Simulating greenhouse gas fluxes and global warming potential in sorghum cropping systems in Texas

Manyowa N. Meki, Armen R. Kemanian, Jurg Blumenthal, Evelyn Steglich, Tom Gerik and Giovanni Piccinni

Blackland Research and Extension Center, Texas AgriLife Research
Department of Soil and Crop Sciences, Texas A&M University
Uvalde Research and Extension Center, Texas AgriLife Research

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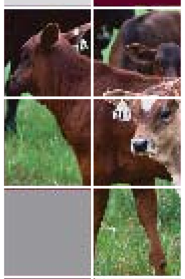
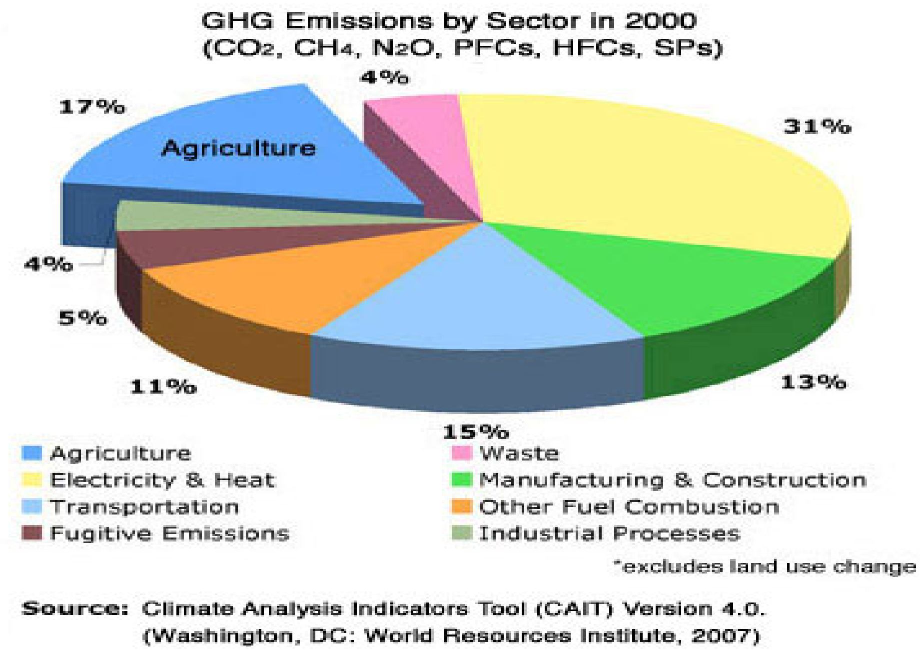
Contents

How much does agriculture contribute to the total greenhouse gas (GHG) emissions?





- CO_2 - 20%
- N_2O - 60%
- CH_4 - 50%

Source: IPCC (1997)

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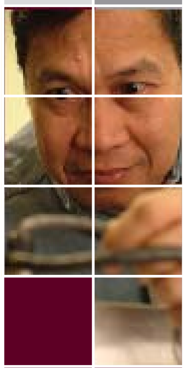
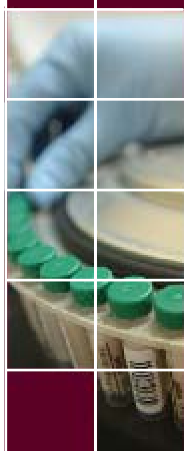
Sources of GHG in agriculture



- CO_2 – plant and soil microbial respiration, liming, and burning of fossil fuel in farming operations

- N_2O – nitrification or de-nitrification

- CH_4 – reduction of CO_2 under anaerobic conditions (rice and cattle production). Under aerobic conditions microbial oxidation of CH_4 causes soils to be sinks for CH_4



Global warming potential (GWP)

- GWP is a measure of how much a given mass of GHG is estimated to contribute to global warming.
- It is a relative scale comparing the gas in question to that of the same mass of CO_2 (measured as CO_2 equivalent, CO_2eq.).
- GWP is calculated over a specific time interval.

Greenhouse gas	Atmospheric lifetime (years)	20-year GWP	100-year GWP	500-yr GWP
Carbon dioxide (CO_2)		1	1	1
Methane (CH_4)	12	62	23	7
Nitrous oxide (N_2O)	114	275	296	156

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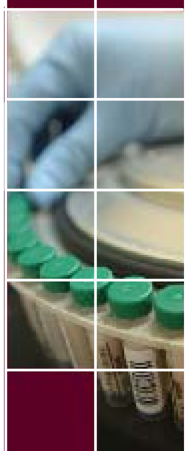
Objectives



- Assess GHG fluxes and GWP in grain sorghum cropping systems of central and south Texas
- Identify how combinations of tillage, conservation practice and irrigation interact to affect GHG fluxes and hence GWP

Methodology

- EPIC simulations - 45 year time series (1960-2004)
- Tillage – NT vs RT (Bell County) and CT vs RT (Cameron County)
- Conservation practice – None vs Contours vs Contours + Terraces
- Irrigation – Non-irrigated vs Irrigated
- County cropping systems (soil type, acreage, non-irrigated or irrigated and weather station) were selected using the NRI database (USDA NRCS, 2004).
- We used Robertson et al. (2000) for CH_4 fluxes.

- Bell – 378 Cropping Systems   Cameron – 1116 Cropping Systems

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Methods: Cropping systems

Bell – central Texas Non-irrigated	Cameron – south Texas: Non-irrigated and Irrigated
No Till (NT)	Conventional Till (CT)
NT + Contours	CT + Contours
NT + Contours + Terraces	CT + Contours + Terraces
Reduced Till (RT)	Reduced Till (RT)
RT + Contours	RT + Contours
RT + Contours + Terraces	RT + Contours + Terraces

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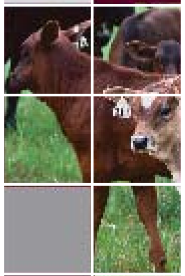
Accounting of GHG and GWP



		Conventional Till	Reduced Till	No Till	*Emission Factor*
GWP Components	**Units**	***Inputs/Emissions***	***Inputs/Emissions***	***Inputs/Emissions***	***kg C /kg***
N fertilizer	**kg/ha**	**134.4**	**134.4**	**134.4**	**0.85*[a]**
P fertilizer	**kg/ha**	**44.8**	**44.8**	**44.8**	**0.17[b]**
Lime	**kg/ha**				
Herbicides	**kg/ha**	**2.3**	**2.3**	**2.8**	**4.70[b]**
Insecticides	**kg/ha**	**0.6**	**0.6**	**0.6**	**4.93[b]**
Seed	**kg/ha**	**6.2 (9.9)**	**6.2 (9.9)**	**6.2**	**0.86[c]**
Diesel	**kg/ha**	**55.7**	**37.2**	**23.0**	**0.94[d]**
Irrigation	**ha-m/ha**	**0(0.2)**	**0 (0.3)**	**0**	**525.10[e]**
Grain drying	**KWh**				
Total					
Δ Soil C	**kg/ha**	**±337**			
N_2O		**0.9% (1.25%)**			**296**
CH_4		**-1-3%**			**23**
GWP	**kg C/ha**				

Multiply input values by the Emission Factor to convert to kg C/ha/yr equivalents
***Add C 12.5 C eq /ha/yr eq to cover N & P fertilizer transportation emissions**
[e]kg C /ha-m
Multiply kg C /ha/yr by 3.667 to convert to kg CO2-C eq/ha/yr

Sources:
[a]Izaurralde et al (1997); Lal et al (1998); West and Marland (2002); Lal (2004); Robertson and Grace (2004)
[b]West and Marland (2002); Lal (2002), Heichel (1980); Borjesson (1996); West and Marland (2002)
[d]Boustead and Hancock (1979); Fluck (1992); Robertson and Grace (2004)

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Effect of Tillage Systems on GWP

Bell county - central Texas: Non-irrigated

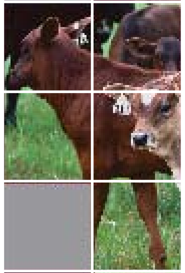
	Reduced Till	No Till
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5
P fertilizer	27.1	27.1
Lime		
Herbicides	39.5	49.0
Insecticides	10.5	10.5
Seed	19.4	19.4
Diesel	128.2	79.4
Irrigation		
Grain drying		
Total	693.2	653.9
Δ Soil C	-859.2	-636.7
Soil N_20	351.5	342.7
Soil CH_4	-50.0	-50.0
GWP	135.6	309.9

Cameron county - south Texas: Non-irrigated

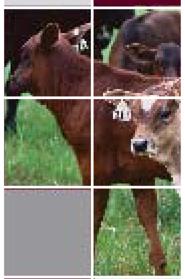
	Conventional Till	Reduced Till
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5
P fertilizer	27.1	27.1
Lime		
Herbicides	39.5	39.5
Insecticides	10.5	10.5
Seed	19.4	19.4
Diesel	192.1	128.2
Irrigation	0.0	0.0
Grain drying		
Total	757.1	693.2
Δ Soil C	1381.6	839.4
Soil N_20	241.4	180.7
Soil CH_4	-50.0	-50.0
GWP	2330.1	1663.3

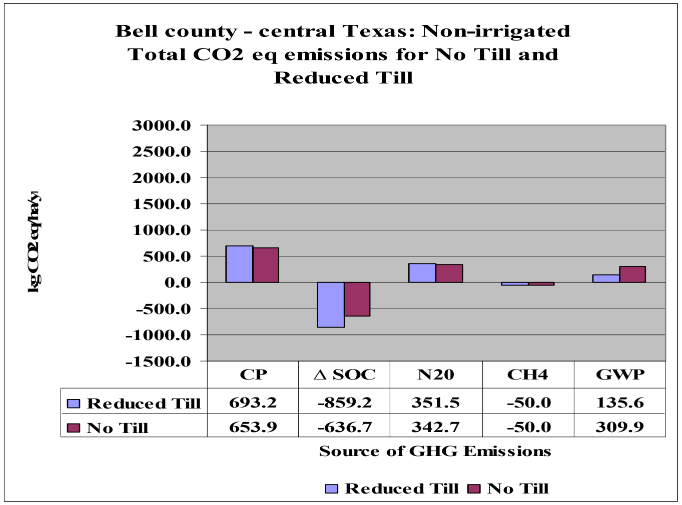
Cameron county - south Texas: Irrigated

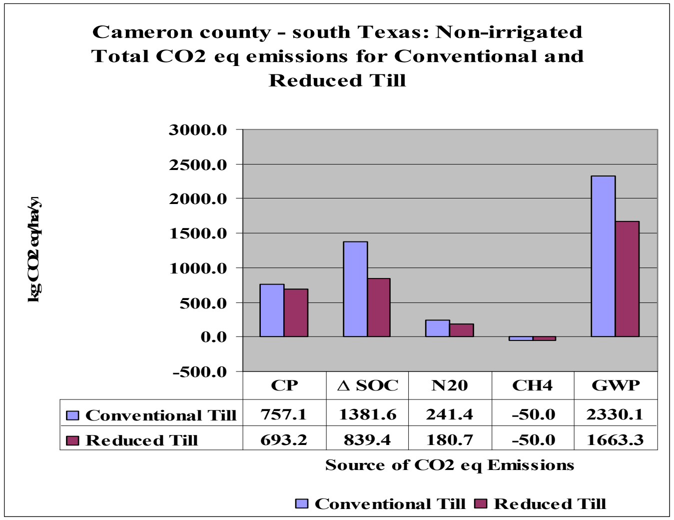
	Conventional Till	Reduced Till
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5
P fertilizer	27.1	27.1
Lime		
Herbicides	39.5	39.5
Insecticides	10.5	10.5
Seed	31.2	31.2
Diesel	192.1	128.2
Irrigation	469.3	523.8
Grain drying		
Total	1238.1	1228.8
Δ Soil C	1183.2	147.4
Soil N_20	188.6	165.7
Soil CH_4	-50.0	-50.0
GWP	2559.9	1491.9

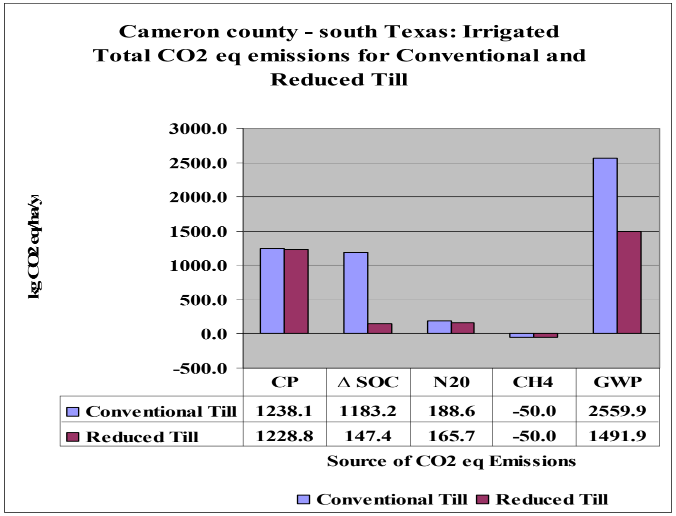


Effect of Tillage Systems on GWP









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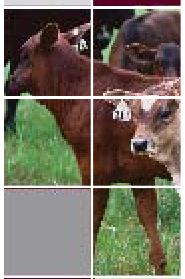
Conservation Practice and GWP



Bell county - central Texas: Non-irrigated	None	Contours	Contours+Terraces
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5	468.5
P fertilizer	27.1	27.1	27.1
Lime			
Herbicides	44.2	44.2	44.2
Insecticides	10.5	10.5	10.5
Seed	19.4	19.4	19.4
Diesel	103.8	103.8	103.8
Irrigation			
Grain drying			
Total	673.6	673.6	673.6
Δ Soil C	-592.9	-753.0	-897.9
Soil N_20	369.1	344.8	327.4
Soil CH_4	-50.0	-50.0	-50.0
GWP	399.8	215.4	53.0

Cameron county - south Texas: Non-irrigated	None	Contours	Contours+Terraces
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5	468.5
P fertilizer	27.1	27.1	27.1
Lime			
Herbicides	39.5	39.5	39.5
Insecticides	10.5	10.5	10.5
Seed	19.4	19.4	19.4
Diesel	160.1	160.1	160.1
Irrigation			
Grain drying			
Total	725.2	725.2	725.2
Δ Soil C	1127.5	1116.5	1087.5
Soil N_20	246.7	201.7	184.7
Soil CH_4	-50.0	-50.0	-50.0
GWP	2049.3	1993.4	1947.3

Cameron county - south Texas: Irrigated	None	Contours	Contours+Terraces
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5	468.5
P fertilizer	27.1	27.1	27.1
Lime			
Herbicides	39.5	39.5	39.5
Insecticides	10.5	10.5	10.5
Seed	31.2	31.2	31.2
Diesel	160.1	160.1	160.1
Irrigation	504.0	494.4	491.2
Grain drying			
Total	1241.0	1231.3	1228.1
Δ Soil C	712.3	650.9	632.8
Soil N_20	190.3	173.3	167.7
Soil CH_4	-50.0	-50.0	-50.0
GWP	2093.6	2005.5	1978.5

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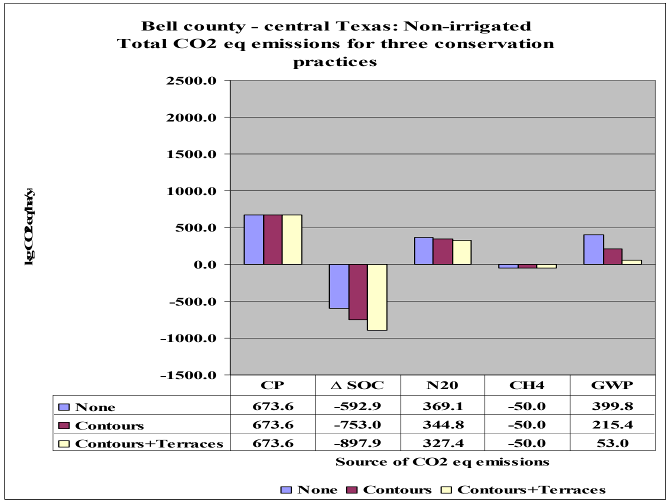
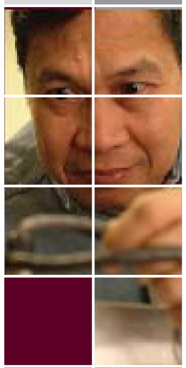
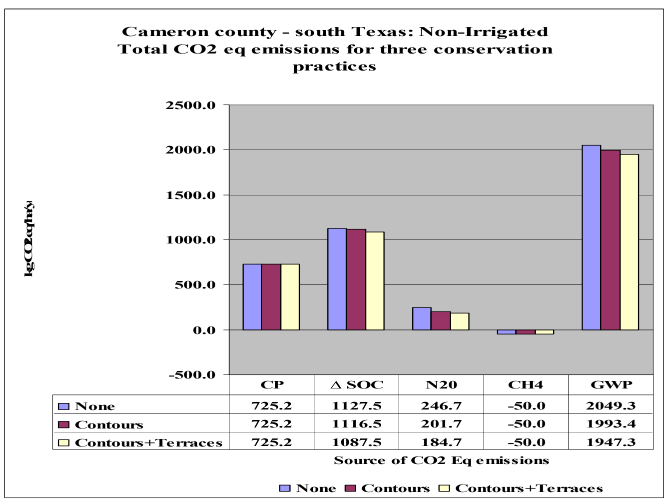
Conservation Practice and GWP

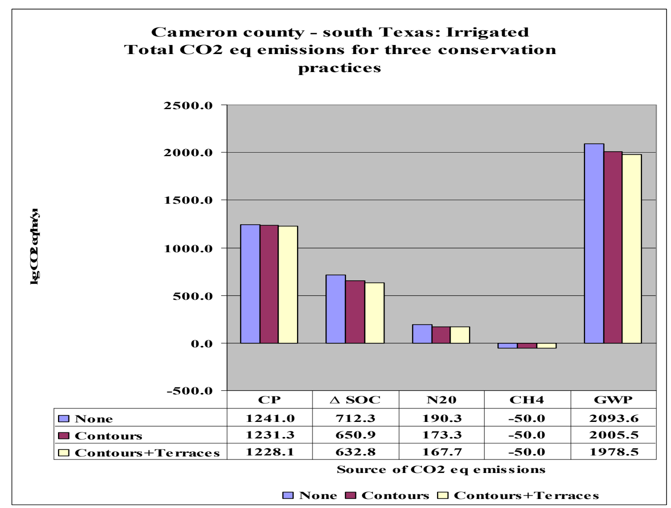


	CP	Δ SOC	N20	CH4	GWP
None	673.6	-592.9	369.1	-50.0	399.8
Contours	673.6	-753.0	344.8	-50.0	215.4
Contours+Terraces	673.6	-897.9	327.4	-50.0	53.0





	CP	Δ SOC	N20	CH4	GWP
None	725.2	1127.5	246.7	-50.0	2049.3
Contours	725.2	1116.5	201.7	-50.0	1993.4
Contours+Terraces	725.2	1087.5	184.7	-50.0	1947.3



	CP	Δ SOC	N20	CH4	GWP
None	1241.0	712.3	190.3	-50.0	2093.6
Contours	1231.3	650.9	173.3	-50.0	2005.5
Contours+Terraces	1228.1	632.8	167.7	-50.0	1978.5

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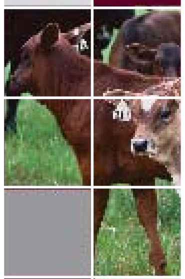
Effect of Irrigation on GWP



Cameron county - south Texas:		
	Non-irrigated	Irrigated
GWP Components	kg CO_2-C eq /ha/yr	kg CO_2-C eq /ha/yr
N fertilizer	468.5	468.5
P fertilizer	27.1	27.1
Lime		
Herbicides	39.5	39.5
Insecticides	10.5	10.5
Seed	19.4	31.2
Diesel	160.1	160.1
Irrigation	0.0	496.5
Grain drying		
Total	725.2	1233.5
Change in Soil C	1110.5	665.3
Soil N_20	211.0	177.1
Soil CH_4	-50.0	-50.0
GWP	1996.7	2025.9

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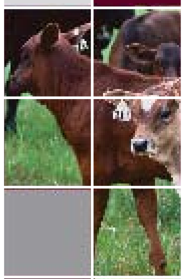
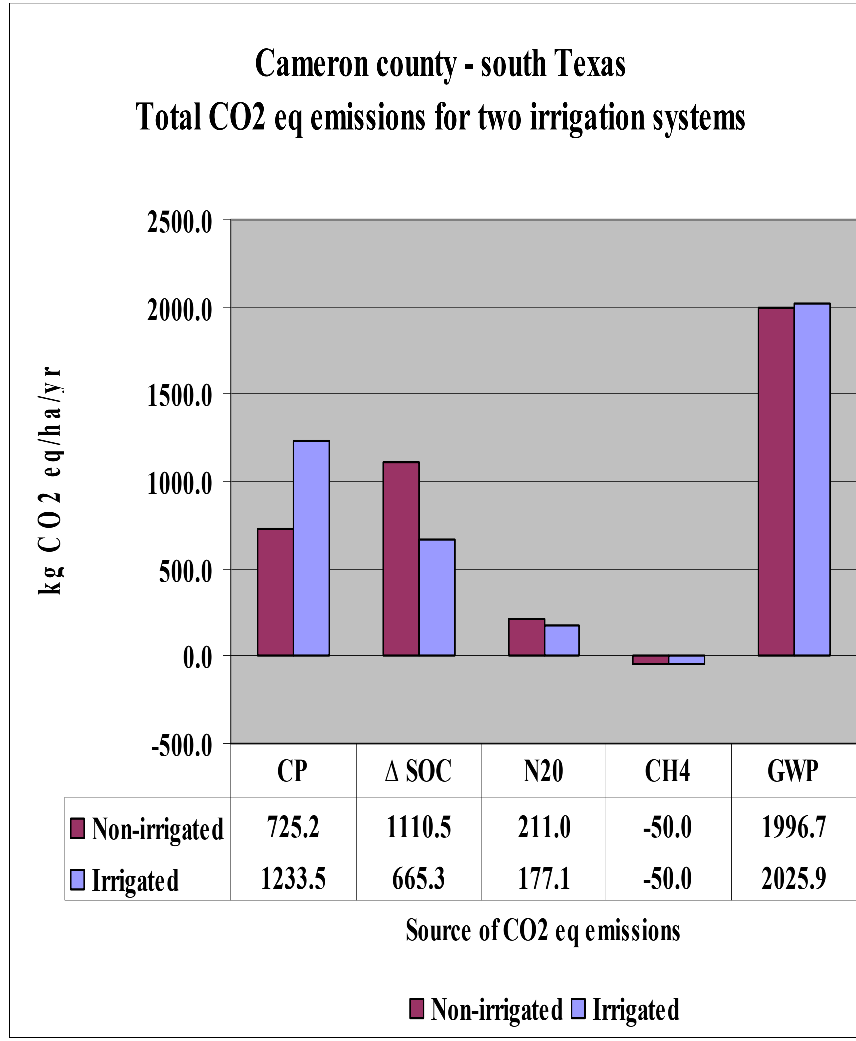
Effect of Irrigation on GWP



Drip (trickle) irrigation waters crops efficiently.
Credit: Nova Scotia Agriculture and Fisheries



	CP	Δ SOC	N20	CH4	GWP
Non-irrigated	725.2	1110.5	211.0	-50.0	1996.7
Irrigated	1233.5	665.3	177.1	-50.0	2025.9

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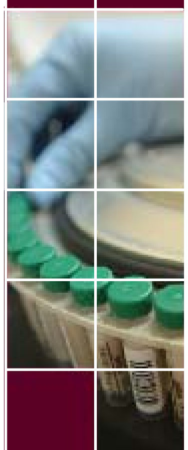
Summary of Results



- Major sources of GHG/GWP in the production inputs and operations:
  Diesel 15%, Nitrogen fertilizer 48%, Irrigation 31%

- Total emissions (GWP) from:
  - inputs and cropping operations 53%
  - change in SOC: 32% and N_2O 12%
  - estimated CH_4: -3%

- The magnitude of tillage and conservation practices on GWP mitigation were:
  - No Till (72%)>Reduced Till (55%)>Conventional Till
  - Contours+Terraces (75%)>Terraces (46%)>None

- Irrigated cropping systems had slightly higher (1.5%) GWP than rainfed systems (irrigation = 31% of production cost).

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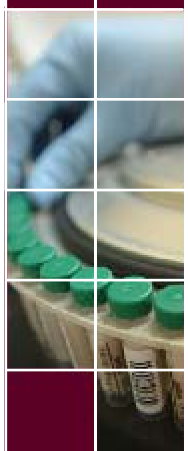
Conclusions



- **Converting from conventional tillage (CT) to reduced till (RT) and no till (NT) coupled with the conservation practices of contours and terraces, minimizes GHG fluxes and hence GWP in both irrigated and non-irrigated sorghum cropping systems.**

- **GWP impact of sorghum cropping systems can be obtained in a cost-effective way by using simulation models such as EPIC.**

- **There is potential to manipulate cropping systems to mitigate GWP through adoption of appropriate conservation tillage management options and water management strategies that enhance C sequestration and decrease N_2O emissions.**

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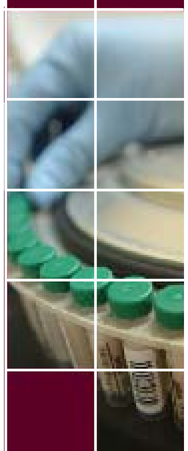
Future work



- State level: use EPIC to assess GWP of grain sorghum cropping systems for the entire state
- Farm level: use APEX to asses the spatial distribution of GWP within farms to design precision conservation technologies, including double-purpose crops (bioenergy / buffer strip)

THANK YOU

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Acknowledgements

CSREES Great Plains Sorghum Improvement & Utilization Center:

Sorghum Cropping Systems Research in Texas

Texas AgriLife Research Cropping Systems Program FY' 2008-2009:

Coupling Bioenergy Crops and Precision Conservation to Enhance Farming Profitability and Environmental Integrity in Dryland and Irrigated Systems

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