 eq in 2001 to over 5.3 billion tonnes in 2011, a 14 % increase.
- Sources of agricultural emissions-2011; 1. Enteric fermentation (39%), 2. Synthetic fertilizers (13%) & 3. Rice cultivation (10%)

Range of Yield Change as affected by climate change

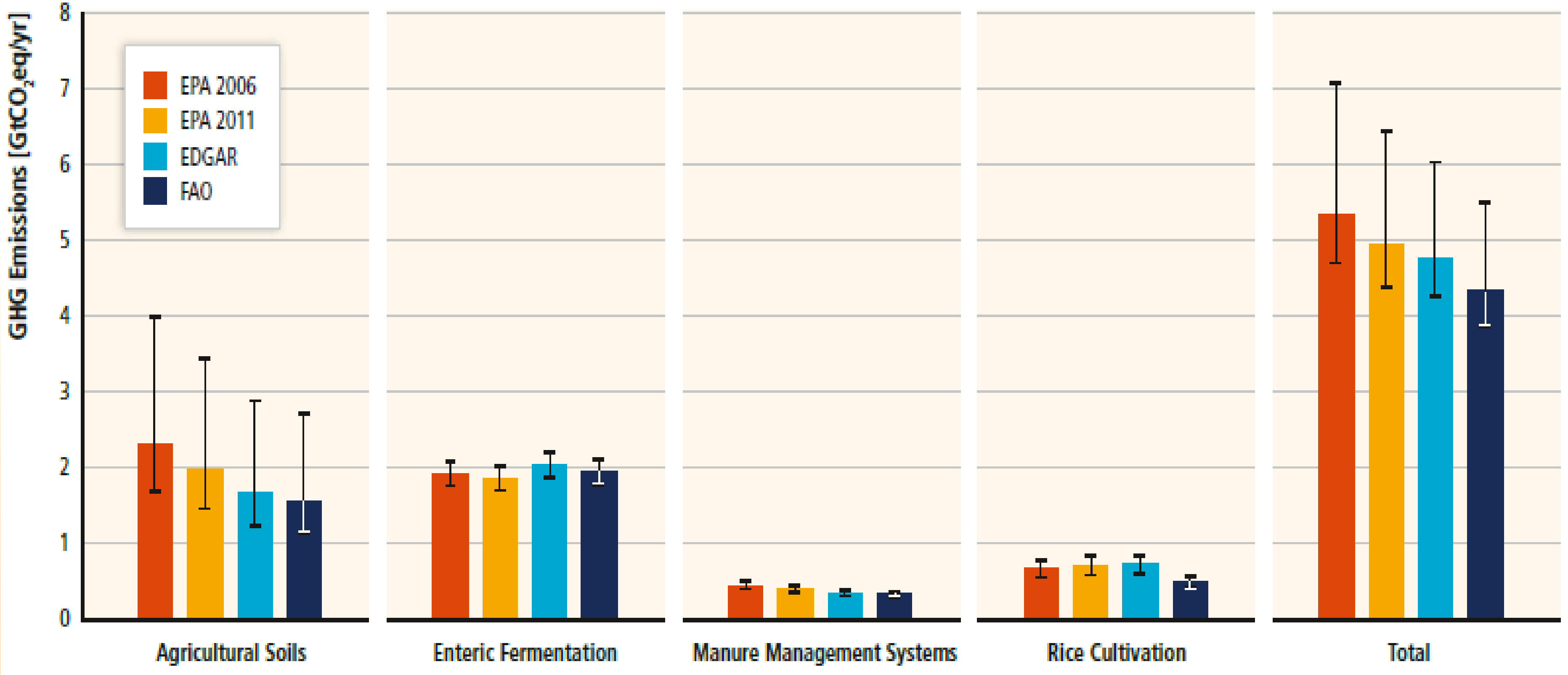


IPCC AR5

Agriculture and GHG Emission

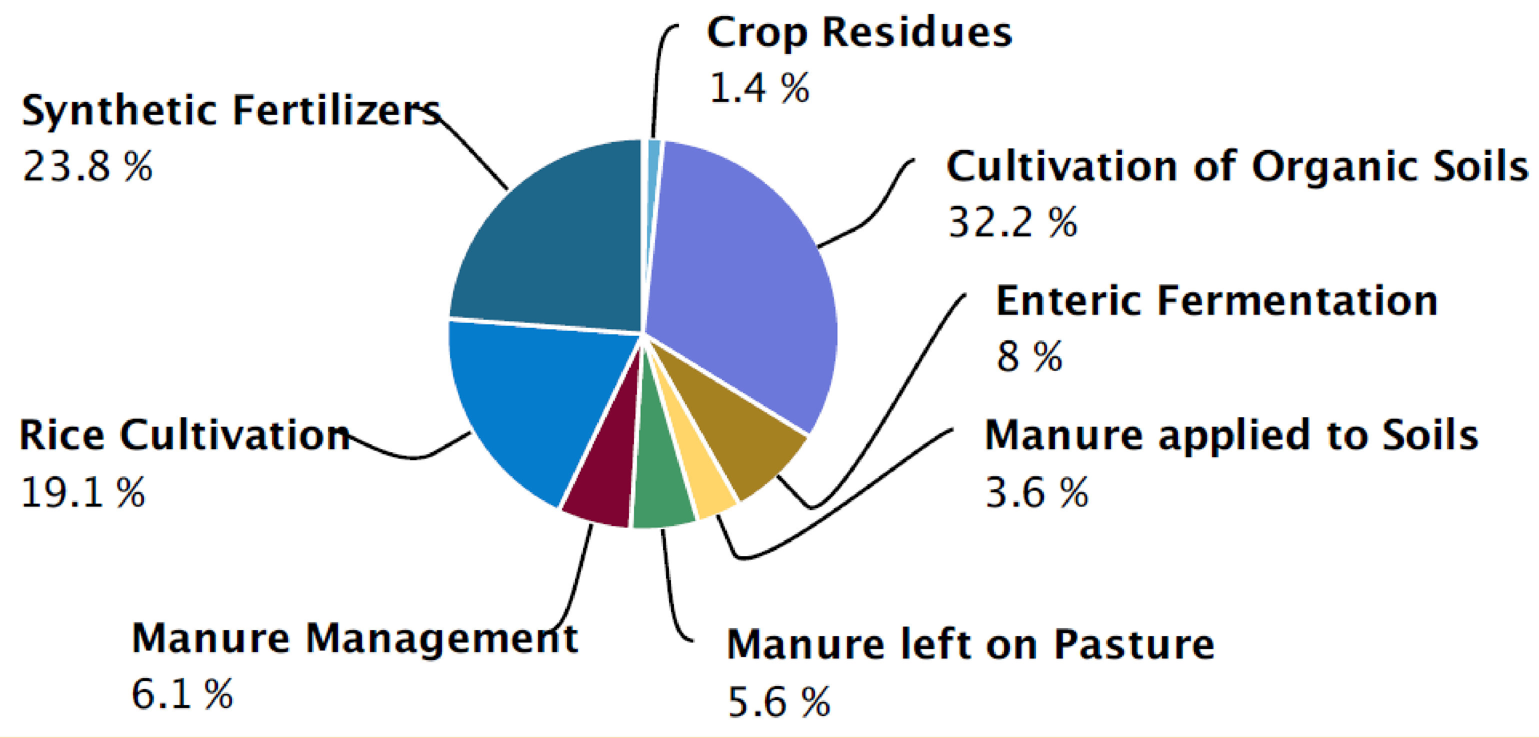
- Rice cultivation - Greenhouse gas emissions from rice cultivation consist of methane, CH4, produced from the anaerobic decomposition of organic matter in paddy fields.
- **Synthetic fertilizers ;** Greenhouse gas emissions from synthetic fertilizers consist of nitrous oxide from synthetic nitrogen added to managed soils.

Trends of GHG emissions from Agriculture-AR5

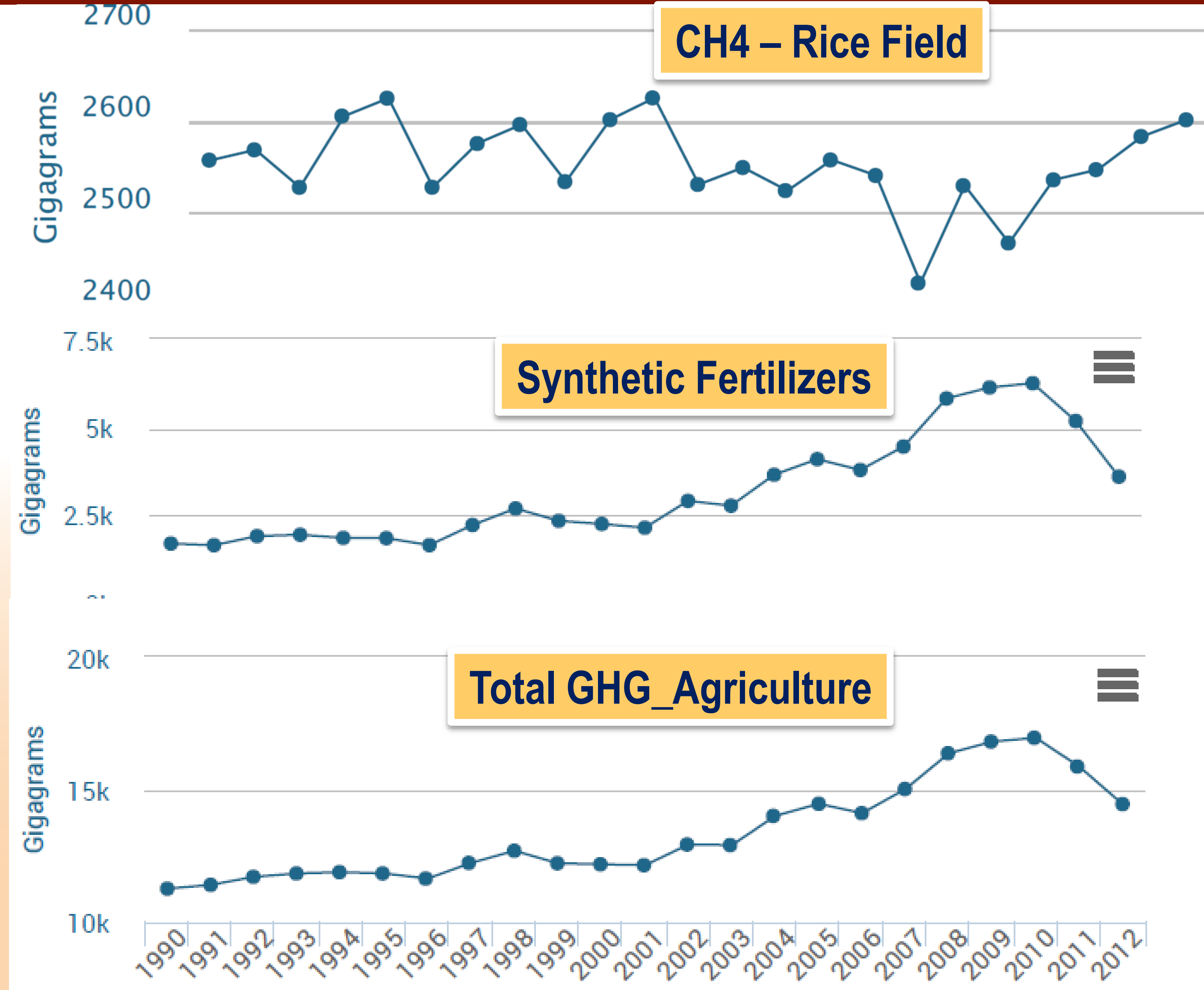


IPCC AR5

Agriculture; Emissions by sector (1990 – 2012)

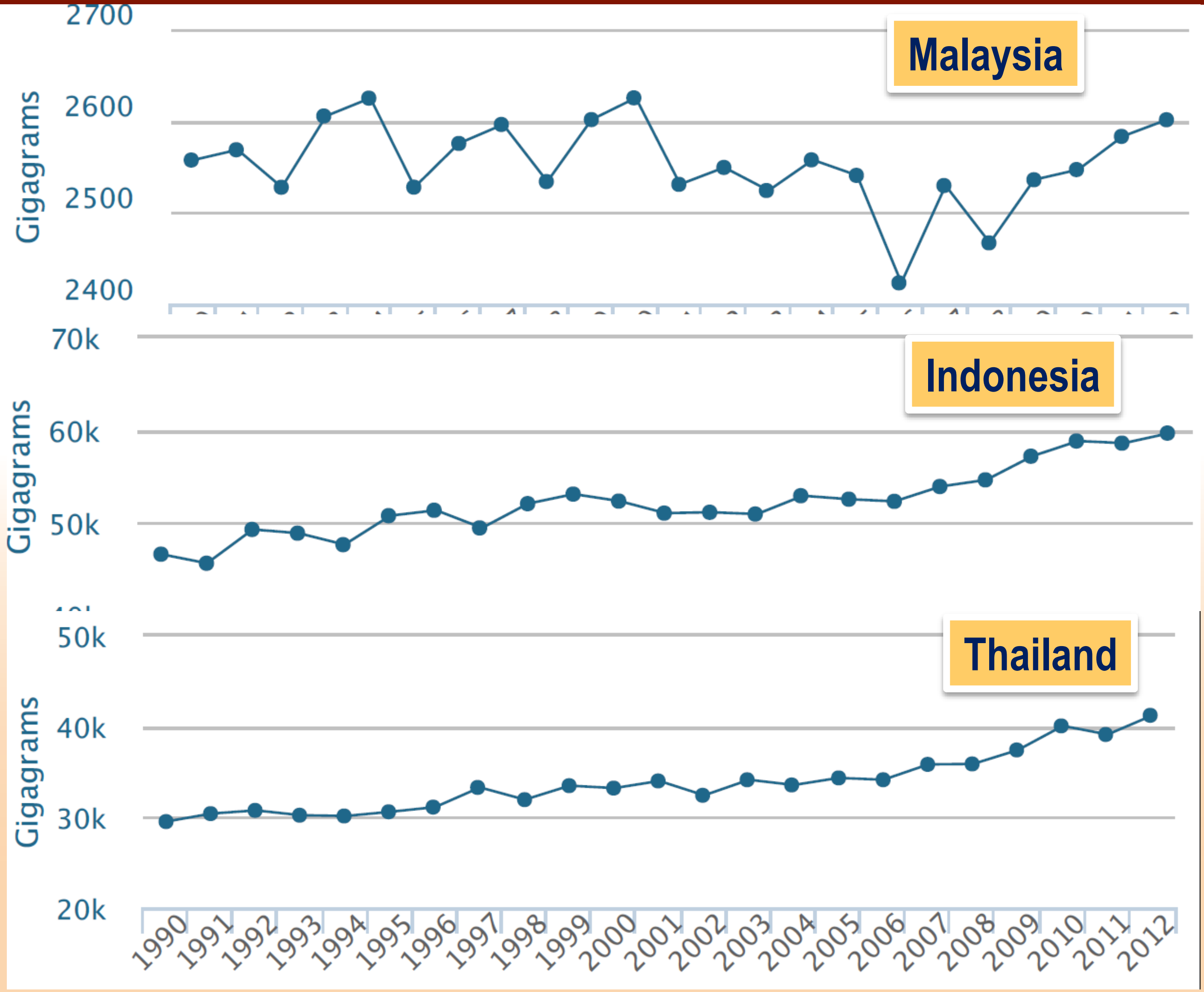


GHG Emission from Malaysian Agriculture 1990-2012



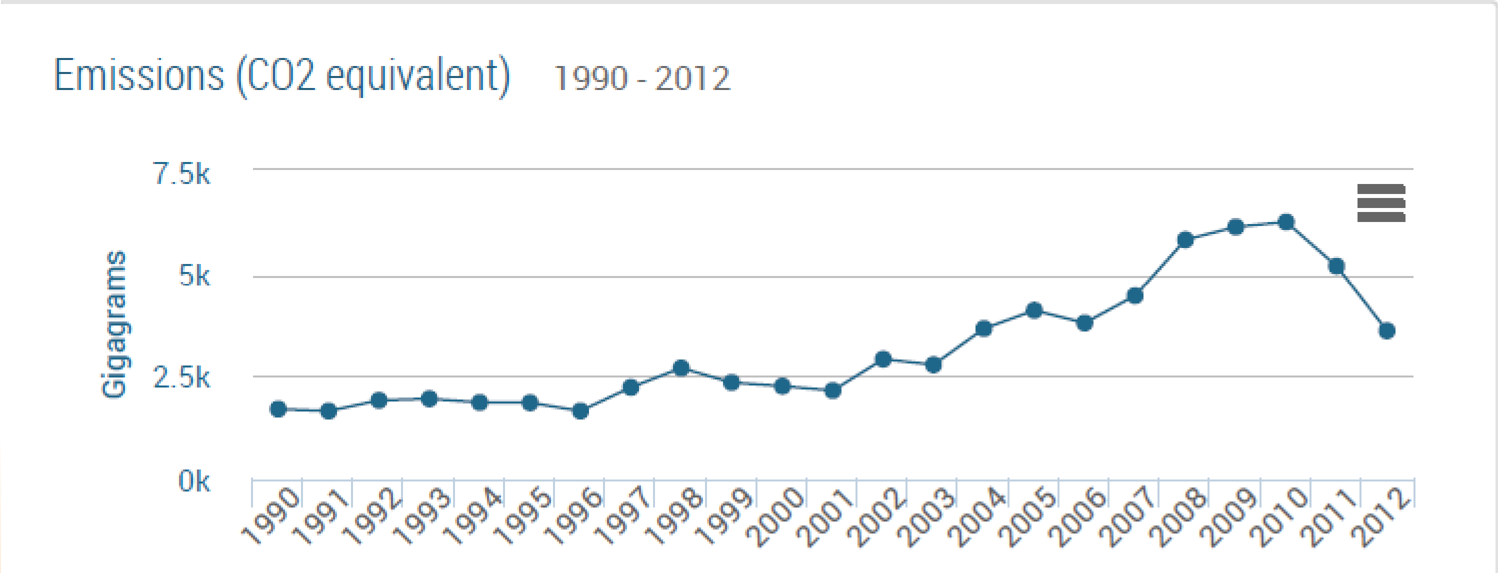
Methane (CH4) emission from rice cultivation fields

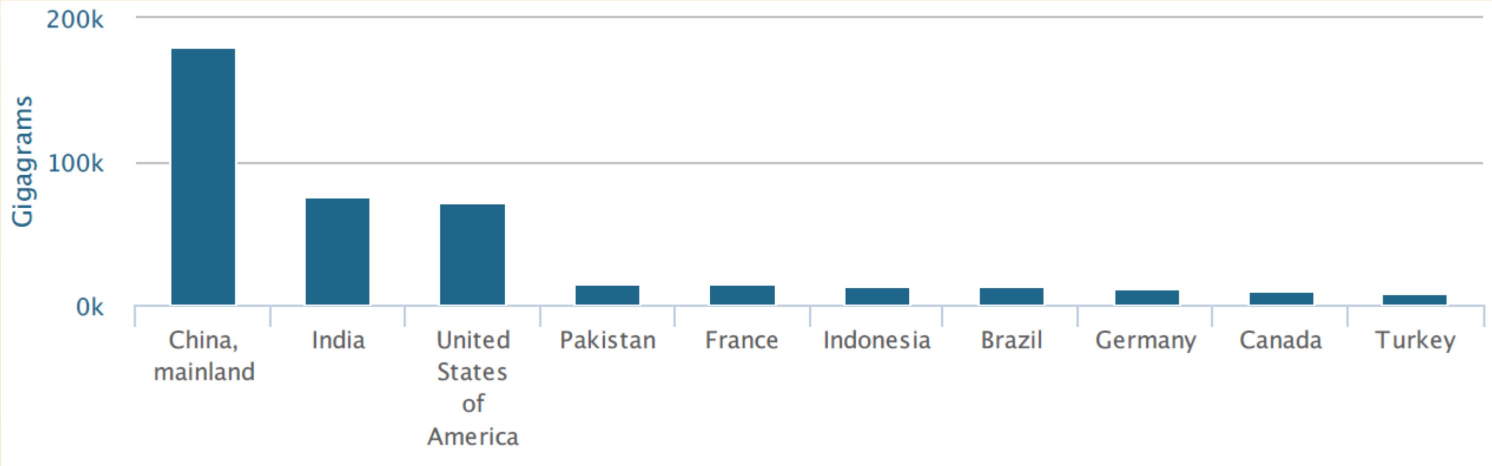
CH4 emitted by anaerobic decomposition of organic matter in paddy fields



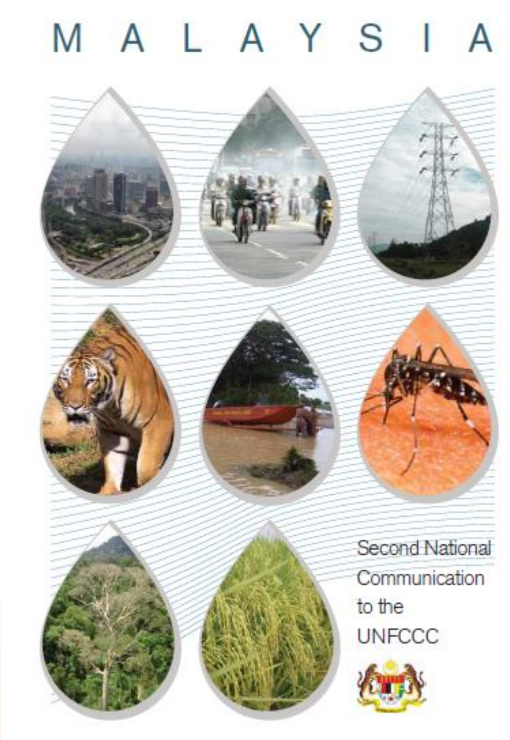
FAO. 2013. FAOSTAT Emissions Database c

GHG emission from Synthetic fertilizers in Malaysia

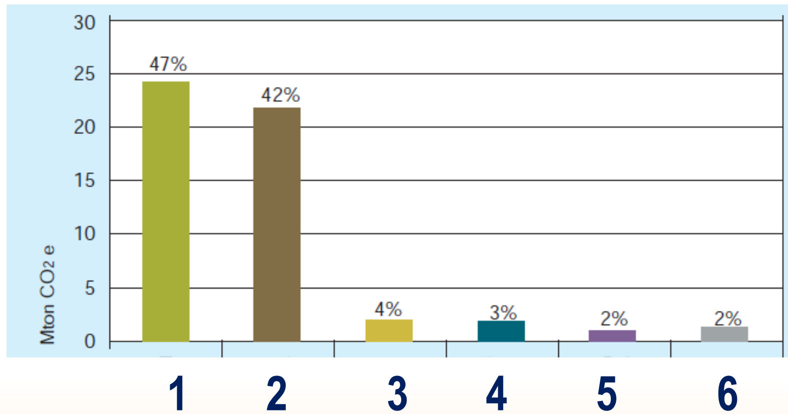




Second National Communication to the UNFCCC

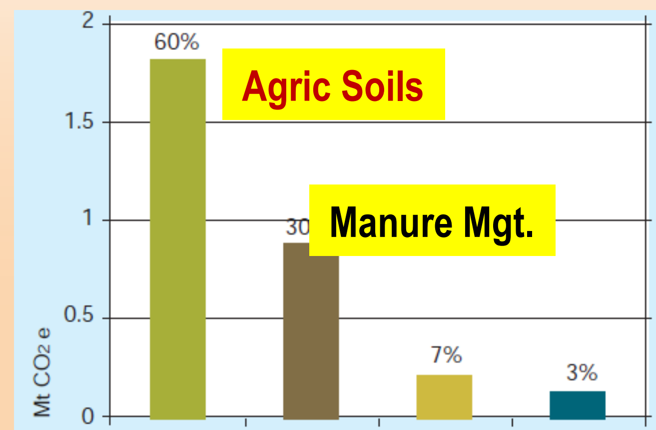


Major Sources of CH4 Emissions



1. Landfill
2. Fugitive emission O&G
3. Rice production
4. Industrial
5. Enteric
6. Others

Major Sources of NO2 Emissions



GHG	Emissions (Gg)	GWP	CO2 eq (Gg)
CH4	153.33	21	3,220
N2O	8.66	310	2,686
Total			5,906

Mitigation Options In The Rice Management

Mitigation technology options and practices,

GHG	Technology/Practice	Technical Mitigation Potential	Ease of Implementation (acceptance or adoption by land manager):	Timescale for Implementation
C	Straw retention	Medium	High	Available
CH_4:	Water management, mid-season paddy drainage	High	Medium	Available
N_2O:	Water management, N fertilizer application rate,	Low	High	Available

FAO DATA; Methodology and Quality Information

- GHG emissions from rice cultivation consist of methane gas (CH_4) emitted by anaerobic decomposition of organic matter in paddy fields. The FAOSTAT data are computed at Tier 1 following IPCC, 1997 Vol. 3, Ch. 4 and IPCC, 2000, Ch. 4.

- The emissions are estimated at country level, using the formula: Emission = A * EF
  - where: Emission = GHG emissions in g CH_4 m^{-2} yr^{-1} ;
  - A = Activity data, representing rice paddy annual harvested area in m^{-2} (1);
  - EF = Tier 1, default IPCC emission factors, in g CH_4 m^{-2} yr^{-1} (2).

- Assessment of land use sustainability and management system must address current global issues i.e.
  - Emission of GHGs from agricultural practices
  - Food security
- The accelerated greenhouse effect,
- In relation to soil and environmental degradation.
- Reducing emissions implies enhancing use efficiency of all these inputs by decreasing losses, and using other C-efficient alternatives

Carbon footprint

- The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product.“
- **Carbon footprint can be defined as the amount of CO_2 and other GHG produced through full life cycle of a process or product ”** (Parliamentary Office of science and technology. POST, 2006).
- Carbon footprint is express in unit of **carbon equivalent** (CE)

Carbon labelling

CARBON LABELLING
AUSTRALIA

CO2 Labels Proposed for Beer Cans by '09

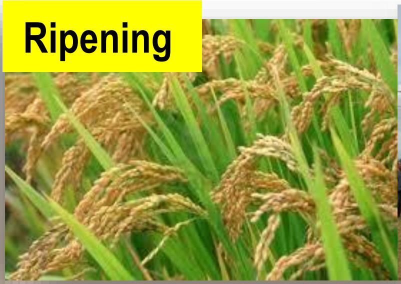
Case Study

Case Study-Objectives

- To assess carbon emission in relation to farming system in selected rice production systems (MADA, KADA, SRI-Seberang Perak).
- To determine differences in GHGs emissions between conventional and organic practices of rice cultivation
- Agronomic practices that most contribute to carbon emission.

Agronomic practices – GHG Emissions

The total CO2 emission from various cultural practices were grouped into six stages of rice growth.



- Mechanization
- Fertilization
- Crop protection
- Miscellaneous

The inputs requirement for each stage varies with the crop requirement hence $\sum$ C emission differs according to stage.

Agronomic practices – Cropping stages

Paddy crop stages	Activities
Land Preparation	Land clearing, herbicide, liming, tillage, soil conditioner, fungicide, molluscicide and rodenticide
Field establishment	Seed broadcasting, herbicide, molluscicide and rodenticide
Tillering	Fertilization, fungicide, insecticide and rodenticide
Active tillering	Fertilization, fungicide and insecticide
Panicle initiation	Fertilizer and rodenticide
Flowering	Fungicide and insecticide
Grain filling	Fertilization, fungicide and insecticide
Ripening & harvesting	Insecticide and farm machinery

Methodology- Calculation of CE

- Carbon footprint value (kg CE) was calculated by using formula:-

Agricultural input (Unit)	X	Emission factor (EF) (literature)

- Agricultural input is the total amount of input used by each agronomic practices.
- **EF is the total of carbon that emit when applied each of the farming activities.**

Mechanization
Units of machineries use x EF (kg CE/ha) = CO_2 eq/ha.
Eg: 1 unit of rotary tiller x 15.2 = 15.2 kg CE/ha

Fertilization
Rate of application (kg/ha) x EF (kg CE/ha) = CO_2 eq/ha.
Eg: 46% N with 83.33 kg/ha rate of application; 46/100 x 83.33 x 1.35 = 51.75 kg CE/ha

Pesticides
Rate of application (kg/ha) x EF (kg CE/ha) = CO_2 eq/ha.
Eg: Glyphosate with 1.25 lt/ha rate of application 1.25 x 9.1 = 11.37 kg CE/ha

Methodology- Calculation of CE

- **Emission factor used by using Tier 1, 2 and 3 approach.**
- **Depends on availability specification of emission factor.**

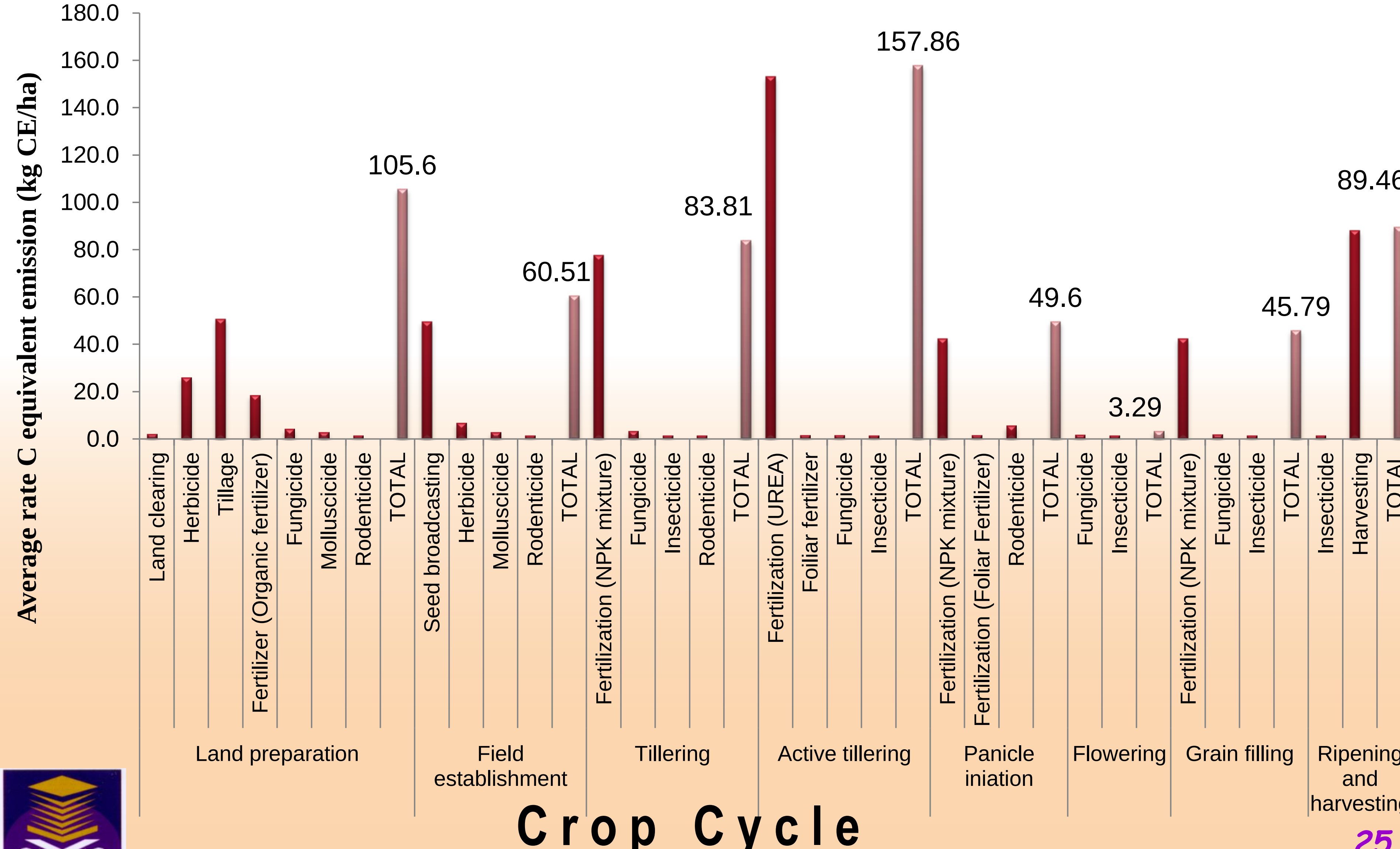
Carbon Footprint = $\sum CO_2$ eq. of all inputs (Dubey,2008)

Tier	Specification	Emission factor
01	Pesticide	6.3 kg CE/kg
02	Fungicide	3.9 kg CE/kg
03	Benomyl	8.0 kg CE/kg a.i.)

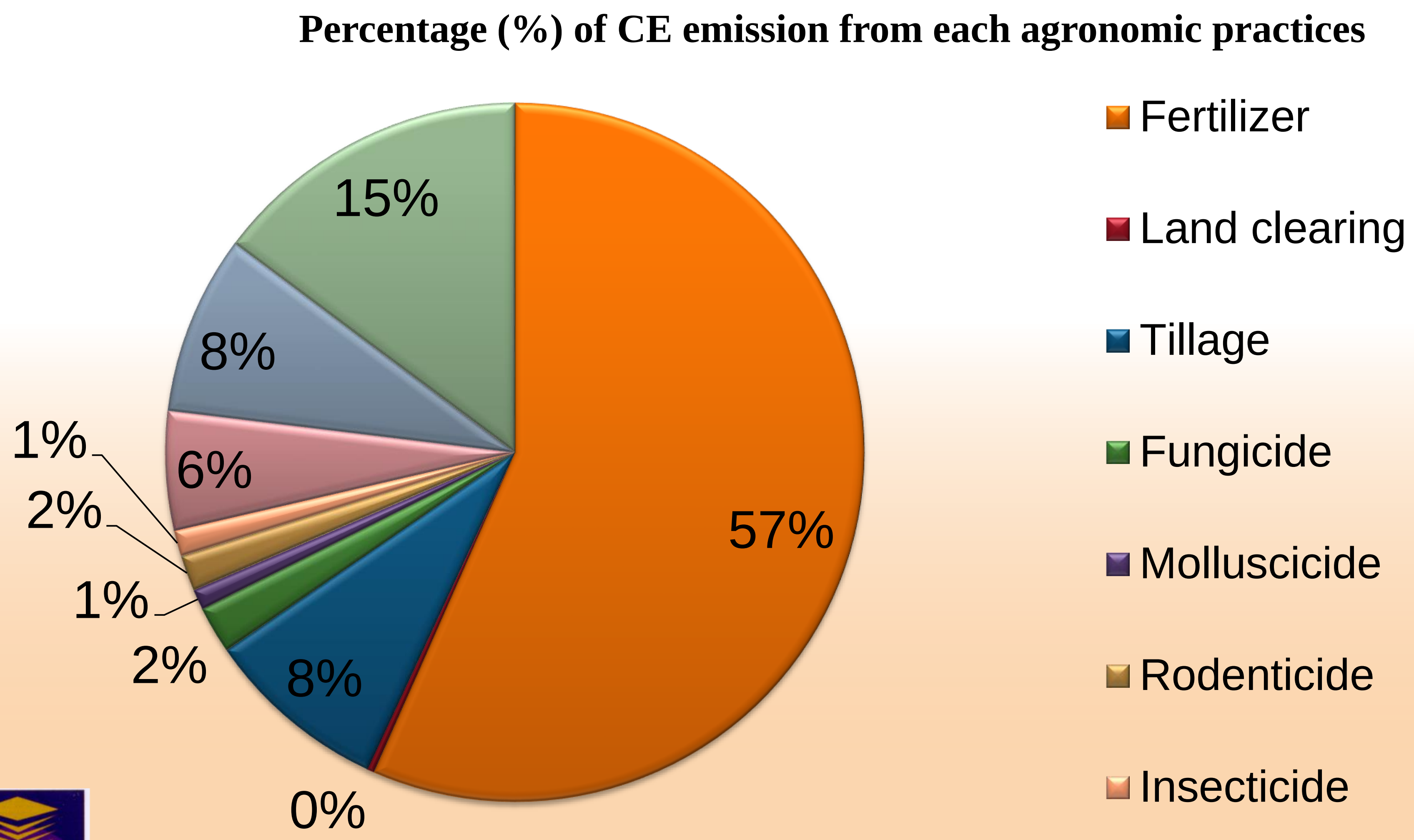
← **More accurate**

Source: (Lal, 2004)

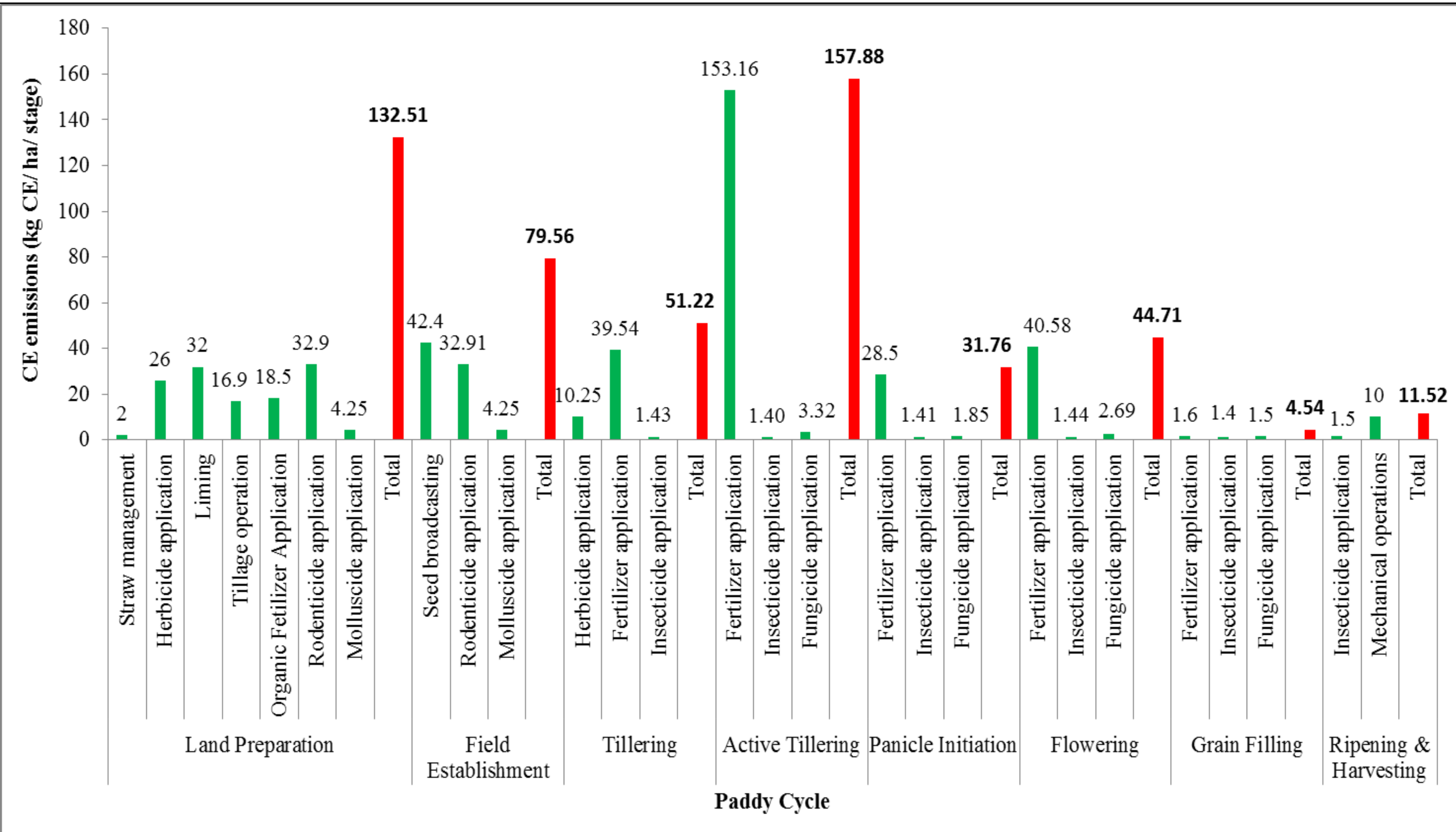
MADA- Trend of carbon footprint over paddy crop cycle



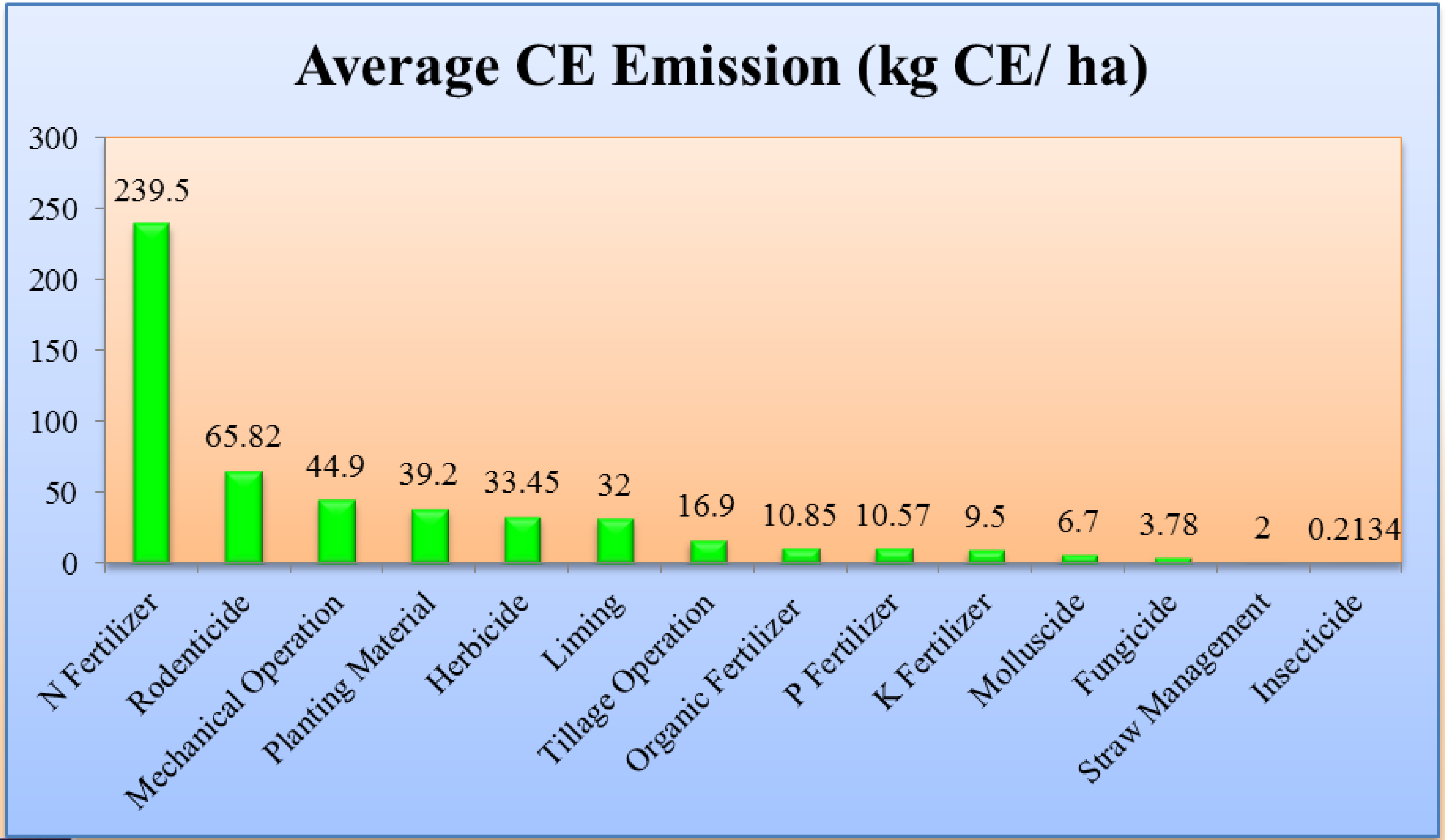
MADA- Trend of carbon footprint by agronomic practices



KADA- Trend of carbon footprint over paddy crop cycle



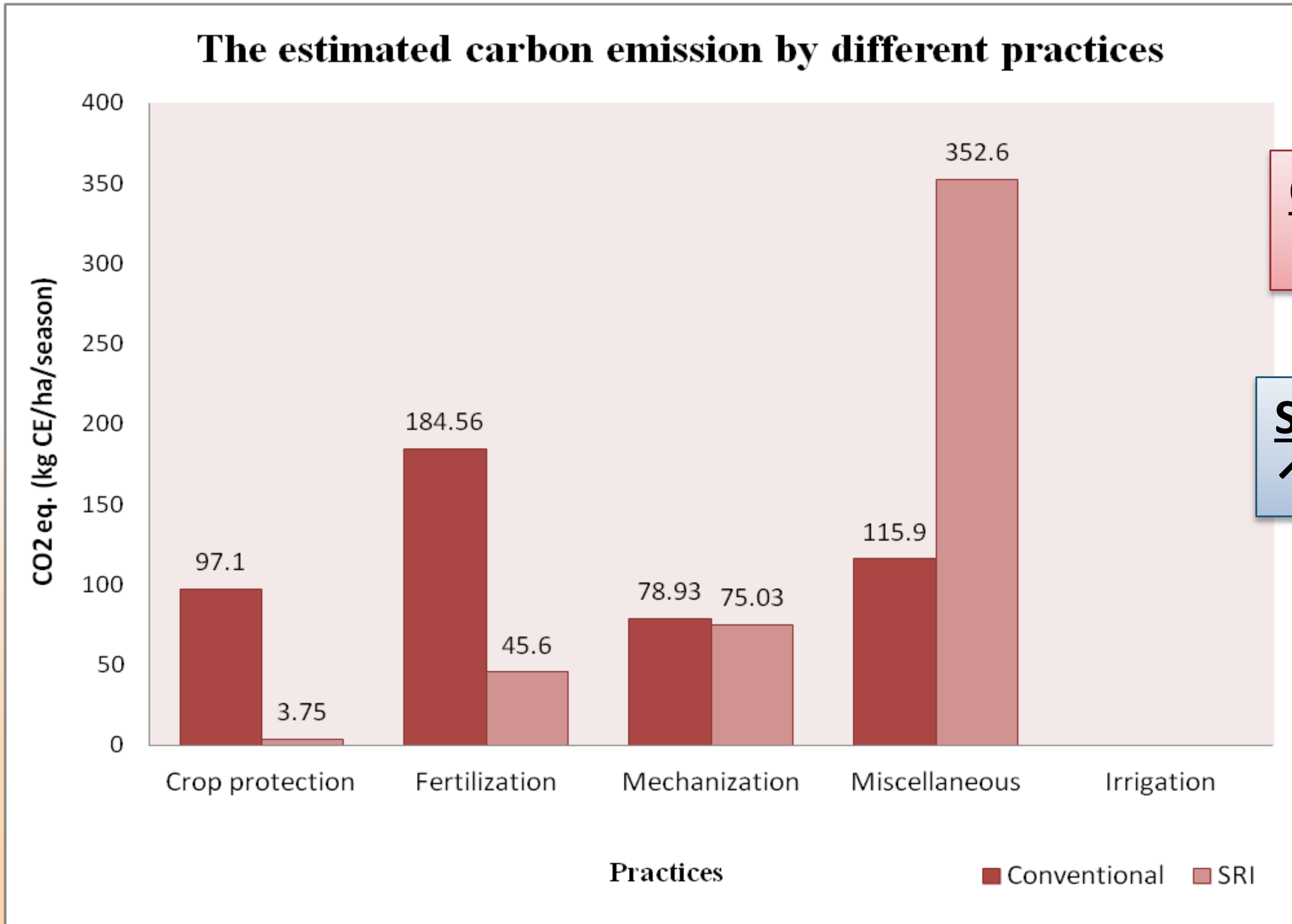
KADA- Trend of carbon footprint by agronomic practices



The estimated C emission of conventional versus SRI practices

Stages	Practices	CO2 eq. (kg CE/ha/season)		Total (kg CE/ha/season)	
		Conv	**SRI**	**Conv**	**SRI**
Land preparation	a) Crop protection b) Mechanization c) Miscellaneous	70.21 45.6 115.9	- 41.7 352.6		
				231.71	**394.3**
Active tillering	a) Crop protection b) Fertilization	26.88 -	1.2 15		
				26.88	**16.2**
Maximum tillering	a) Crop protection b) Fertilization	35.18 111.8	1.2 0.6		
				146.98	**1.8**
Panicle initiation	a) Crop protection b) Fertilization	2.42 -	0.15 15		
				2.42	**15.15**
Heading	a) Crop protection b) Fertilization	13.17 72.76	0.6 15		
				85.93	**15.6**
Ripening	a) Crop protection b) Mechanization	- 33.33	0.6 33.33		
				33.33	**33.93**
				527.25	**476.98**

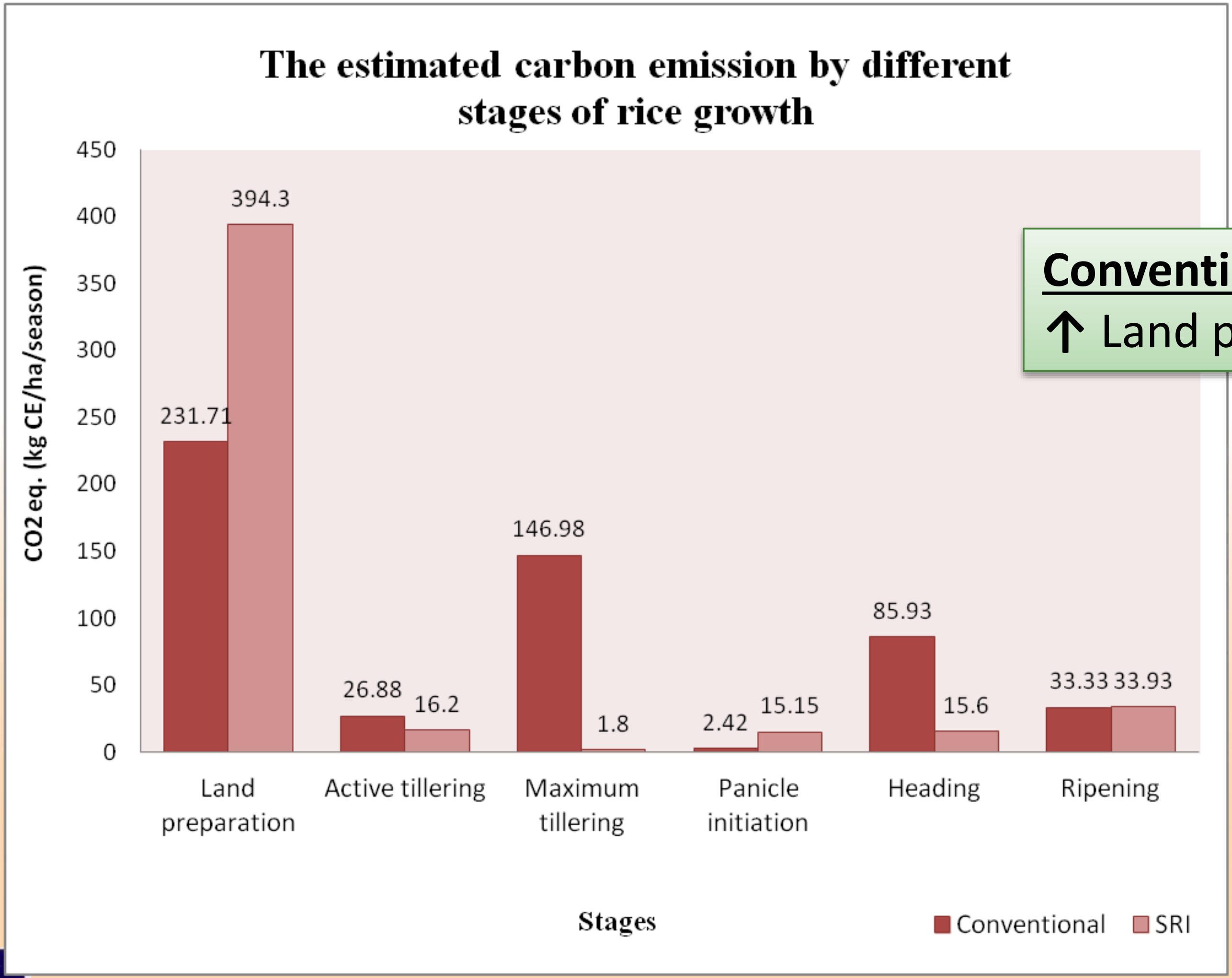
Conventional versus SRI practices



Conventional
↑ Fertilization

SRI
↑ Miscellaneous

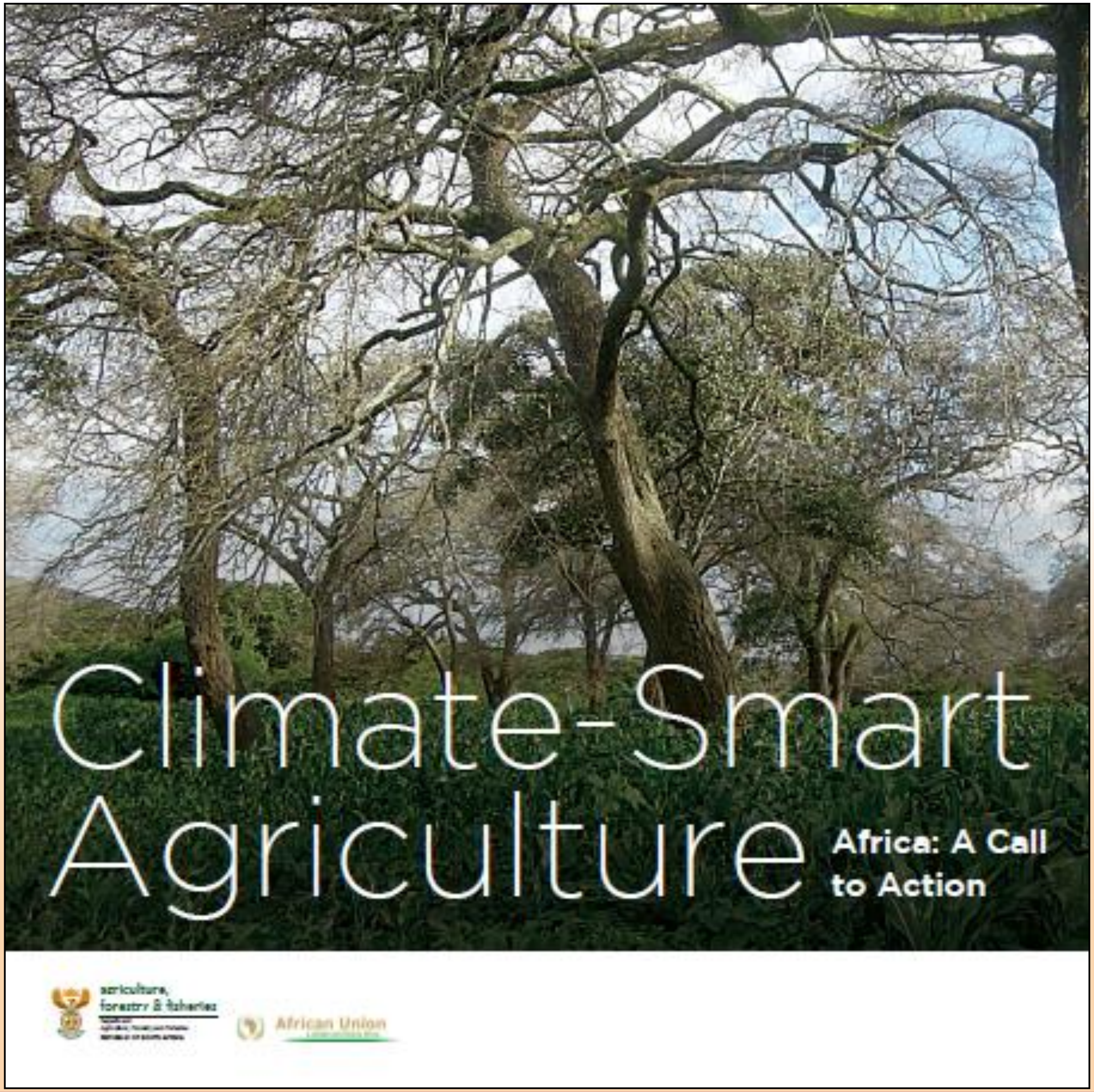
Conventional versus SRI practices



Conventional & SRI

↑ Land preparation

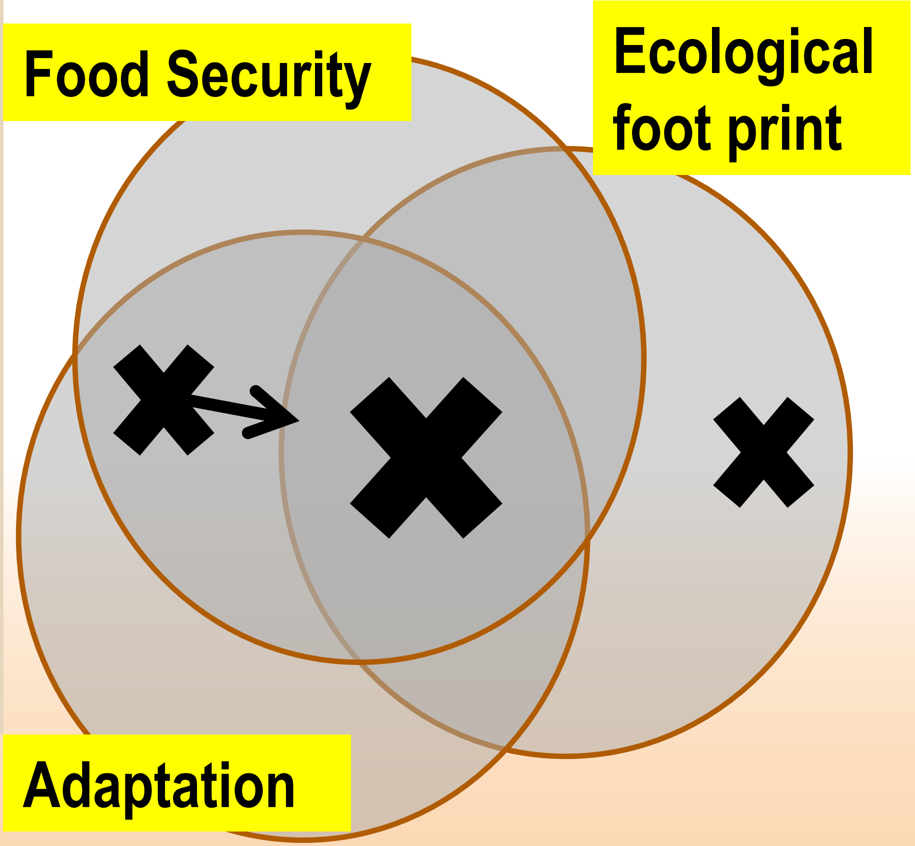
Climate Smart Agriculture



Climate Smart Agriculture

Agriculture that sustainably:

1. Increases **productivity**
2. **Resilience** (adaptation)
3. Reduces **GHG** (mitigation) and enhances achievement of national **food security** and **development goals** (FAO, 2010)-
(www.fao.org/climatechange/climatesmart/en)



Climate smart means landscape and policy smart

- A slogan for sustainable agriculture: 'Mot Phai, Nam Giam' rice production
- A catch phrase for a climate-smart way to produce rice has shown small farmers how they can boost rice profitability, while also reducing greenhouse gas emissions – World Bank.

Aerobic Rice

MARDI Aerob 1

- Water saving technology
- Climate change mitigation

Options that mitigate GHG emissions

- Irrigation patterns,
- Modifying tillage permutations
- Managing organic and fertilizer inputs,
- Selecting suitable cultivar,
- Cropping regime

.

Modifying irrigation pattern

Relative mitigation potential (GHG emissions) of various water management practices as compared to traditional flooding in rice

- Intermittent irrigation
- Mid-season drainage
- Multiple drainage
- Controlled irrigation
- Alternate wetting and drying
- No flooding (wet)

- Mitigate: CH_4, N_2O
- Mitigation potential ; varies from as low as 15%- 73%

Source: (Hussain S etal 2015.

Modifying tillage permutations

- Generally reducing tillage and soil disturbance in rice-based cropping systems could lead to less GHG emissions
- The field CO_2 fluxes after crop harvest generally lesser under no tillage than conventional tillage
- CH_4 emissions reduction under NT could be due to the increase in soil bulk density resulting in decrease volume fraction of large pores and less decomposition of organic matter
- The effects of NT on N_2O emission gave diverse results
- NT practices are capable of offsetting overall GHG emissions because of C sequestration and CH_4 mitigation ability.
- Overall GWP of NT is less than CT in rice fields

Conventional (CT) and no-till (NT) practices on GHG emissions in rice

	CH4 (kg ha^{-1})	N2O (kg ha^{-1})	CO2 (kg ha^{-1})	Reference
NT	279	–	–	Ali et al. (2009)
CT	381	–	–	
NT	188.1	0.51	–	Zhang et al. (2013)
CT	228.3	0.43	–	
NT	297.0	–	10,553.0	Li et al. (2013)
CT	721.5	–	16,328.5	

The adoption of NT is beneficial in GHG mitigation and C-smart agriculture and needs to be promoted in rice-based cropping systems.

Managing organic additives

- Field straw removal is an effective measure reducing GHG emission of all three gases as compared with straw incorporation
- In the long run with reduction in organic manure application; rice soils need straw recycling to overcome C losses due to soil cultivation and crop harvesting.

Fertilizer management

- Enhancing the fertilizer use efficiency can reduce GHG emissions especially N2O and it can also indirectly minimize CO2 emissions from manufacturing of nitrogenous fertilizer
- Selected suggested fertilizer management that can reduce GHG emissions from rice field
  - Site specific nutrient management (NO2, CH4, CO2)
  - Adjustment on rate, placement and application time (4R concept) (NO2, CH4)
  - Slow release fertilizers & nitrification inhibitors (NO2, CH4)

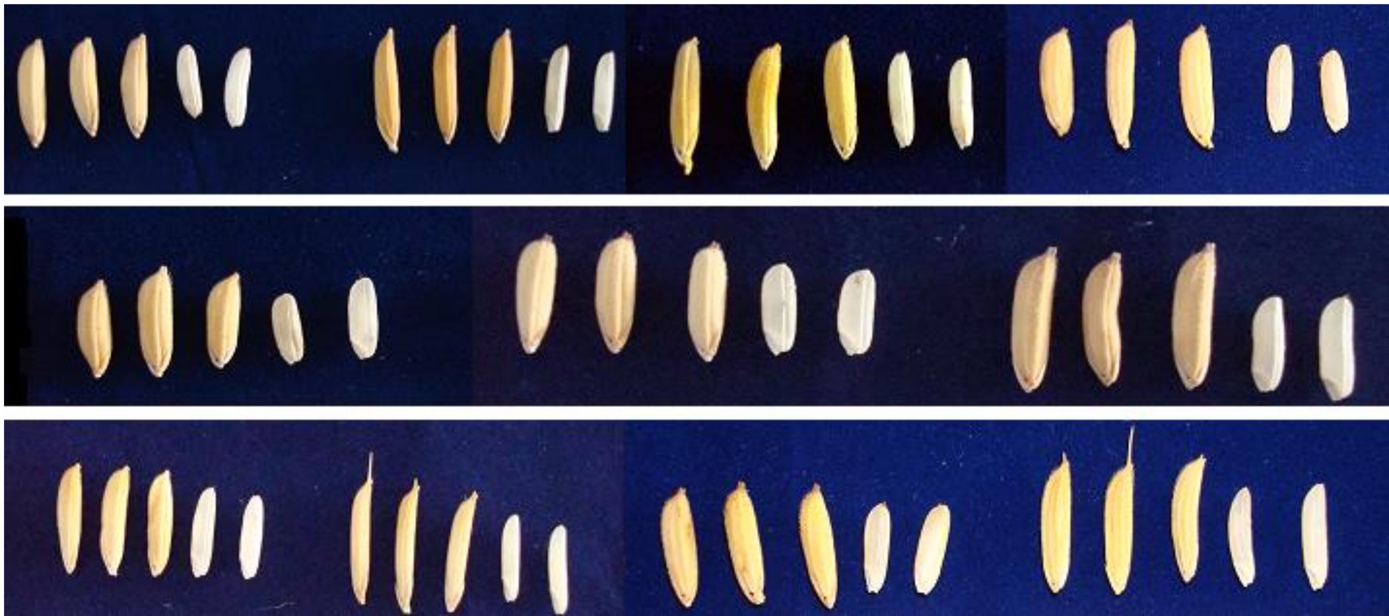
Looking for the right rice cultivar

- Breeding is always a promising strategy to minimize GHG emissions particularly CH4.
- The target - selection of less CH4 emitting and N responsive cultivar that wll minimise CH4 and NO2 emissions
- Taking advantage of cultivars variabilities (gene bank) on the basis of morphological and physiological traits and adaptation to a wide range of environmental parameters.

Looking for the right rice cultivar

- Assessment and selection on the following aspects;
  - Cultivars variations in CH_4 emission - variation in CH_4 production, oxidation, and transport capacities.
  - Soil redox potential (Eh) controls the CH_4 production rate of rice soils, with a specific threshold level.
  - Root respiration and exudation influence soil redox potential (Eh)
  - Overall growth development; aboveground biomass, plant development over the entire rice growing season will influence Eh
  - Cultivars with stronger root system can release more oxygen into the soil, enhance resistance to environmental stresses, and increase crop yield

Rice Gene Bank



CONCLUSION

- Information on increasing trend of GHG emissions under conventional rice cultivation under *Business As Usual scenario* is plenty and real
- Most of the available technologies on mitigating GHG are ready for the adoption
- Policy intervention maybe needed.
- Aerobic rice is the production system for water scarce environment and changing climate


Terima
Kasih