Midsouth Grower Outreach Summary

Below is a list of presentations and meetings conducted by ACR/Winrock and its sub, White River Irrigation District, in the Midsouth under the 2011 Rice CIG. Copies of representative presentations and agendas accompany this list.

2011-2015 | NRCS Conservation Innovation Grant 69-3A75-11-133

I. Grower outreach workshop(s) in AR

- Focus Group Kickoff Workshop, Five Oaks Lodge, Humphrey, AR, December 6, 2011
- Michelle Reba Grower Information meeting with Kevin Cochran at NRCS Jonesboro office to inform producers of project. 15 producers. Jonesboro, AR. February 2013.
- Michelle Reba presenting at the Mississippi county extension meeting. 20 participants. Keiser, AR. March 2013.
- Michelle Reba presenting at the American Water Resources Spring Specialty Conference, Agricultural Hydrology & Water Quality, St. Louis, MO March, 2013.
- Arkansas Soil and Water Education Conference. Jonesboro, AR. Merle Anders and Earl Kline presented on AWD. January 31, 2014. 230 participants.
- International Fertilizer Development Center's workshop 2013 & 2014, Keiser, AR. ~50 participants.
- Cotton and rice production conference, Baton Rouge, LA. Michelle Reba presenting with Mike Sullivan. January 15 & 16, 2015

II. Training workshops in AR on data collection and project implementation requirements

- Michelle Reba met with producers individually to discuss field data collection for 2013/2014 field season.
- Dennis Carman GHG Data Collection presentation, July 14, 2014
- Mike Sullivan: March 2013, March 2014, field visit with Terra Global July 2014 to discuss data availability and implementation requirements.
- Mark Wimpy: April 2013, March 2014, field visit with Terra Global July 2014 to discuss data availability and implementation requirements.

III. Results dissemination workshops in AR

- Dr. Merle Anders presented *Intermittent Flooding of Rice* at the *Mid South Chapter of ASFMRA 2014 Summer Meeting* in Little Rock, AR on June 5, 2014 (agenda can be found at http://www.asfmra.org/wp-content/uploads/2014/06/Mid-South-Chapter-2014-Summer-Meeting-Final.pdf)
- Dr. Joe Massey presented *Water Usage Studies of Major MS Delta Crops* and *What are IWMs & How they are Assisting Mississippi Rice Farmers* at the *2014 Delta States Irrigation Conference & Tradeshow,* December 17 – 18, 2014 *Rice Irrigation*

- Dennis Carman presented *Bringing Voluntary Agricultural Carbon Credits to MidSouth Rice Growers* at 2015 Arkansas Soil & Water Conference, Arkansas State University, January 30, 2015
- Dr. Michelle Reba presented *Water Resources Management of Cotton & Rice Production in the MidSouth* at the *2013 American Water Resources Spring Specialty Conference,* March 25, 2015
- June 2015 MidSouth Rice Tour, June 9 – 11, 2015

IV. Miscellaneous

- *Bringing Voluntary Agricultural Carbon Credits to Environmental Markets*, presentation by Dennis Carman to the Coalition on Agricultural Greenhouse Gases, November 6, 2013

Appendix E.1
Water resources management of cotton and rice production in the midsouth

By Michele L. Reba, PhD, PE
USDA-Agricultural Research Service

WATER RESOURCES MANAGEMENT OF COTTON AND RICE PRODUCTION IN THE MIDSOUTH

Michele L. Reba, PhD, PE
USDA-Agricultural Research Service

2013 American Water Resources Spring Specialty Conference
Agricultural Hydrology & Water Quality II
St. Louis, MO
March 25, 2013

ACKNOWLEDGEMENTS

- Dr. Tina Gray Teague, Arkansas State University & University of Arkansas, Division of Agriculture
- Dr. Paul Counce, University of Arkansas
- Dr. Christopher G. Henry, University of Arkansas
- Dr. Earl Vories, USDA-ARS, Portageville, MO
- USDA-NRCS-Conservation Innovation Grant
- Cotton Incorporated

OVERVIEW

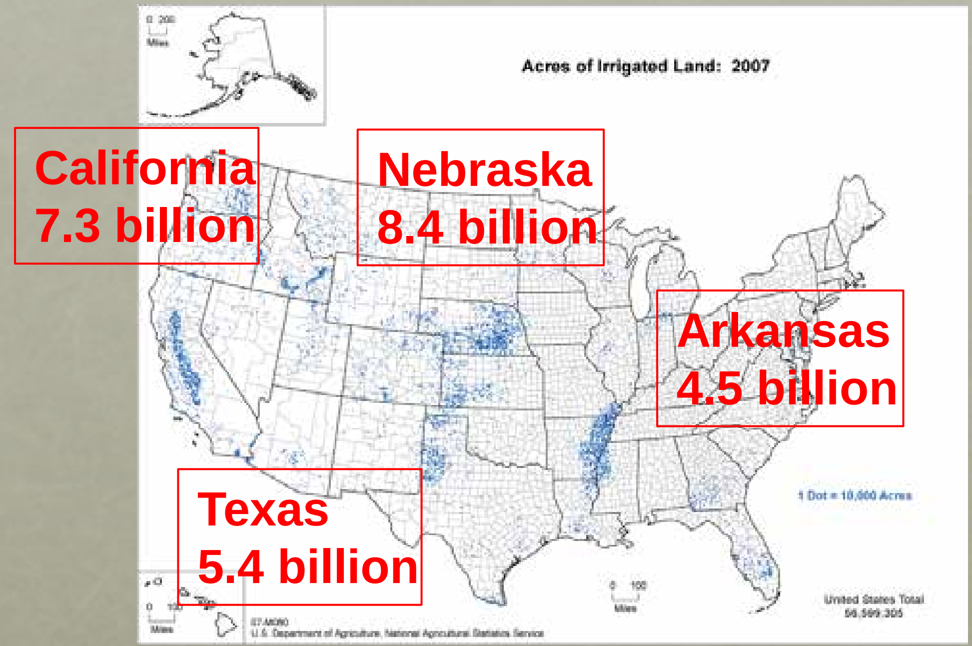
- Agriculture & water are important
- Conservation practices impact water
- Cotton production
  - Termination guidelines
- Rice production
  - Technology innovation
  - Irrigation management

AGRICULTURE

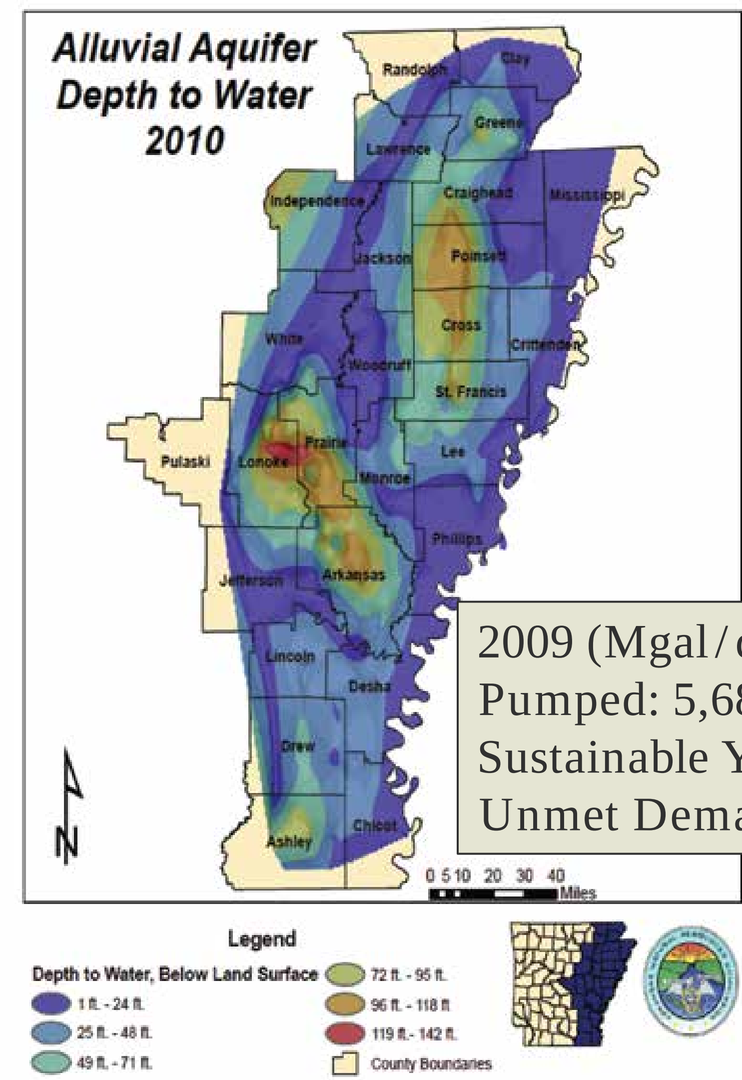
- Year 2050
- Arkansas production
  - % of GDP
  - #1 Rice
  - #2 Broilers
  - #3 Cotton
  - Top 25 for 24 commodities
- Water Resources

WATER RESOURCES

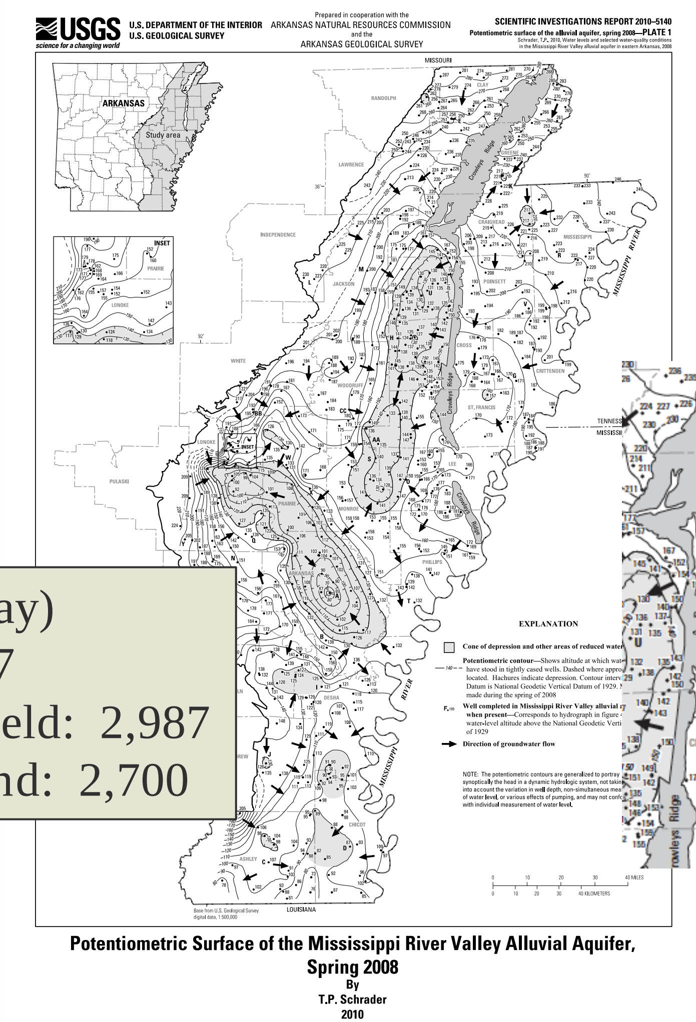
- Irrigation
  - Yield increase
  - Efficiency improvements
- Arkansas
  - 4.50 M ac
  - Rice/soybean
    - 77% or 3.46 M ac
    - Furrow 46%, Flood 35%
  - Cotton
    - 12% or 519,707 ac
    - Furrow/sprinkler: 60/40
    - 10% rainfed
- Groundwater decline
  - 84% Lower Miss. R.
  - 80/20 Arkansas



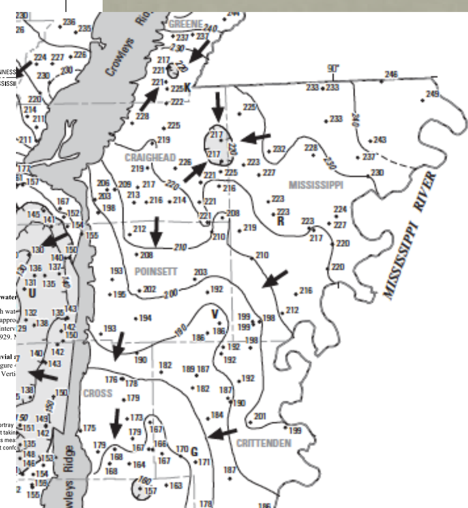
ALLUVIAL AQUIFER DECLINE



2009 (Mgal/day)
Pumped: 5,687
Sustainable Yield: 2,987
Unmet Demand: 2,700

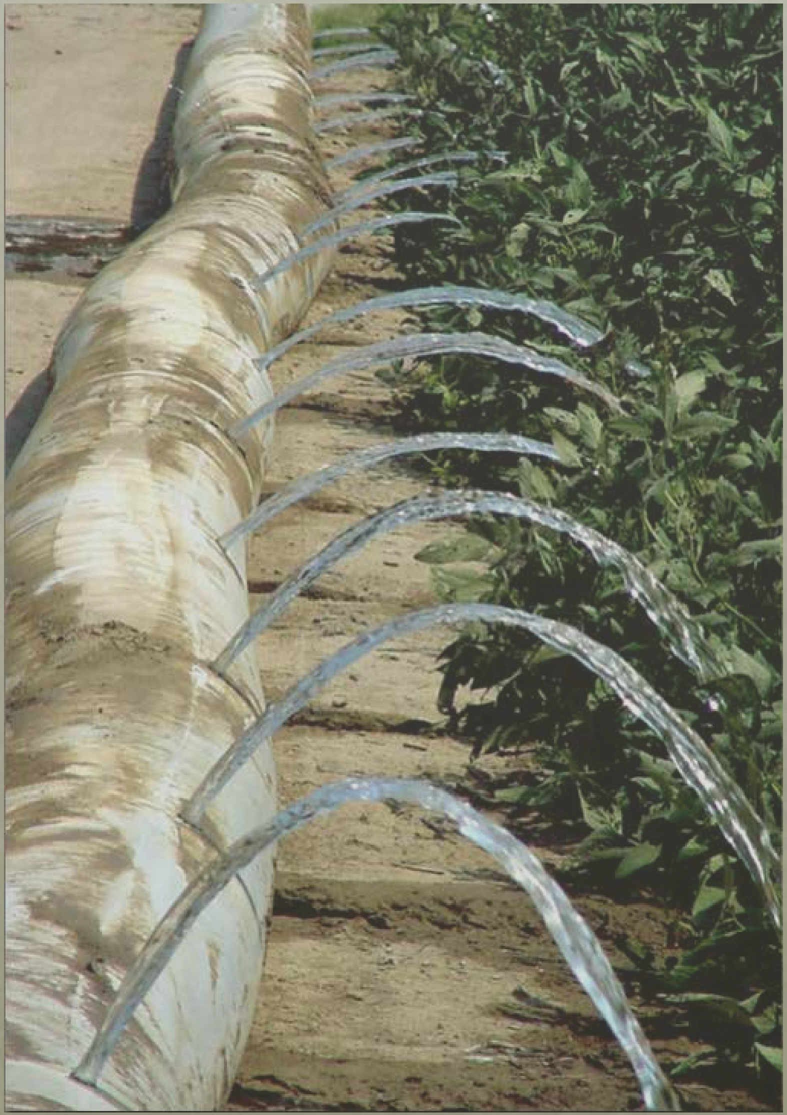


Potentiometric Surface of the Mississippi River Valley Alluvial Aquifer, Spring 2008
By
T.P. Schrader
2010



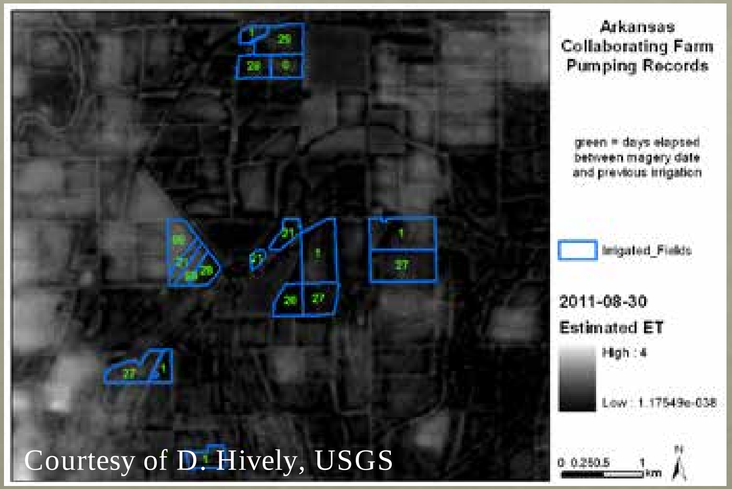
WATER CONSERVATION

- Water use
- Irrigation planning
  - Phaucet
  - Pipe Planner
- Surge valves
- Irrigation scheduling
- **Termination guidelines**
- **Remote monitoring & control of pump & motor systems**
- **Intermittent flodding**



OBJECTIVES

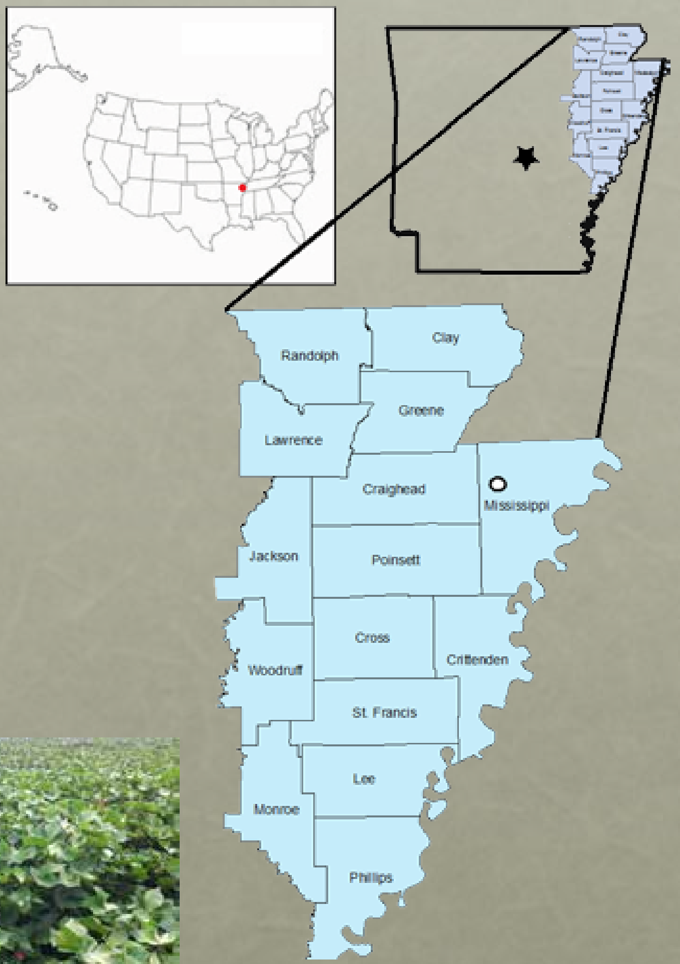
- Cotton: Evaluate irrigation termination on producer fields
  - Furrow irrigation
  - Pivot irrigation
- Rice: Evaluate land grading & remote control of pump and motor systems
- Determine water applied over a range of conditions
  - Compare to future innovations
- Relate water use to yield.



Courtesy of D. Hively, USGS

COTTON STUDY SITE

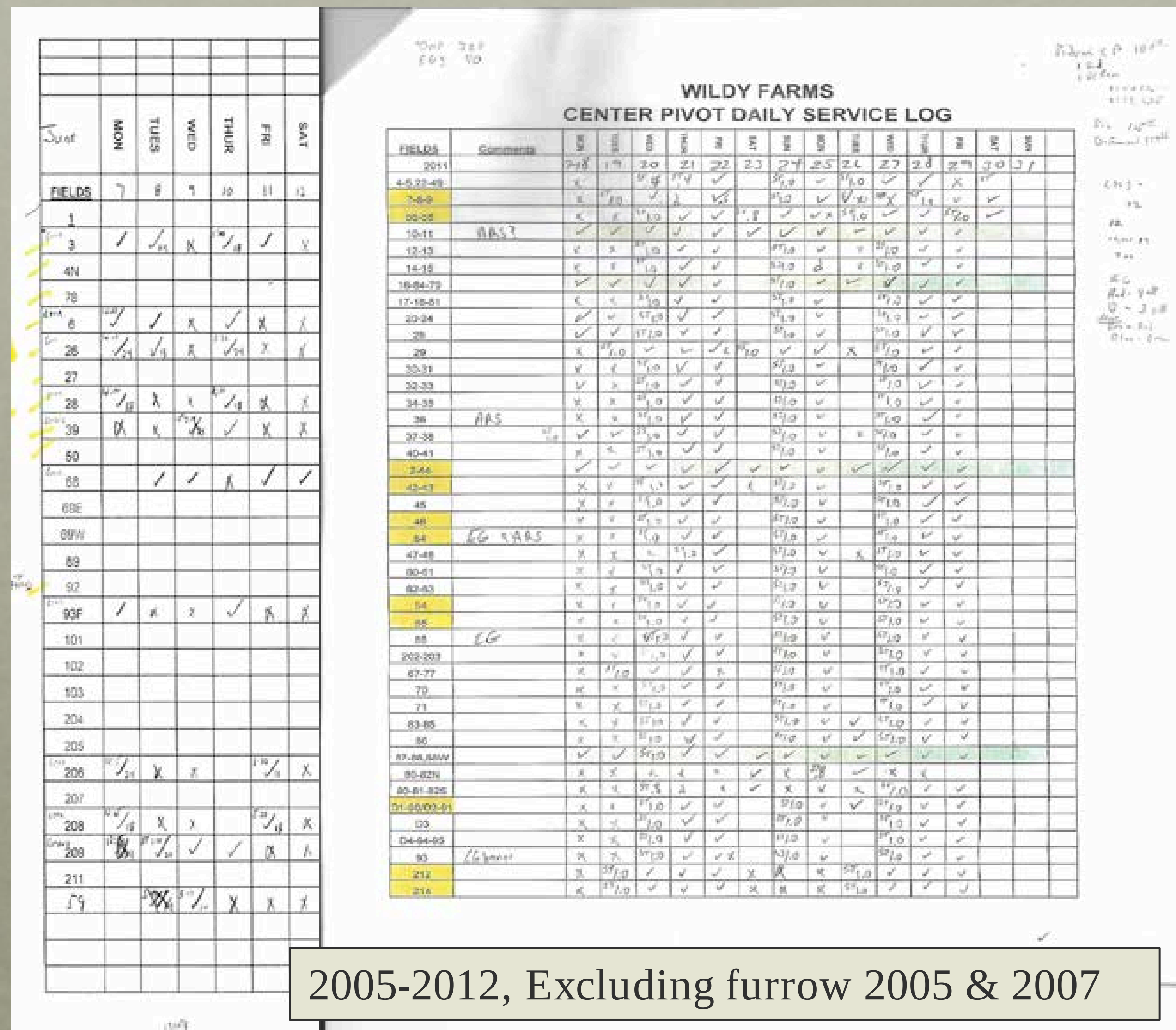
- Lower Mississippi River Basin
- Arkansas delta
- Wildy Family Farms
- Acreage 7,405
  - Pivot: 82% (6,076 ac) on 43 fields
  - Furrow: 18% (1,330 ac) on 27 fields
  - Arkansas 60/40 furrow/sprinkler
  - Corn (2012: 12.5%)



Watershed Physical Processes

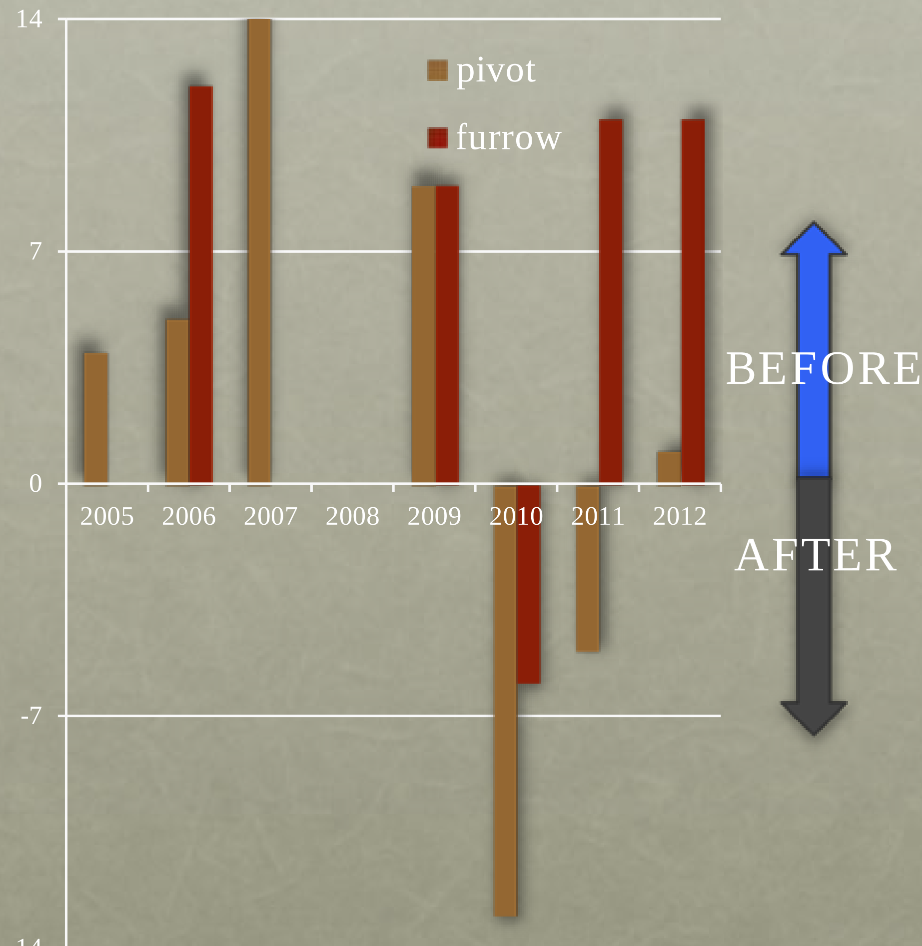
COTTON DATA

- Meteorological
  - Keiser Experimental Station
- Irrigation logs
  - Furrow: on/off
    - 3” applied/day
  - Pivot: applied
- Plant monitoring
  - NAWF5 date
  - Calculate 350 HU
- Yield
  - lb lint/ac



2005-2012, Excluding furrow 2005 & 2007

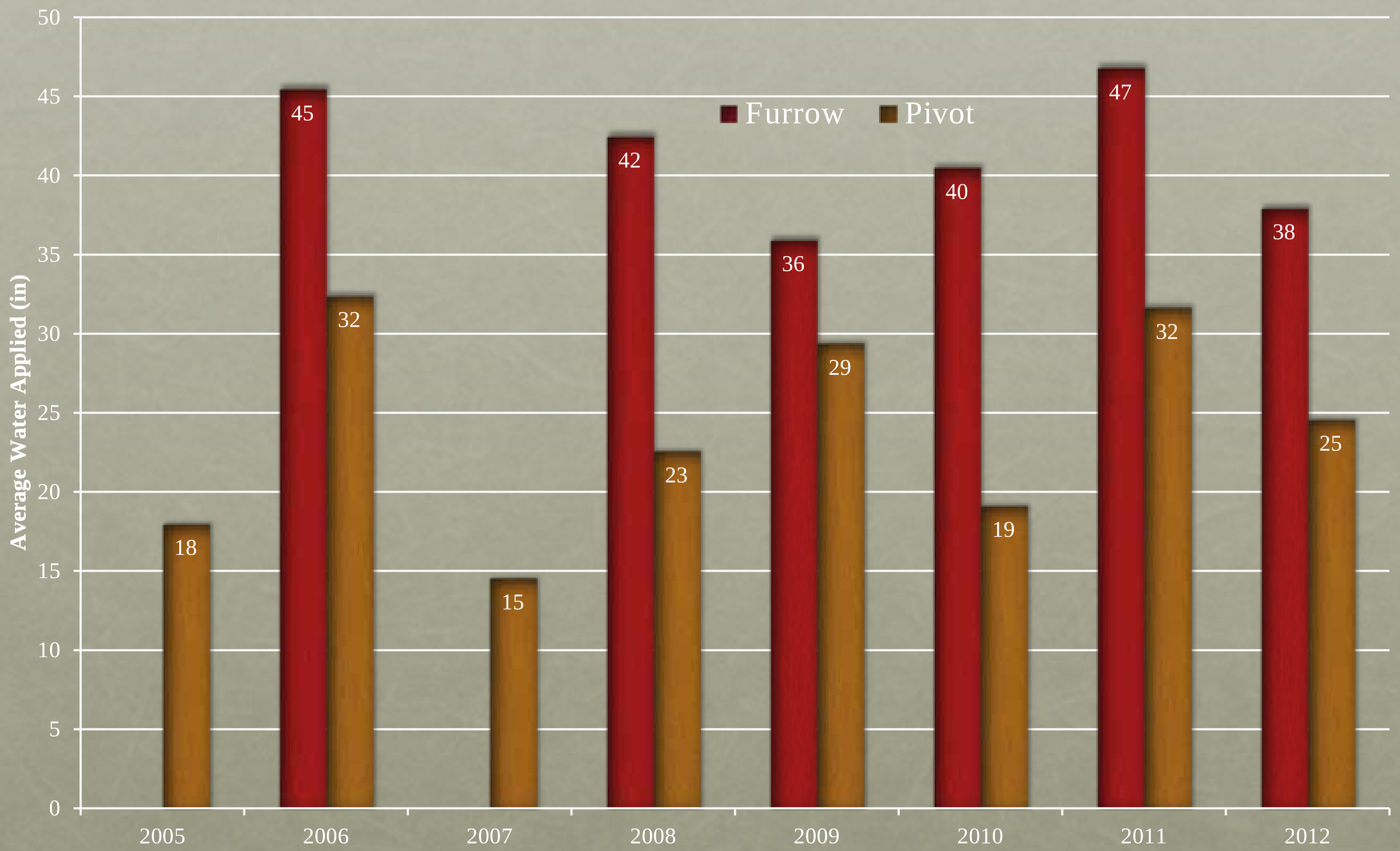
TERMINATION



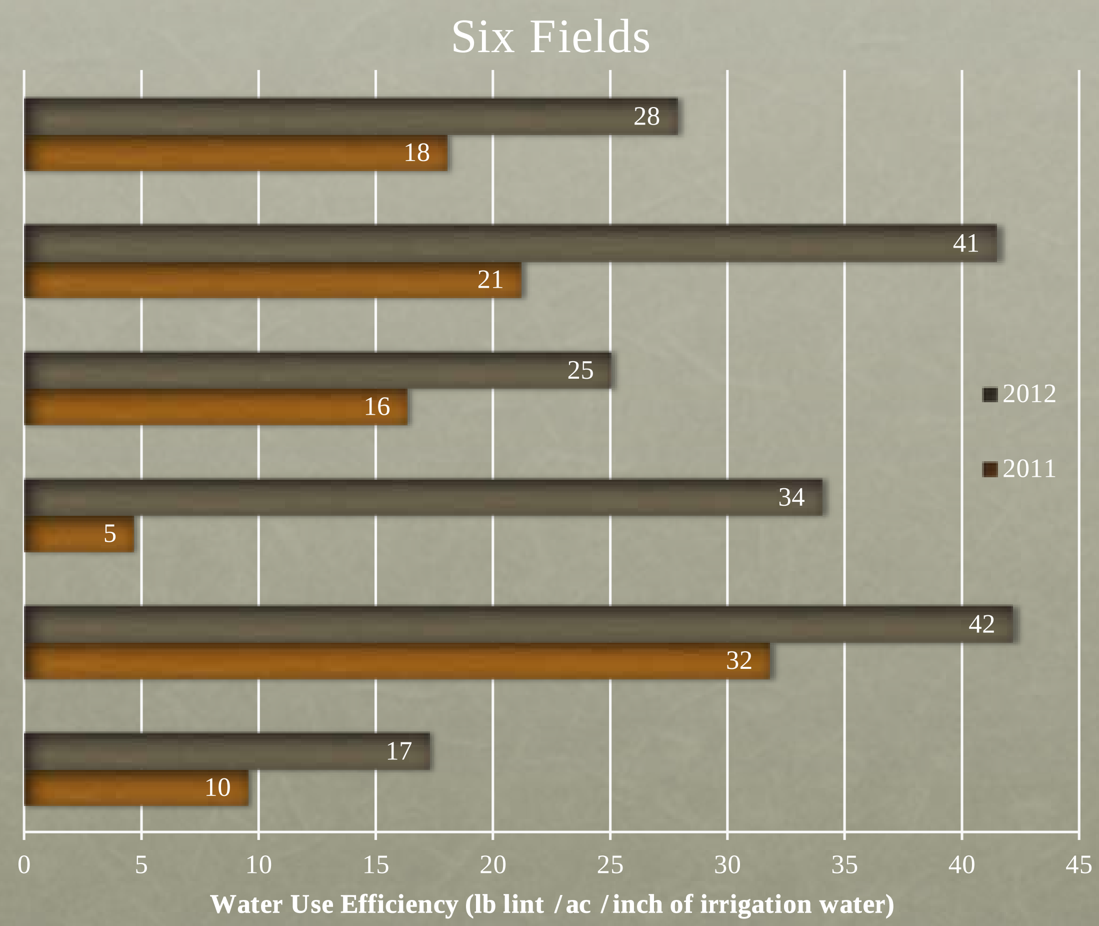
Year	Furrow	Pivot
2005		5
2006	14	7
2007		16
2008		
2009	9	11
2010	-13	-8
2011	13	-3
2012	15	2

- Missing plant data 2008

AVERAGE WATER APPLIED + PPT



WATER USE EFFICIENCY 2011 & 2012



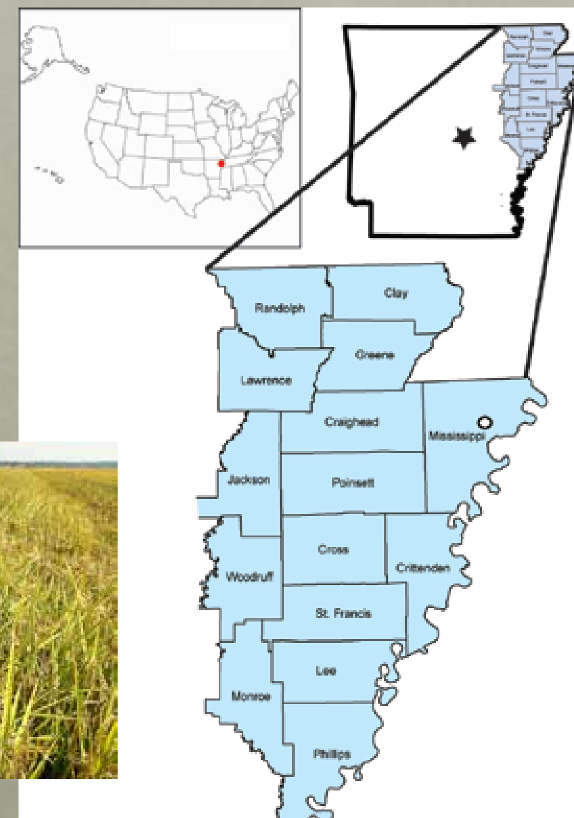
	2011	2012
Furrow (lb lint/ac/in)		
Maximum	29	39
Minimum	4	9
Average	15	19
Pivot (lb lint/ac/in)		
Maximum	55	47
Minimum	2	19
Average	22	35

COTTON CONCLUSIONS

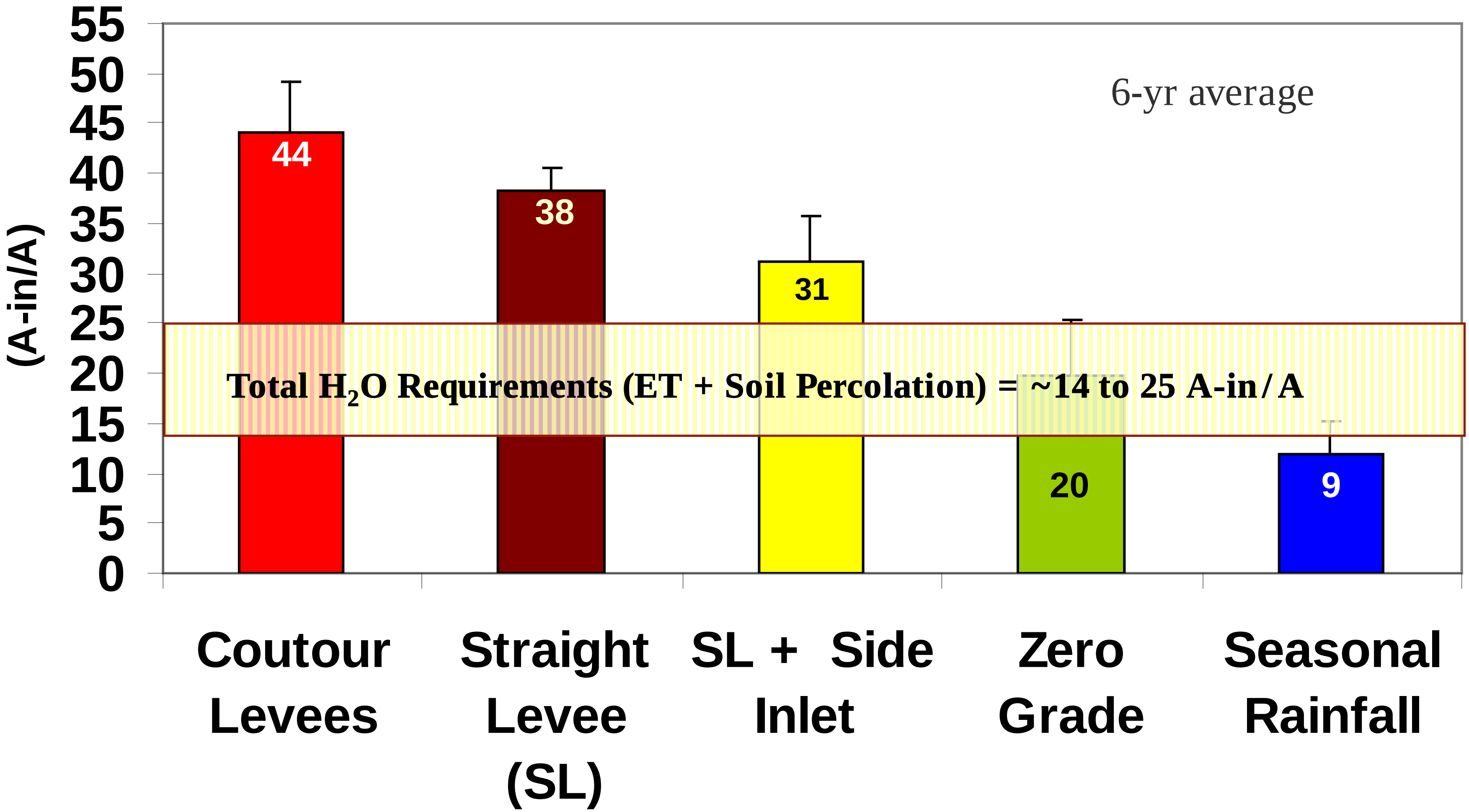
- Water applied within range
  - Furrow: 38 - 47 in
  - Pivot: 15-32 in
  - Minor field-to-field variation
- Termination guidelines
- Yield increase from irrigation
  - Average 17 & 31 lbs lint/inch
  - Max 42 lbs lint/inch
  - 2011 & 2012 only
- Future analysis
  - Seasonal cycle
  - Improvements with innovation

RICE STUDY SITE

- Lower Mississippi River Basin
- Arkansas delta
- Florenden Farms-Mike Sullivan
- Acreage 3,000 ac
    - Rice/soybean rotation
- Land grading
- Remote control of pump & motor systems



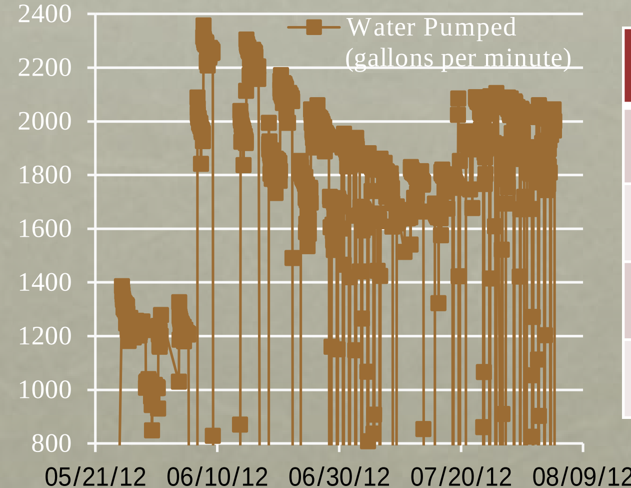
WATER USE MS RICE PRODUCTION



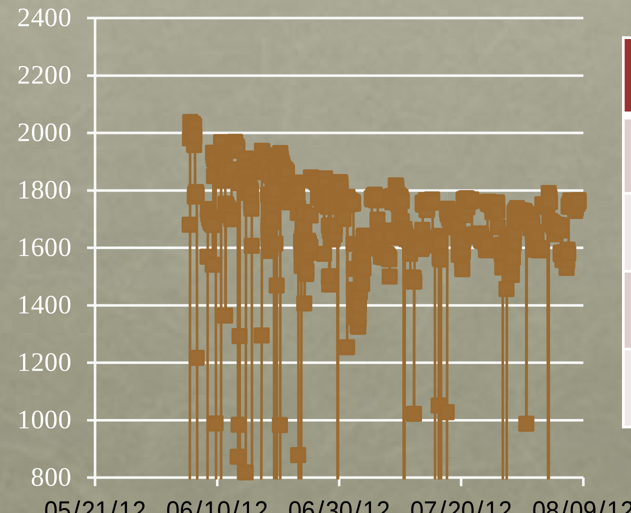
Pringle (1994): Water Use Requirements for Rice in the MS Delta

Source: Dr. Joe Massey, Mississippi State University

RICE WATER USE



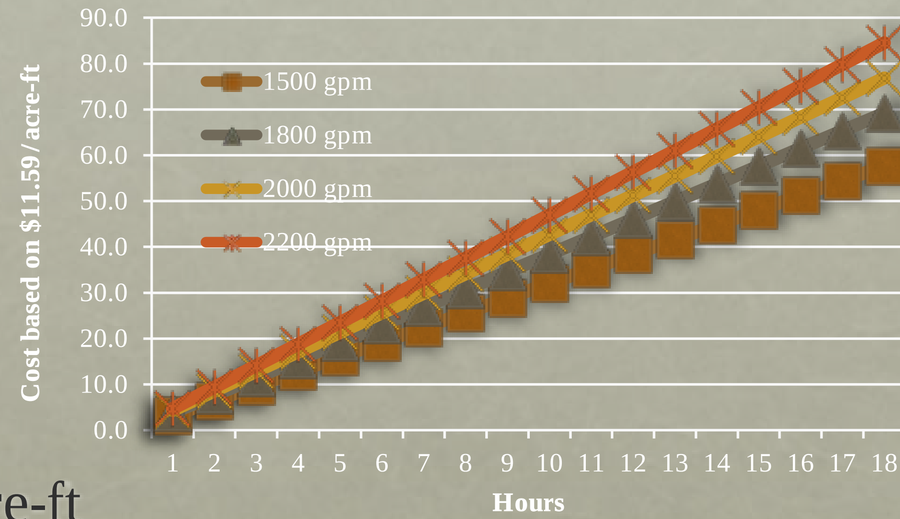
	Zero-grade
Acreage	206 ac
Water	25.2 in
Yield	184.5 Bu/A
Efficiency	8.0 Bu/in



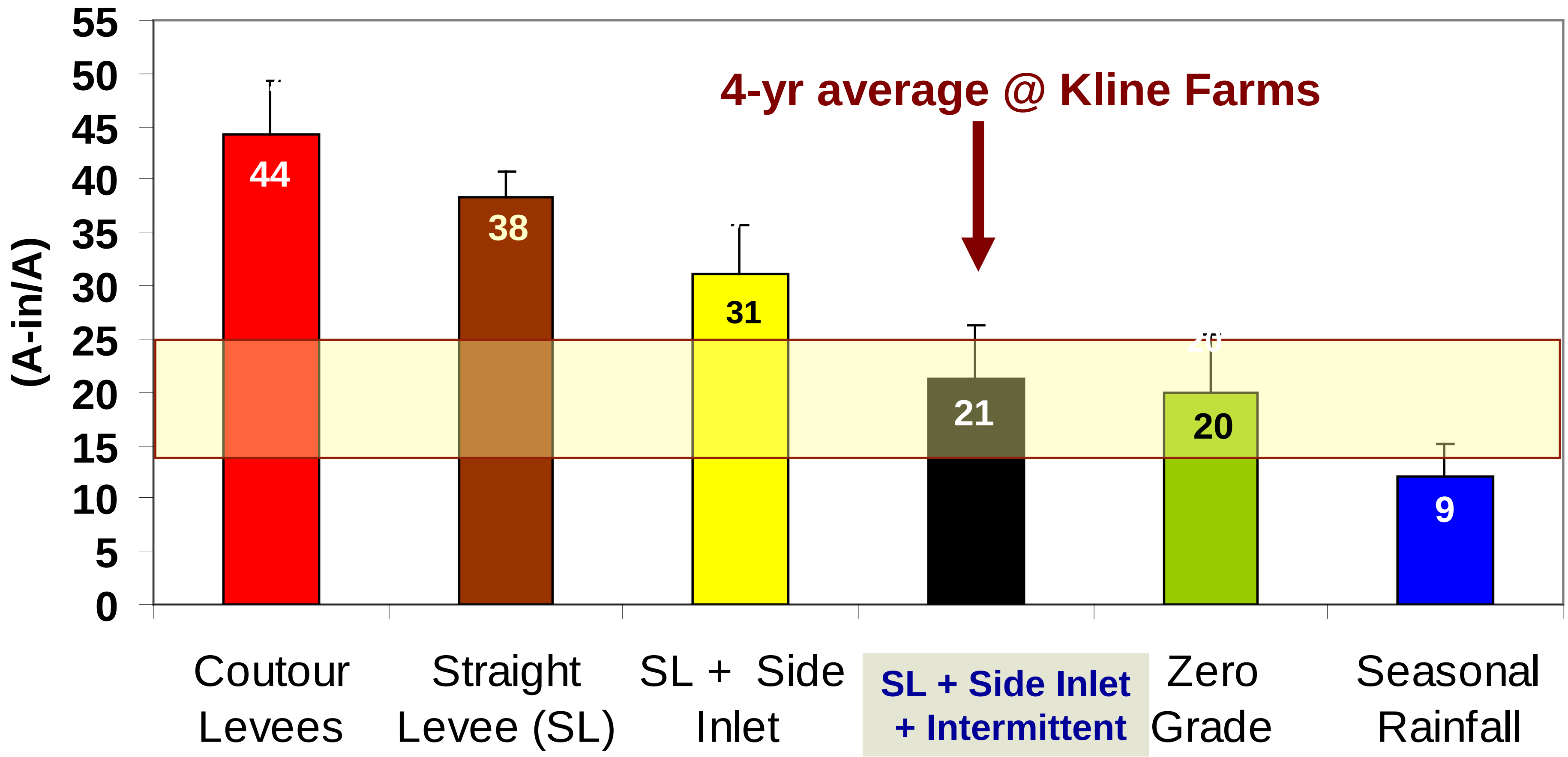
	Precision-grade
Acreage	146 ac
Water	33.3 in
Yield	192.4 Bu/A
Efficiency	5.8 Bu/in

REMOTE MONITOR & CONTROL

- Water use
- Pump performance
- Labor reduction
- Precipitation event
  - 2,000 gpm, 8 hours, 2.9 acre-ft
  - $11.59/acre-ft, $34.10
  - Multiple fields ~$600-$1000 per storm



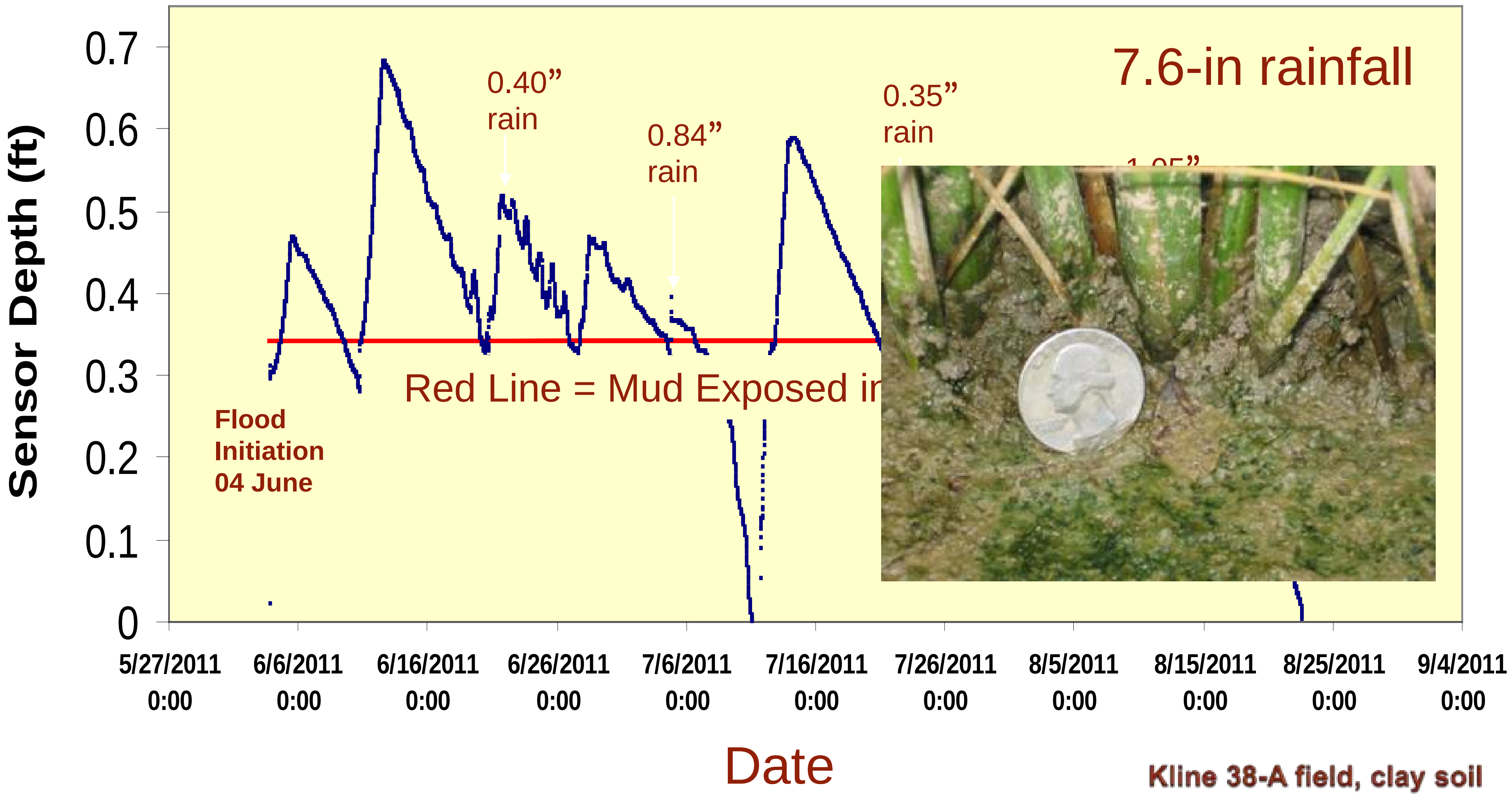
WATER USE BY IRRIGATION INTERMITTENT FLOOD



Pringle (1994): Water Use Requirements for Rice in the MS Delta
Source: Dr. Joe Massey, Mississippi State University

IRRIGATION TRIALS MISSISSIPPI STATE

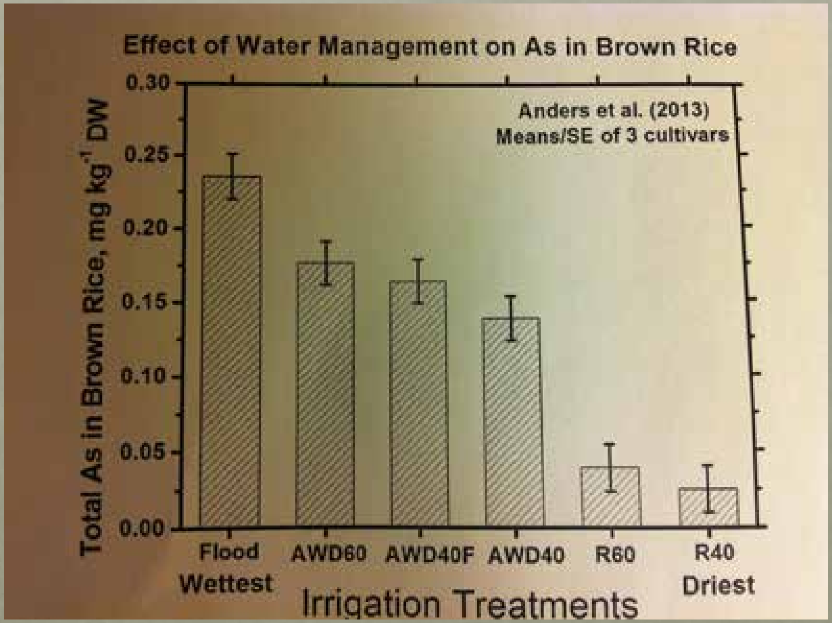
Water Pumped: 18 A-in/A



Source: Dr. Joe Massey, Mississippi State University

RICE CONCLUSIONS

- Grading impacts water use
- Remote monitor & control
- Intermittent flooding Arkansas & Mississippi
  - GHG CIG-2013-2015
  - NRCS announcement
  - GHG implications
  - Arsenic implications



REVIEW

- Agriculture & water are important
- Conservation practices impact water
- Cotton production
  - Termination guidelines
- Rice production
  - Technology innovation
  - Irrigation management

Michele L. Reba, PhD, PE

Research Hydrologist

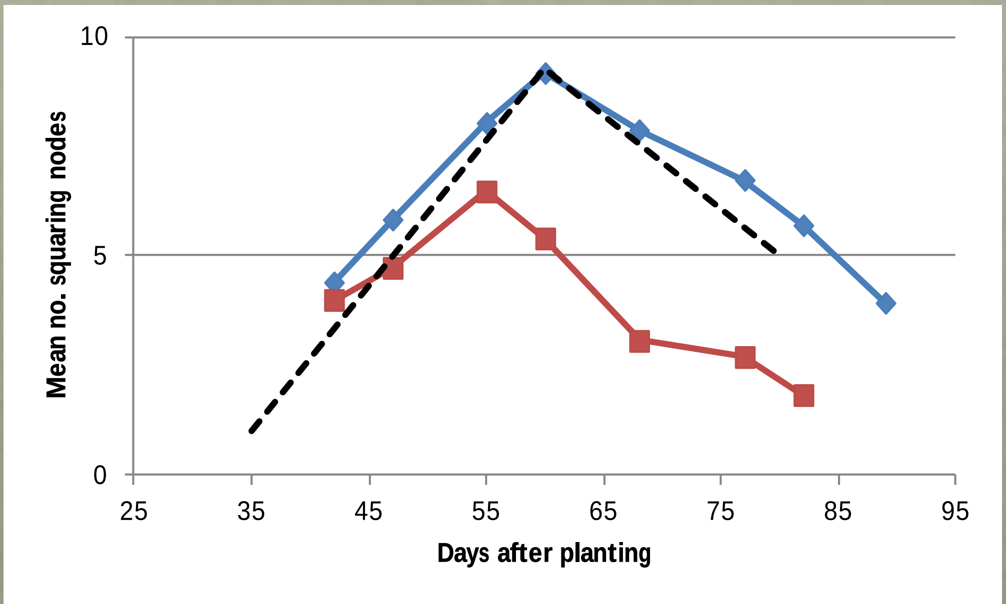
USDA-ARS-Jonesboro, AR

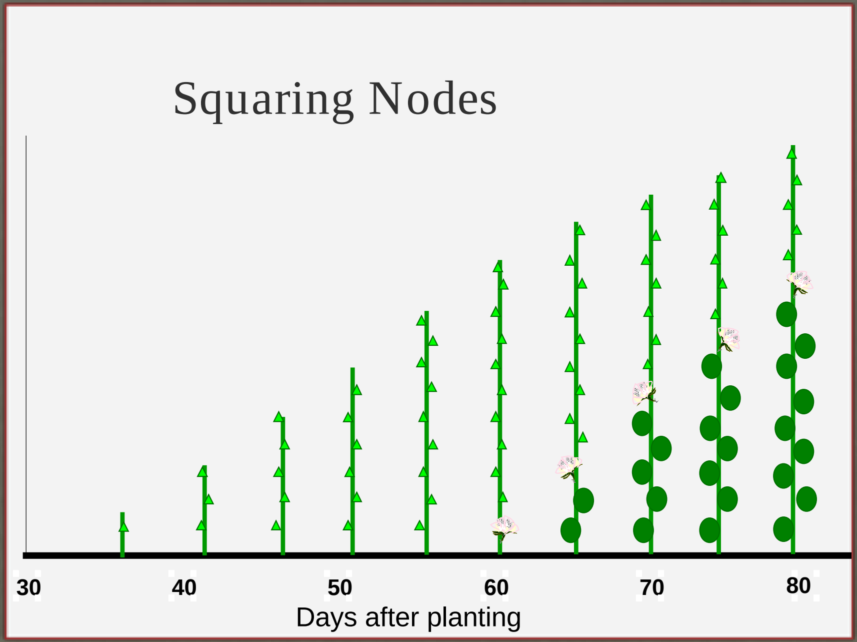
National Sedimentation Laboratory

michele.reba@ars.usda.gov

COTMAN

- Crop monitoring system (Oosterhaus & Bourland 2008)
- Crop development
  - Irrigation & fertilizer treatment
  - Squaring until physiological cutout, NAWF5





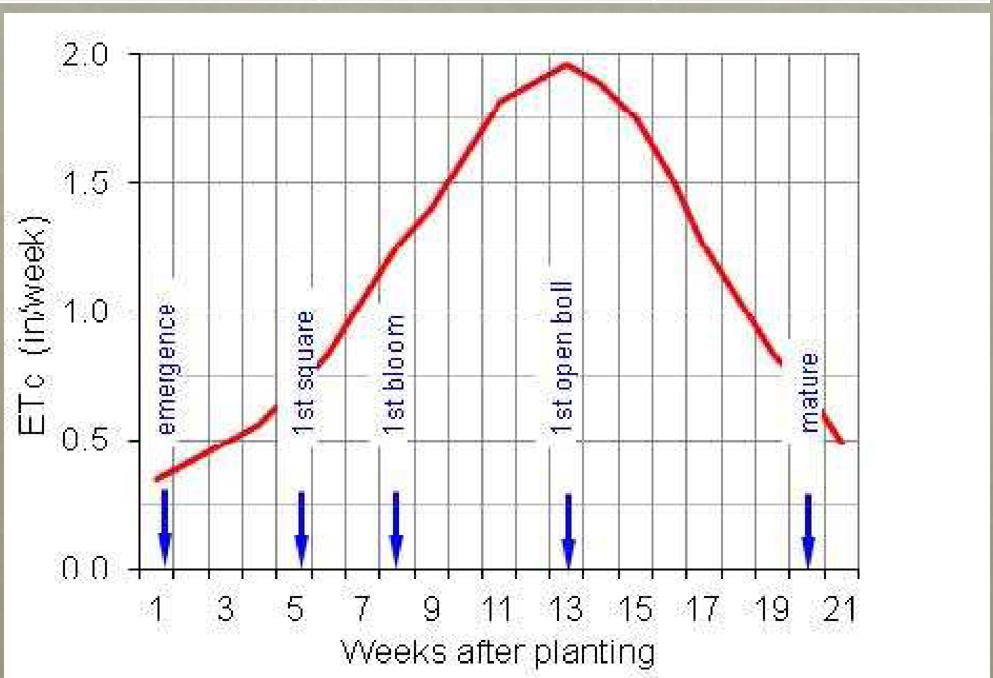
COTTON WATER REQUIREMENTS

- 20-25 in/year

Stage	Length (days)	Daily Etc (in)	Average Daily Etc (in)
Initial	25	0.03-0.20	0.09
Crop Development	35	0.09-0.36	0.22
Midseason	50	0.18-0.44	0.3

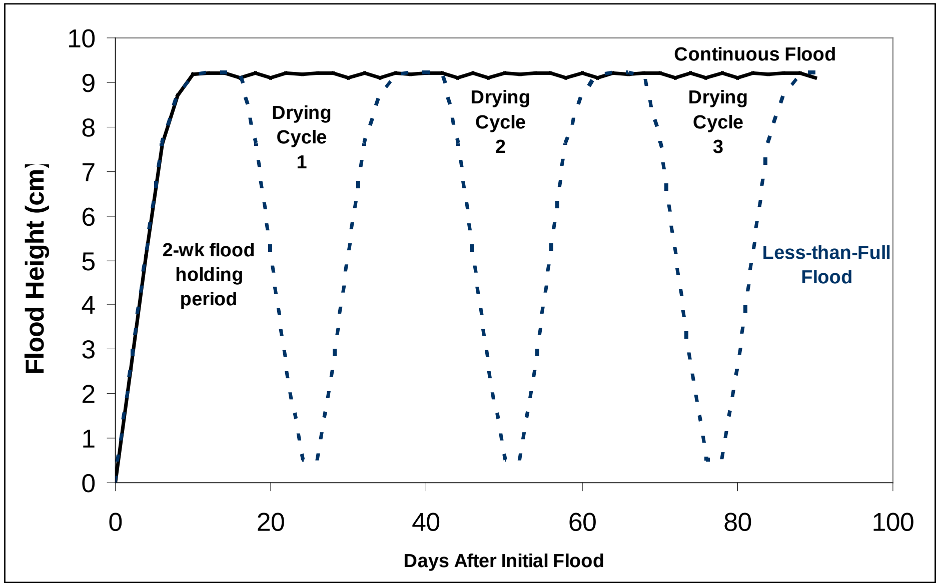
- Initial: 0.5 in/wk
- Development: 1-1.5 in/wk
- Midseason: > 2 in/wk

Modified from K. Fisher (2011) Cotton water requirement in Cotton Irrigation Management for Humid Regions



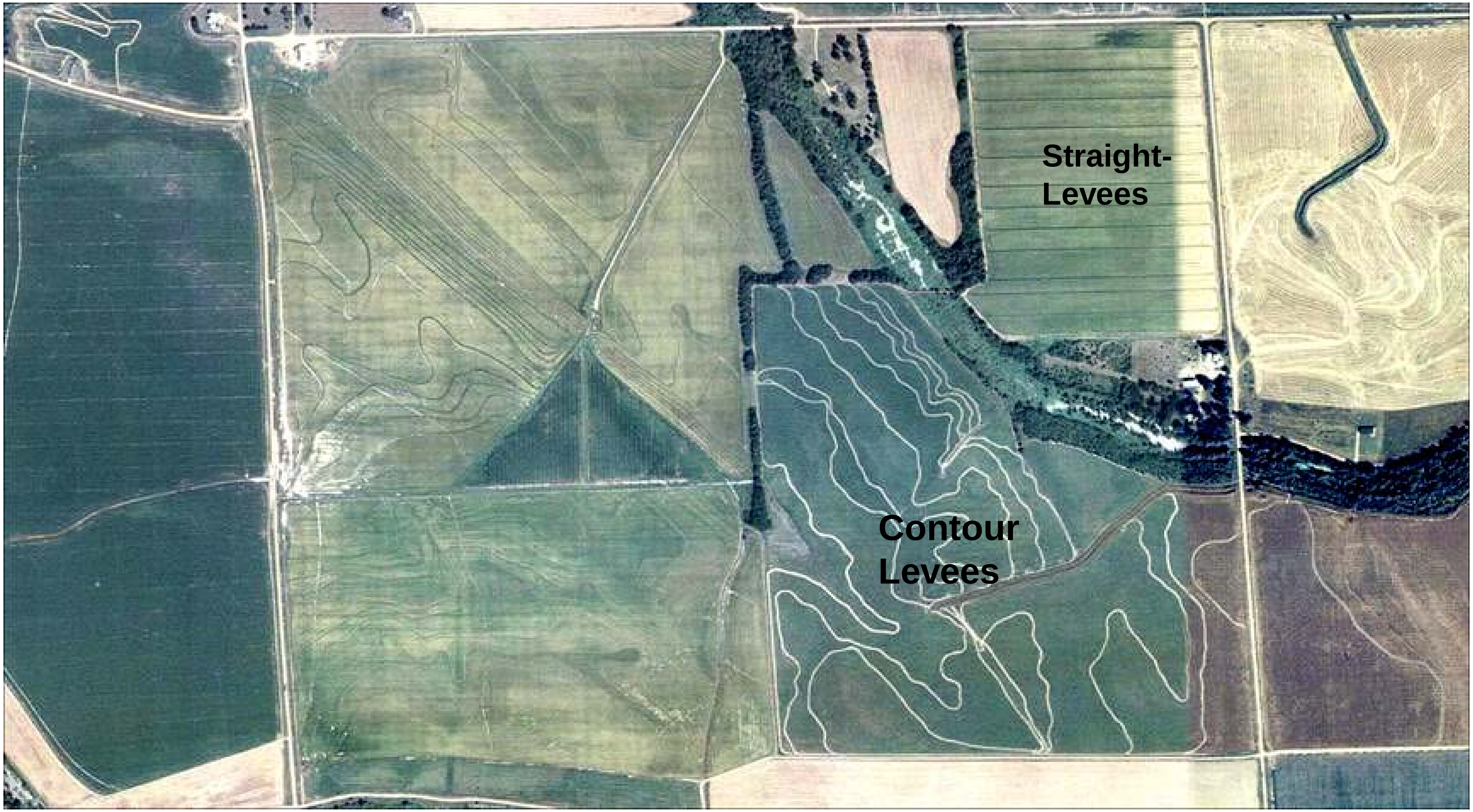
Appendix E.2
Multiple-Inlet Flood Distribution and Intermittent Flood Management
By Joe Massey & Earl Kline

Multiple-Inlet Flood Distribution + Intermittent Flood Management



Joe Massey & Earl Kline

Contour vs. Straight-Levee Systems



Aerial photo credit: YMD data package

Multiple-Inlet Irrigation
in Straight-Levee Systems

MAFES Publication No. 2338
Thomas et al. (2004)

Advantages of Side-Inlets:

• More rapid flood establishment.

• Reduced nitrogen loss.

• Improved herbicide activation.

•Greater control of flood.

• Facilitates adoption of other water-saving practices.

Tacker (2010): Approximate cost = $12/A (tubing + labor)

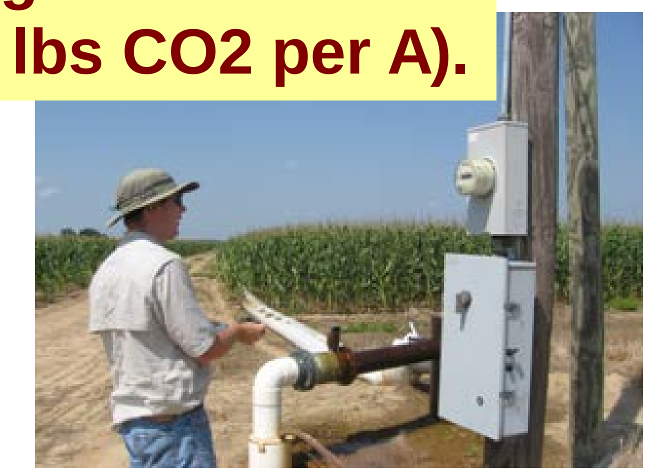
Zero-Grade (Level Basin) Rice
(no levees)

Irrigation System	6-yr Avg. MS Water Use (A-in/A)	Water Savings (%)
Contour-Levee	**44 ± 5**	**0**
Straight-Levee	**38 ± 2**	**14**
Straight-Levee using Multiple Inlets	**31 ± 5**	**30**
Zero-Grade	20 ± 6	54

Estimated Energy Used By Groundwater-Based Irrigation Systems per A-in Water Delivered

State	Diesel (gallons)	Electric (kWh)
	per Acre-in water pumped	
AR (Tacker	[illegible]	[illegible]
LA (Sheffie	[illegible]	[illegible]
MO (Vories)	**0.8**	**30**
MS (Thomas)	**0.7**	**27**
Avg.	**0.9 gal**	**34 kWh**

For every inch of water not pumped, at least 0.7 gallon diesel fuel per irrigated A saved (represents reduction of ~16 lbs CO_2 per A).

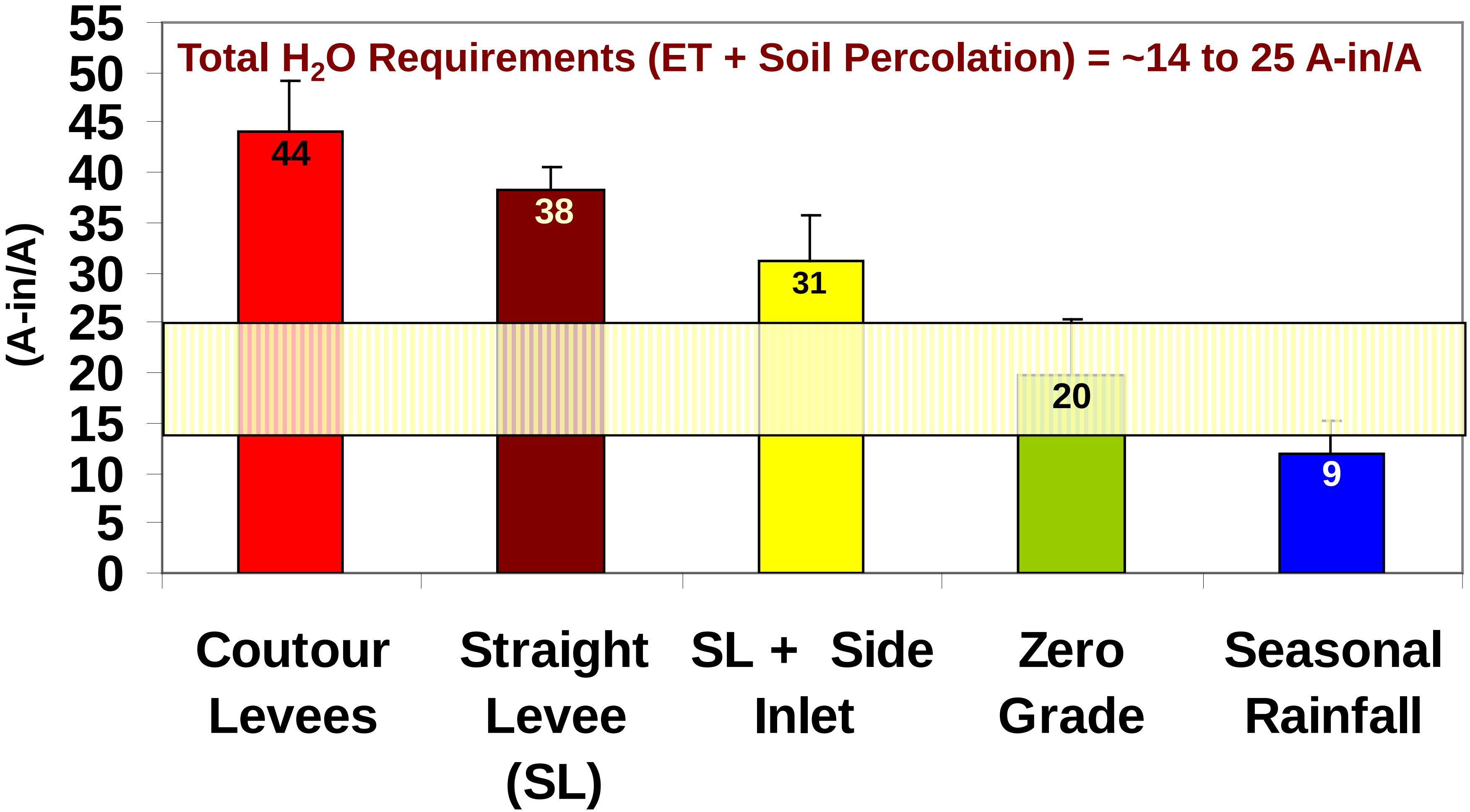


Estimated Savings

Irrigation System	6-yr Avg. MS Water Use (A-in/A)	Diesel Saved (Gal/A)	Savings ($/A)	Savings (lbs CO2/A)
Contour-Levee	**44 ± 5**	**0**	**0**	**0**
Straight-Levee	**38 ± 2**	**4**	**12**	**88**
Straight-Levee using Multiple Inlets	**31 ± 5**	**9**	**27**	**198**
Zero-Grade	20 ± 6	17	51	374

Irrigation Options for Mississippi Rice Producers

- **Increase zero-grade acres**



Zero-Grade Rice Irrigation

Agronomic Issues Limit Adoption

Drawbacks of Zero-Grade Systems:

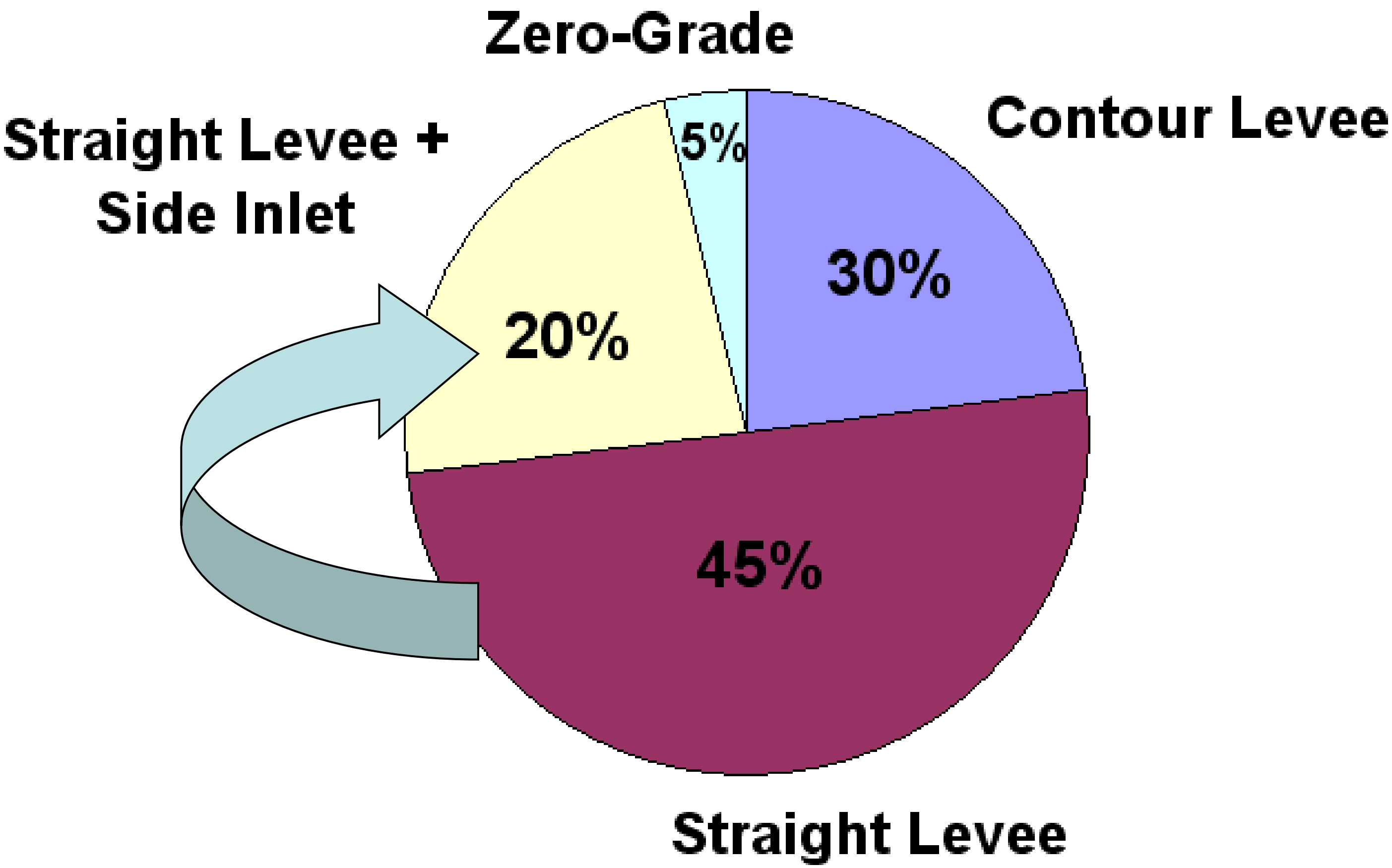
1. **Water-logging of rotational crops, leading to continuous rice systems which can result in**

2. **Pest management issues (weed resistance; herbicide carry-over) and**

3. **Loss of yield bump associated with Soy-Rice Rotation**

Most Readily-Available Irrigation Option for the Majority of Mississippi Rice Acres?

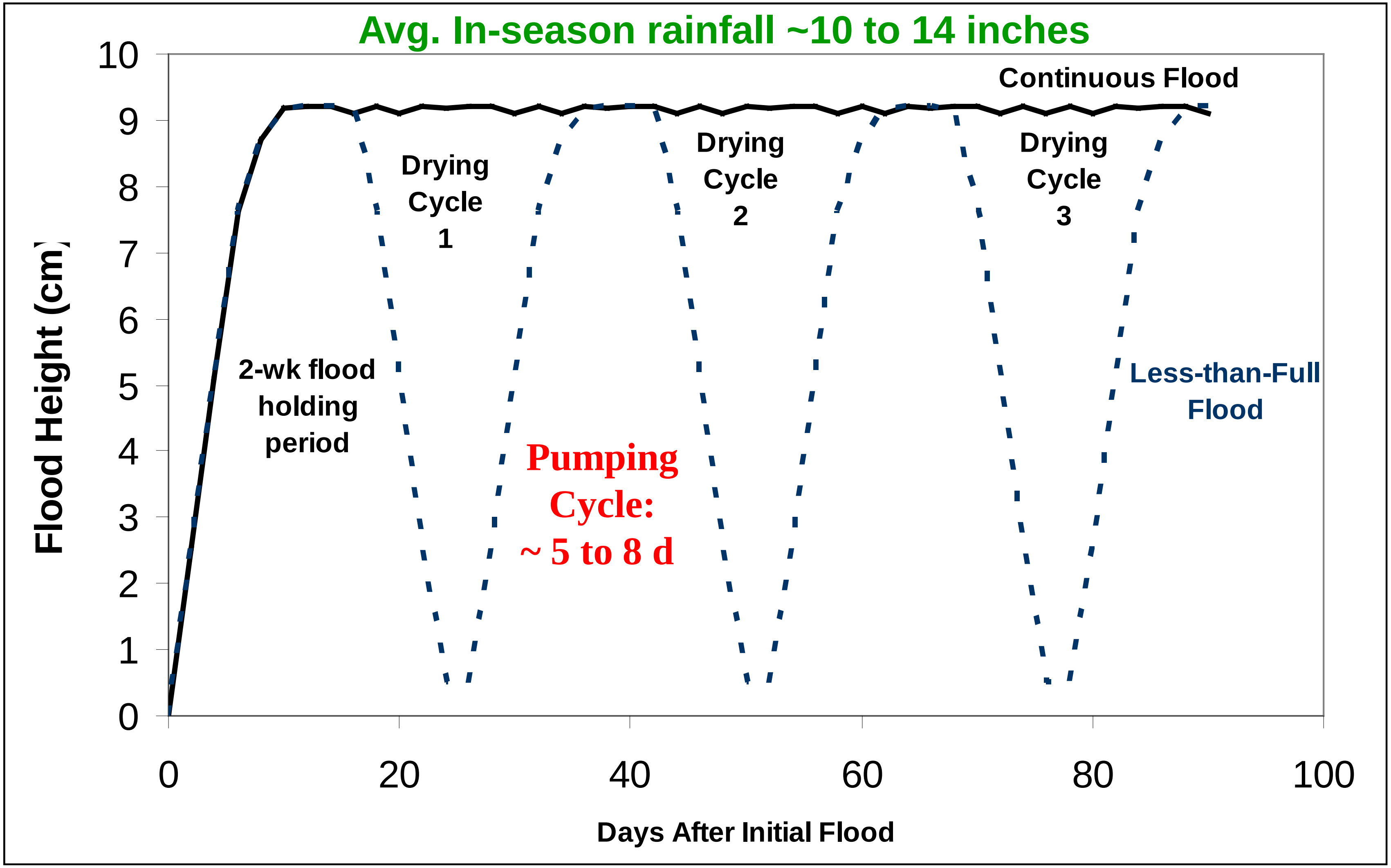
Estimated Adoption Rates for Rice Irrigation Systems in MS (2009)



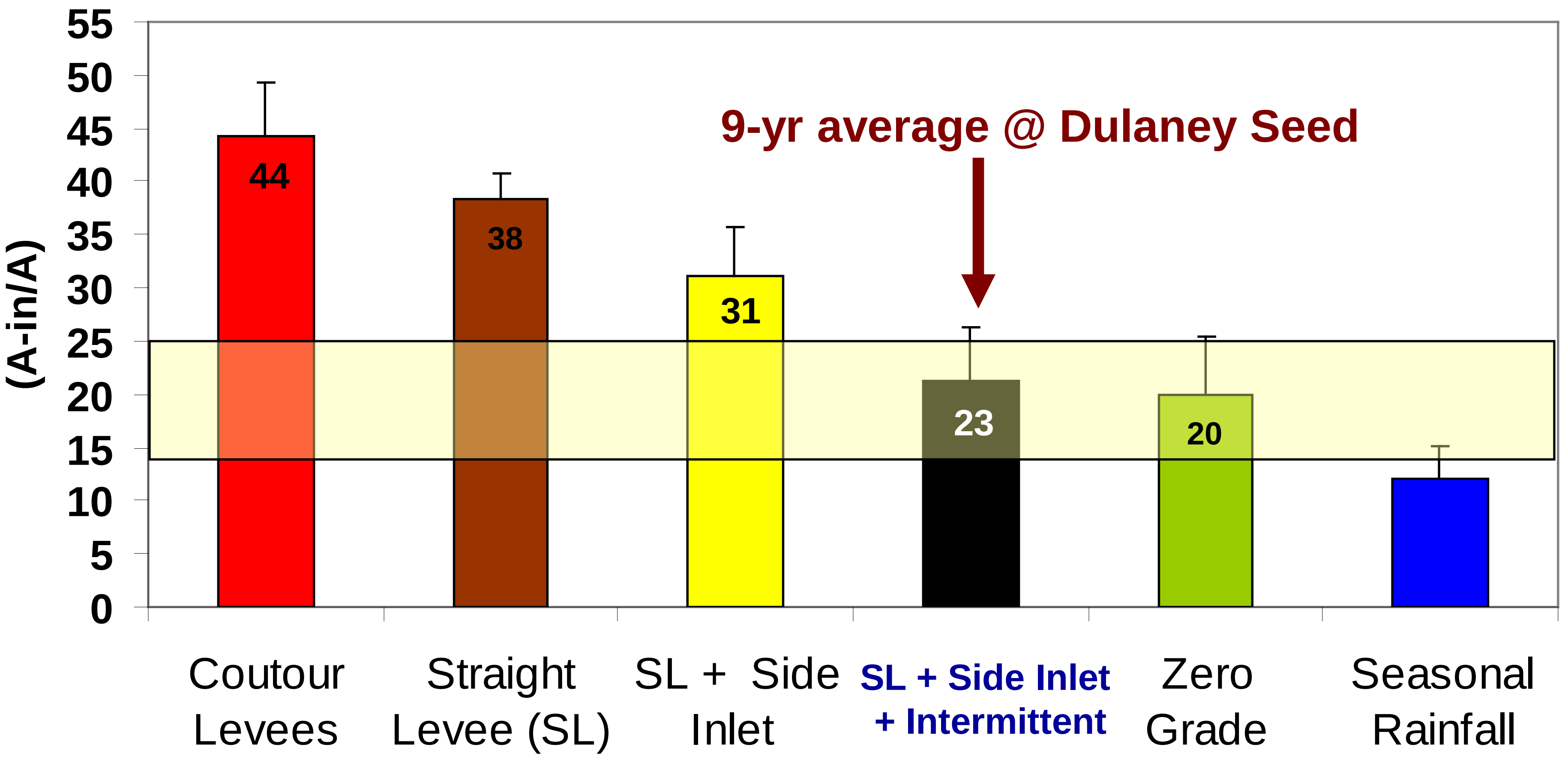
Sources: MSU Extension Service grower surveys; rice consultant surveys; YMD permitting data.

Intermittent Flood Management

to Increase Rainfall Capture & Reduce Over-Pumping



Average Water Use by Different MS Rice Irrigation Systems



Kline-2009 Field B

38 Acres, 8 paddies, Cocodrie, Sharkey Clay

2009 MS Rice Water Use (YMD, 2010)

State avg. = 37 A-in/A

Pringle (1996):

~14 to 25 A-in/A required by rice

Rice Yield: 190 bu/A (dry)

Avg. Milling Quality:
Not different top vs. bottom of paddies

Rainfall:	11 A-in/A
Water Pumped:	15 A-in/A
Total:	26 A-in/A

Electric cost: $40/A

2011 Kline On-Farm Trials
Intermittent Rice Irrigation

Study 1: Varietal Response

• 8 Clearfield rice varieties using 4 reps per variety.

• Planted at the top (alternating wet-dry) and bottom (~continuous flood) of paddy.

• 150 lbs N per A applied.

• Yield and milling quality.

• Water use.

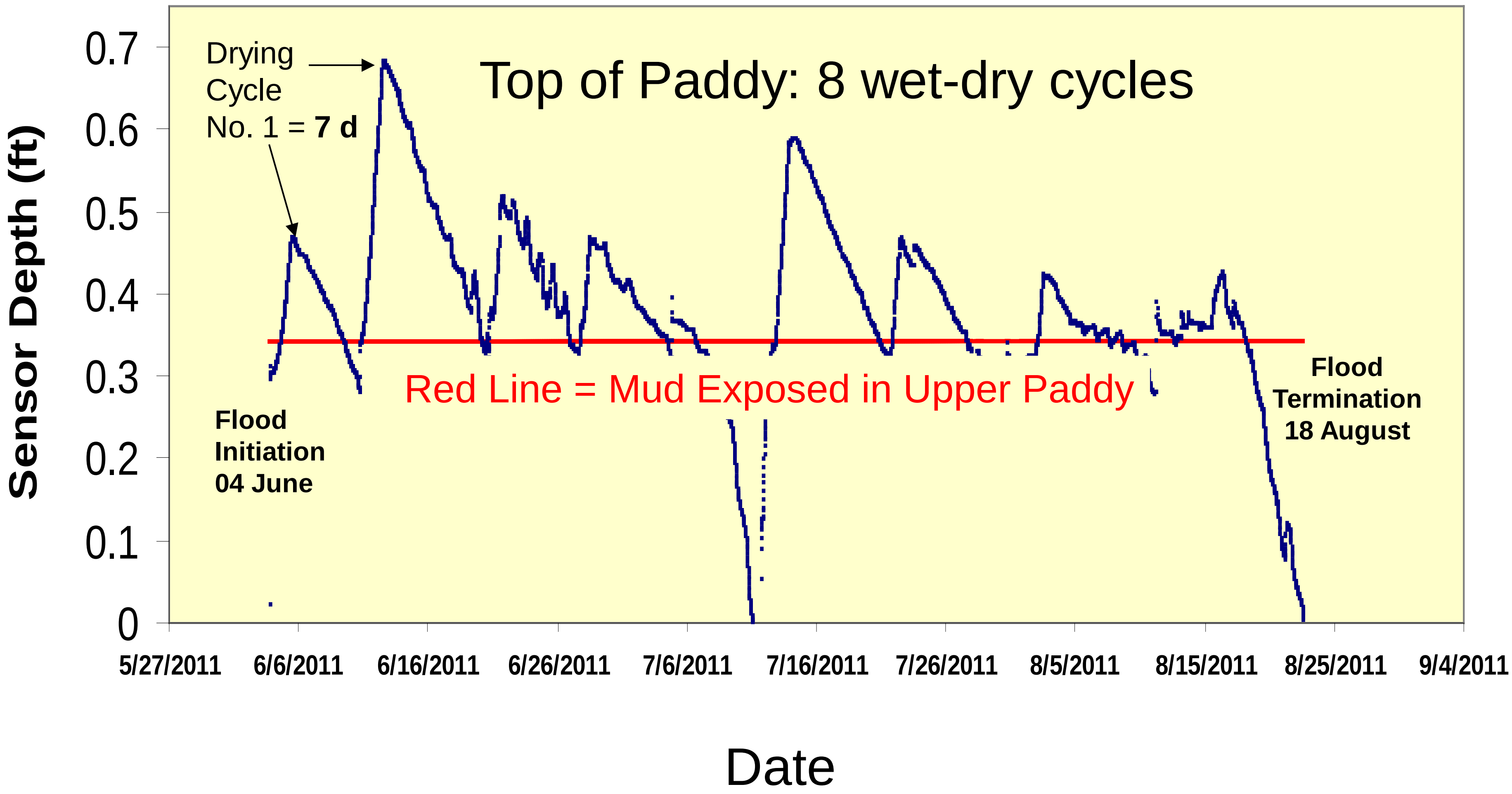
2011 Kline On-Farm Trials
Intermittent Rice Irrigation

Study 2: Nitrogen Loss

- 1 Clearfield variety (CL162) planted at top and bottom of paddy.
- 6 Nitrogen rates (0 to 240 lbs/A) applied pre-flood using 4 reps each.
- Yield and milling quality.
- Water use.

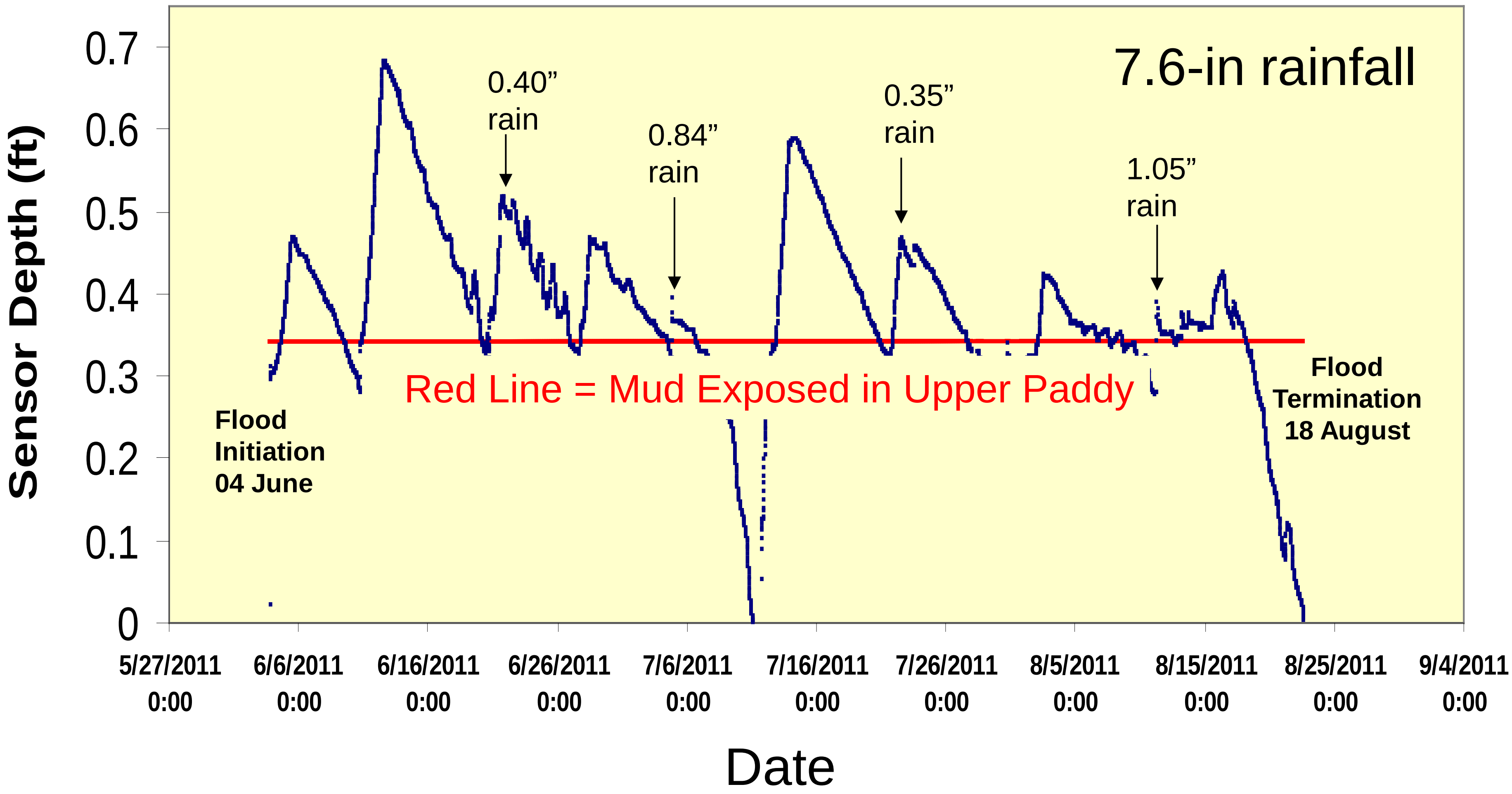
2011 Intermittent Irrigation Trials
Kline 38-A field, clay soil

Water Pumped: 18 A-in/A



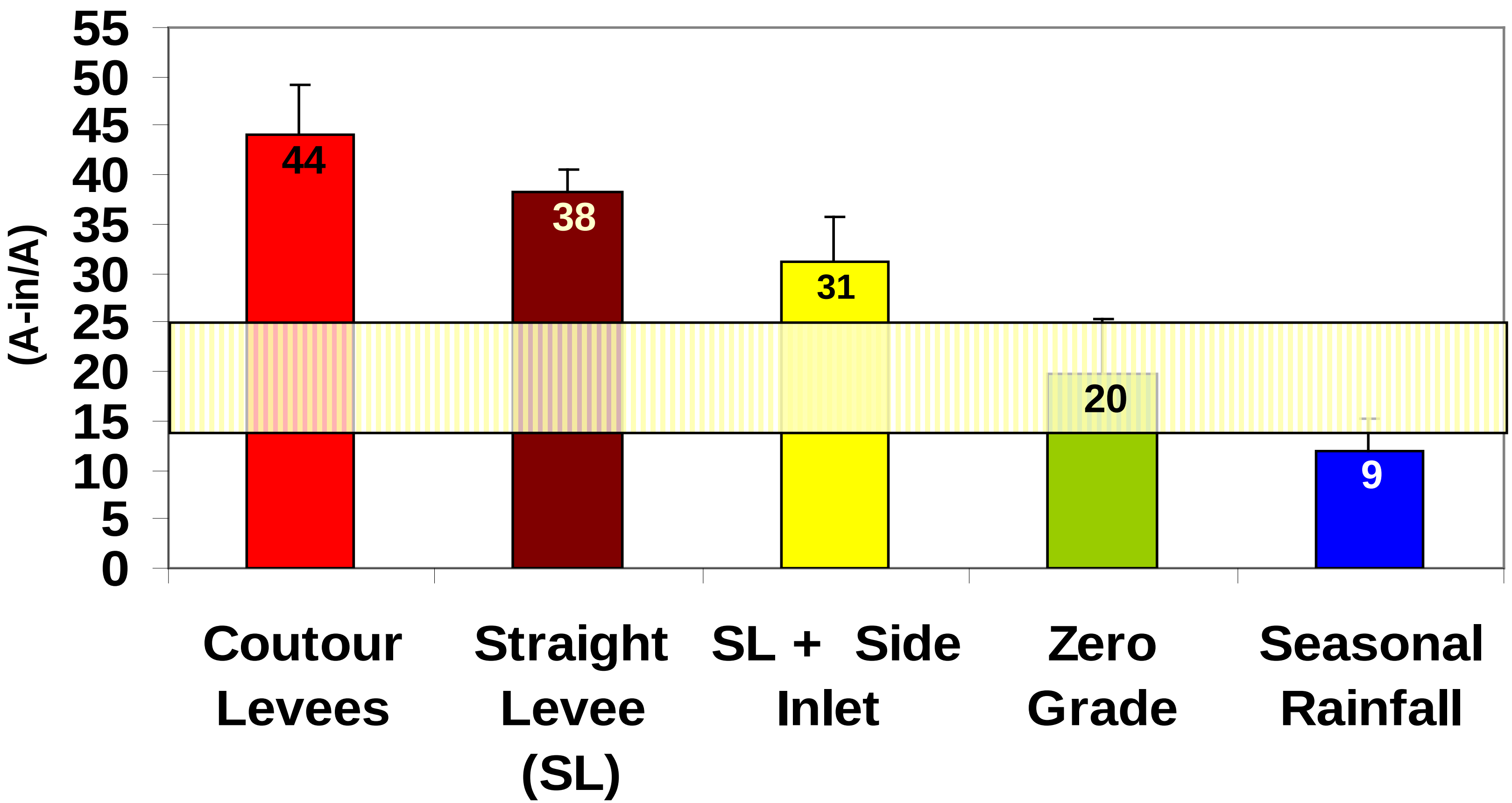
2011 Intermittent Irrigation Trials
Kline 38-A field, clay soil

Water Pumped: 18 A-in/A



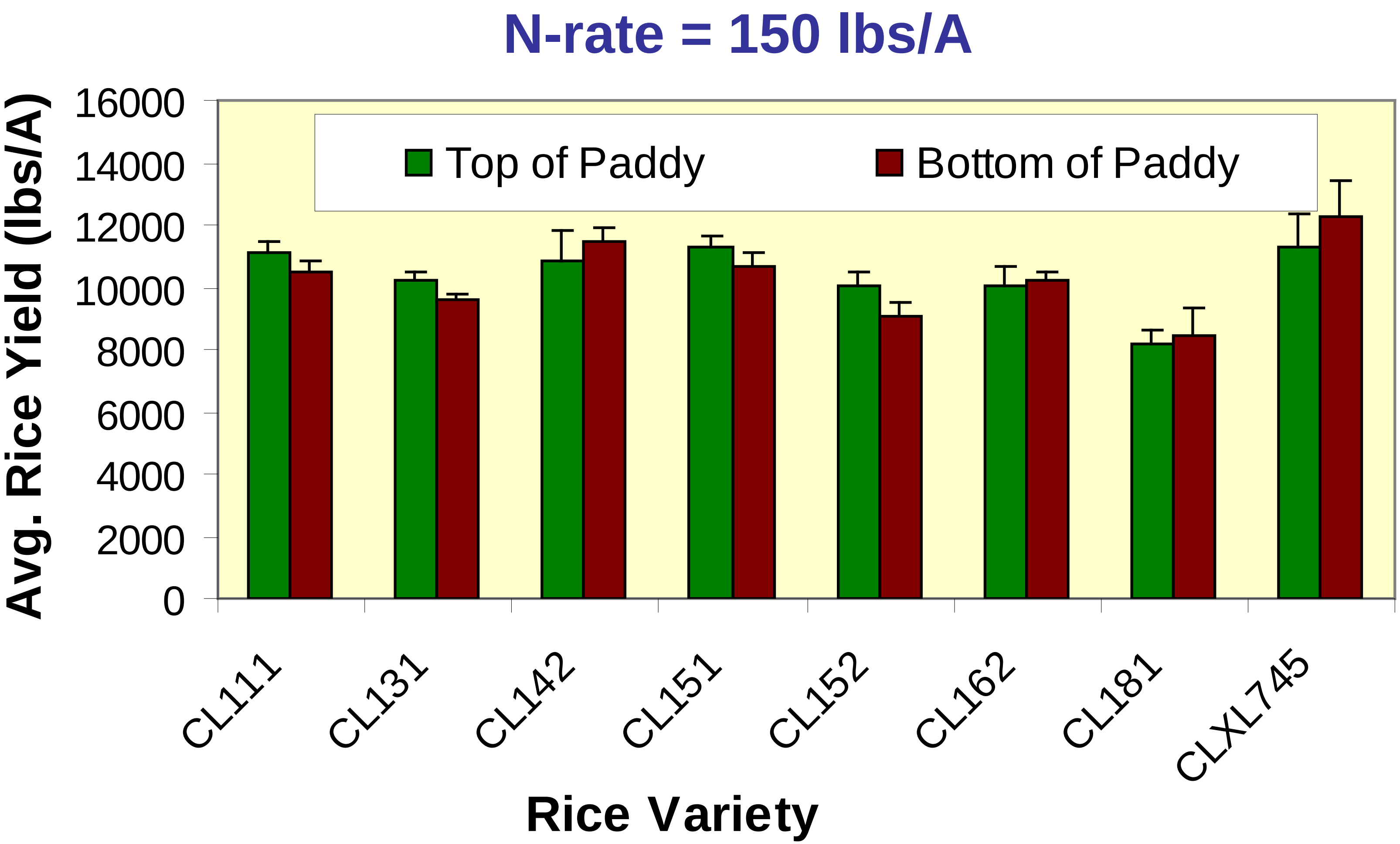
2011 Intermittent Irrigation Trials
Kline 38-A field, clay soil

Total H_2O Use = 7.6-in (rainfall) + 18-in (irrigation) = 25.6-in

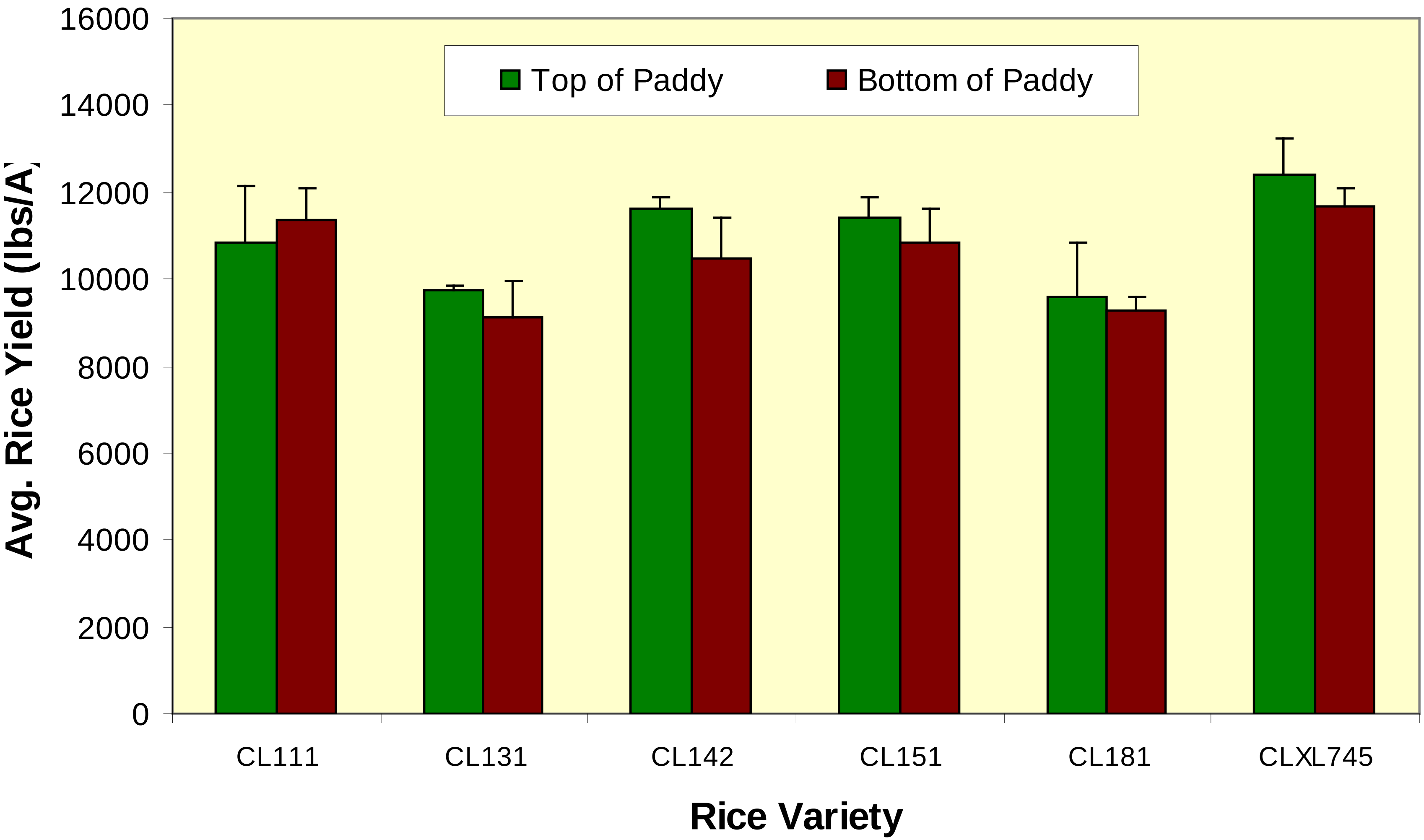


2011 Rice On-Farm

Variety x Intermittent Irrigation Trials



2010 Variety x Intermittent Irrigation Trial
Clay soil w/ 5 wet-drying cycles using 23 A-in/A



2010 Variety x Intermittent Irrigation Trial

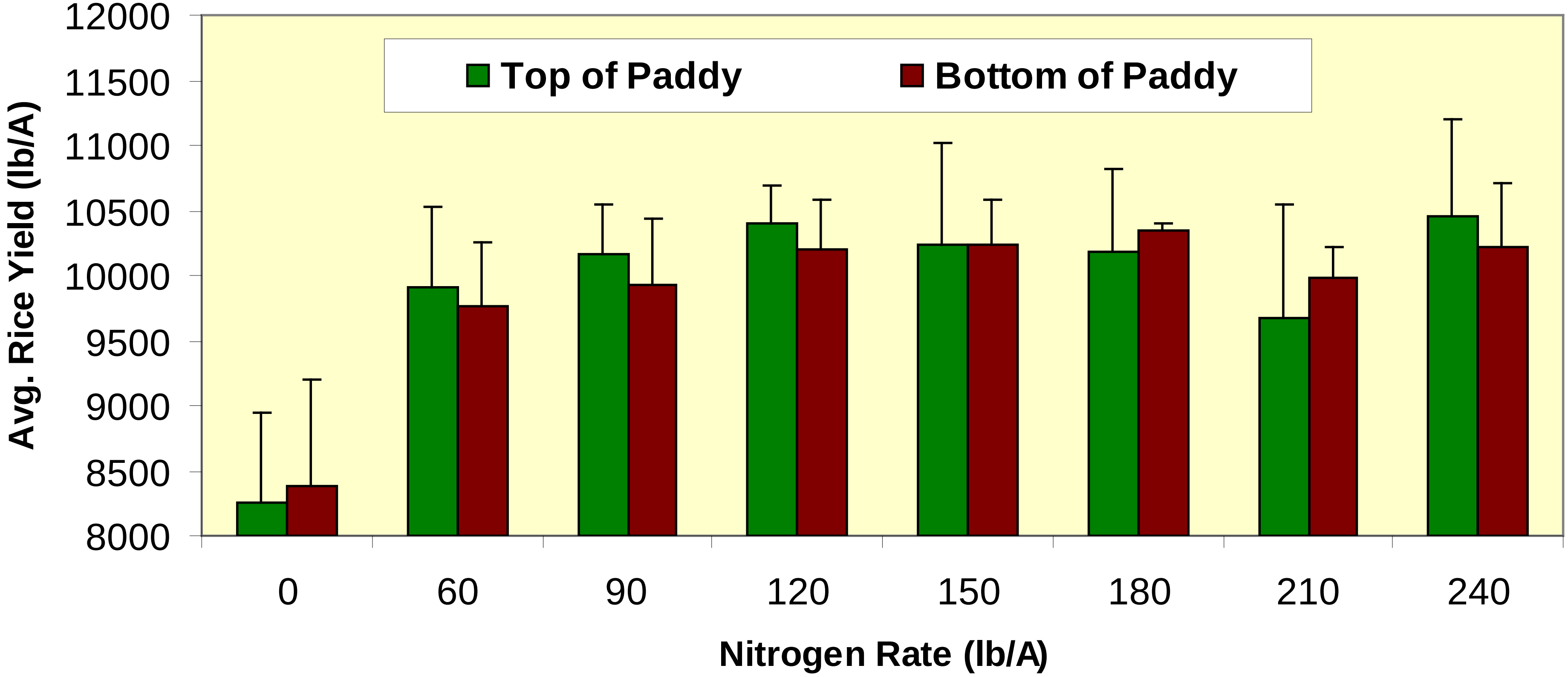
Clay soil w/ 5 wet-drying cycles using 23 A-in/A

Variety	Top of Paddy (int flood)	Bottom of Paddy (cont flood)	Type III Pr > F
	Rice Yield (lb/A) dry		
6004	10,548	9,067	0.0326
Bowman	9,838	9,905	0.9004
CL111	10,850	11,380	0.5048
Cocodrie	10,796	10,528	0.2154
Neptune	10,396	9,452	0.0756
Rex	10,481	9,899	0.1846
Taggart	11,486	10,961	0.3535
Templeton	11,083	9,933	0.0618
XL723	12,809	12,808	0.9986

No differences in grain yield or milling quality observed in 15 rice varieties when grown using intermittent flood (top of paddy) versus ~continuous flood (bottom of paddy).

2011 Rice On-Farm
N-Rate x Intermittent Irrigation Trials

Rice variety = CL162



Water-Conserving Irrigation Options for Rice Producers

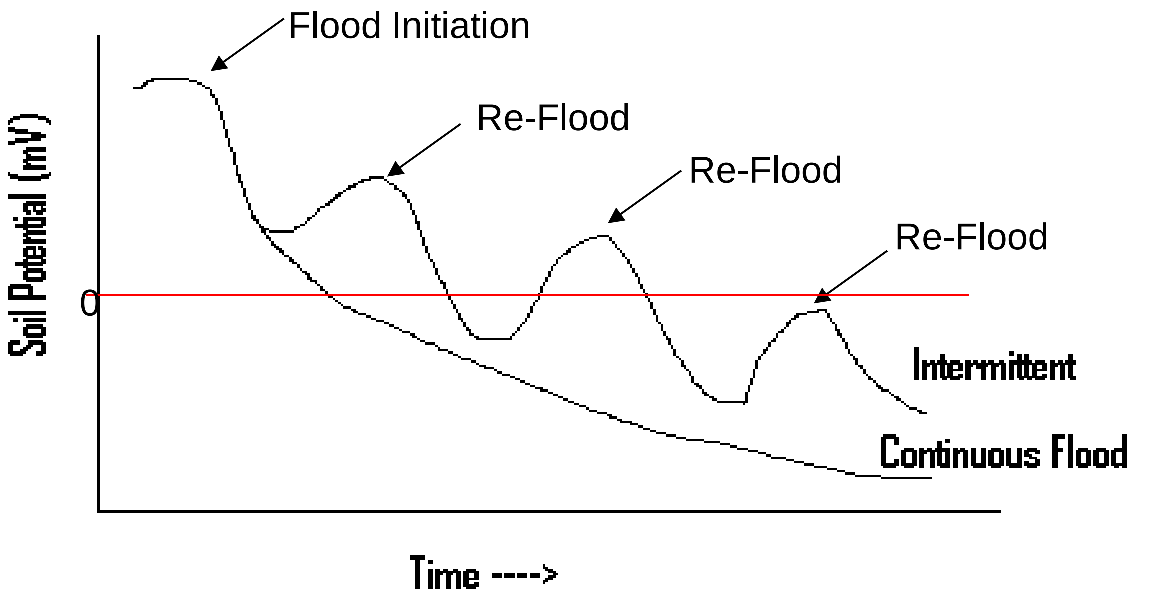
- Increase zero-grade acres

- Sprinkler-irrigated rice

- Tailwater recovery systems and on-farm reservoirs

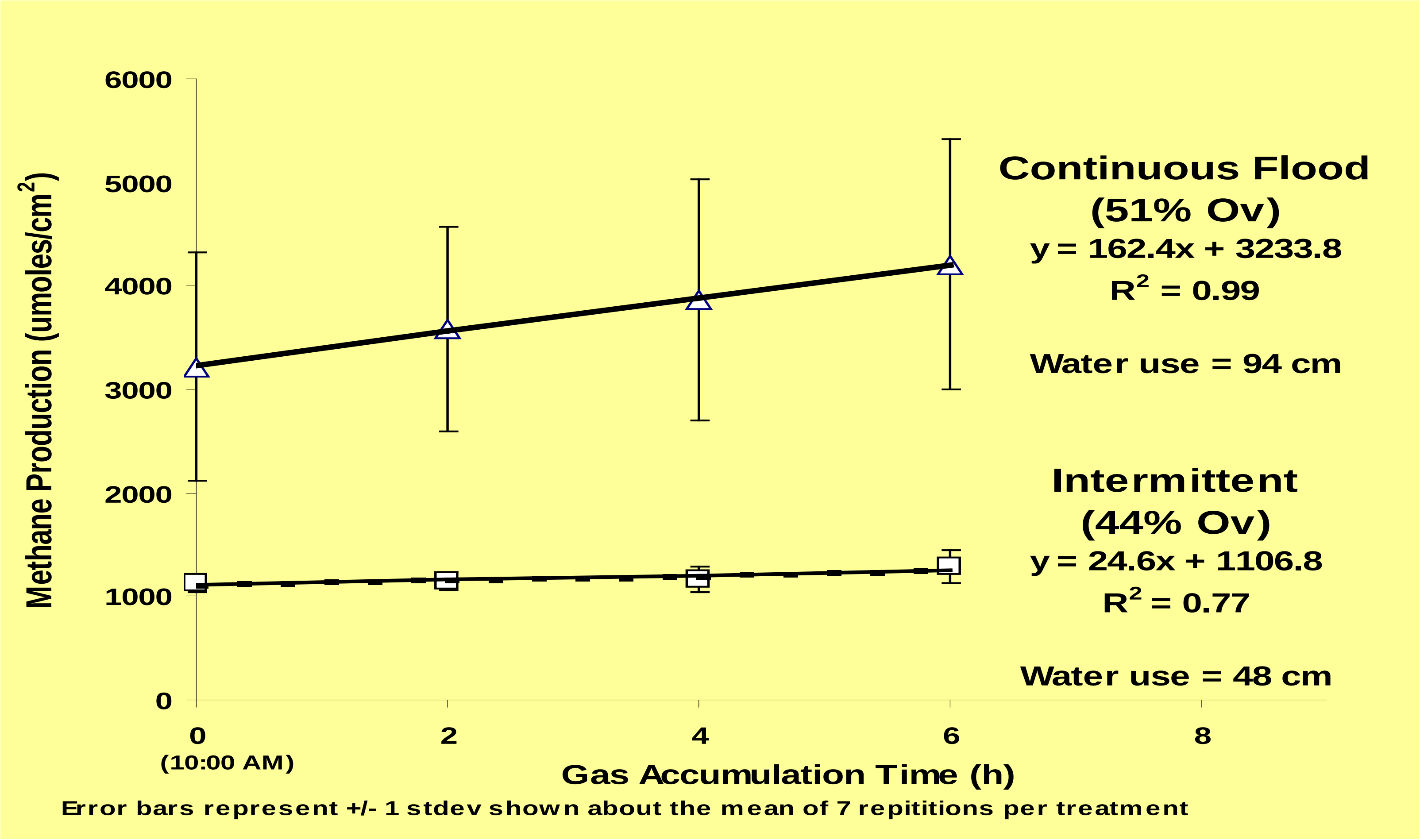
- Drought-tolerant rice

- Automated irrigation control systems

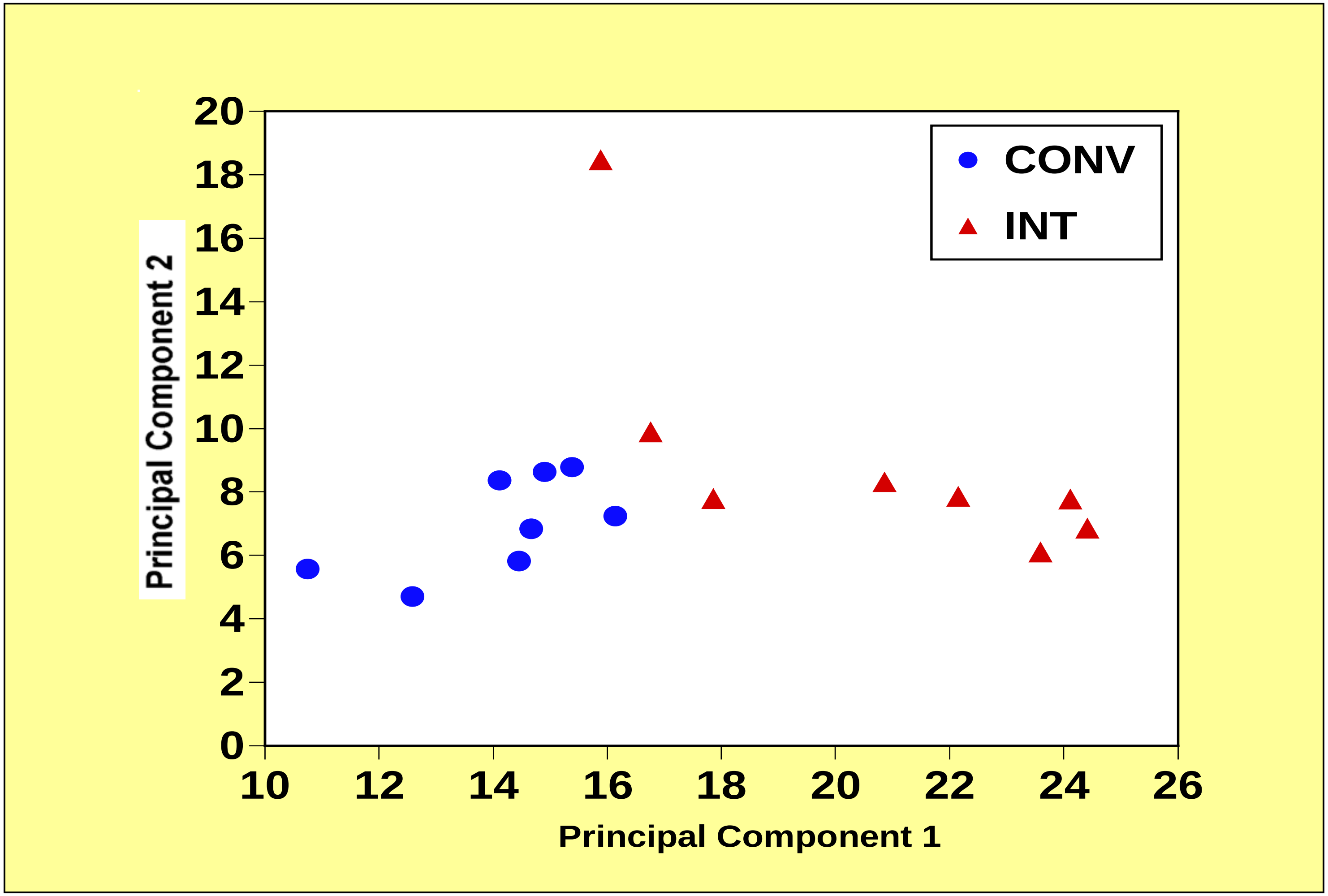


Intermittent flooding reduces methane emissions due to reducing time that soil is flooded

Methane Flux at Pine Tree, AR
65-d after initial flood



Fatty Acid Methyl Ester (FAME) Analysis to Differentiate Between Microbial Communities in Soil



Summary

Multiple (Side) Inlet Irrigation is:

The most proven, cost-effective flood management tool currently available to MS growers.

Serves as a '*foundation*' on which greater water and energy savings can be based.

2010 tubing + labor costs: ~$12/A (Tacker, 2010)

Takes a 3-person crew ~1 hour to install one roll of tubing incl. gates (J. Dulaney, 2011)

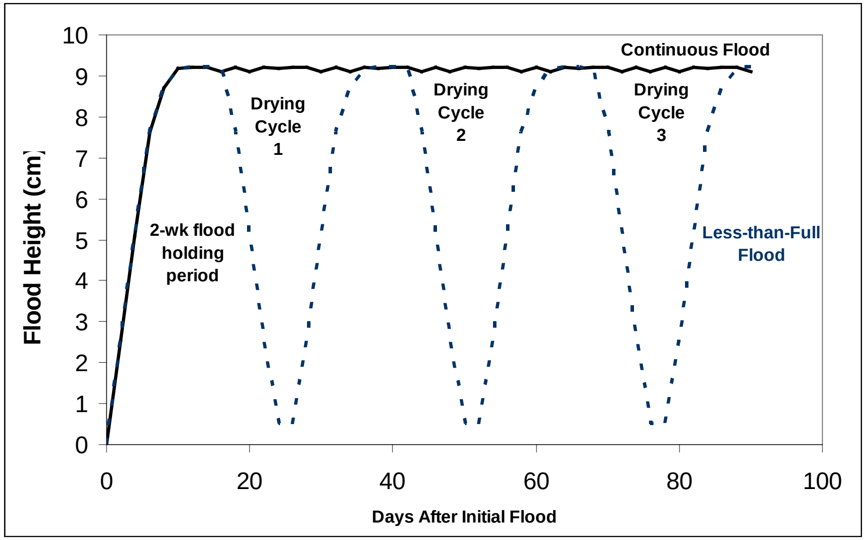
Summary

Intermittent Irrigation:

Extends water and energy savings of side-inlet with no additional cost.

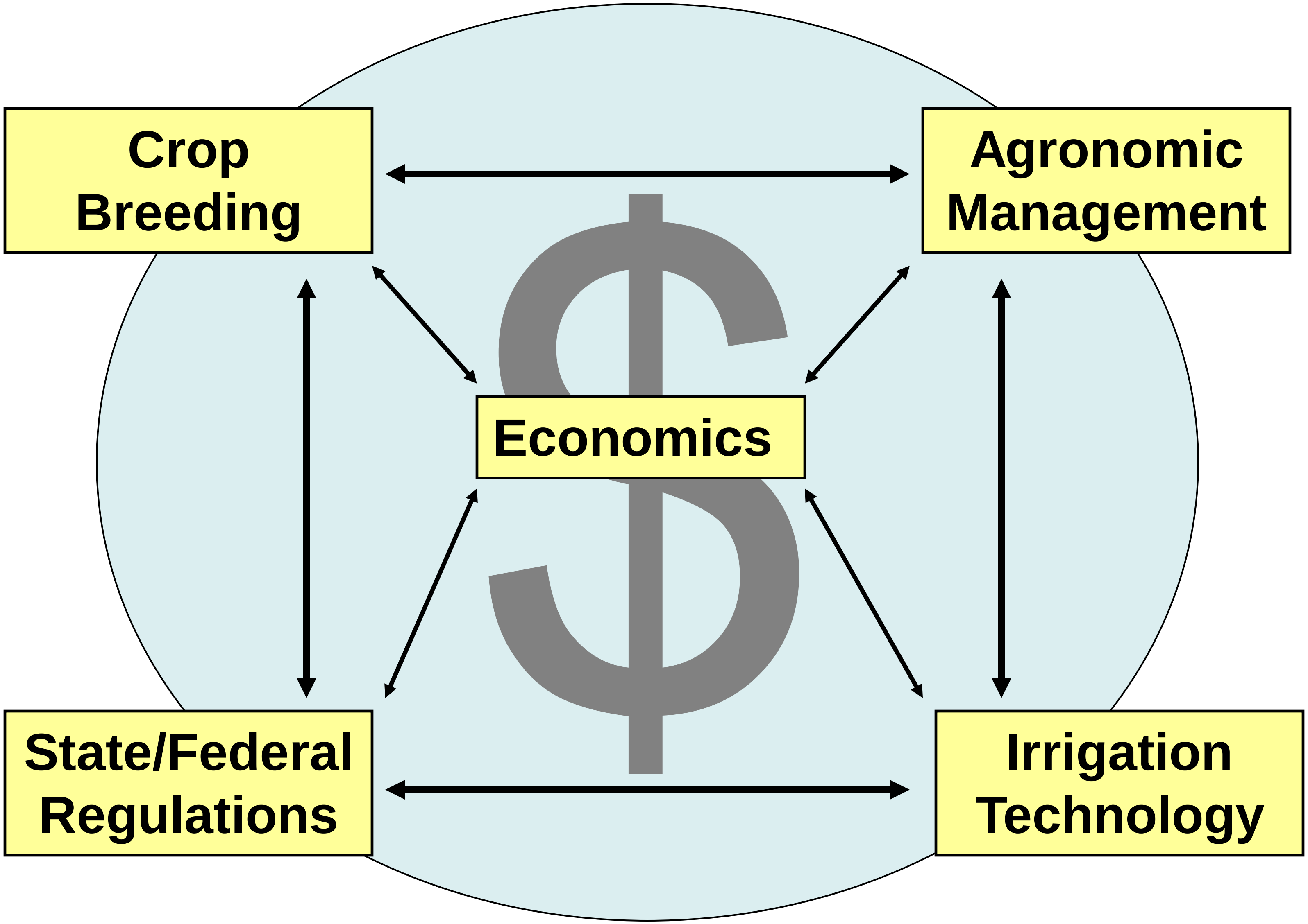
Does not have to be fully adopted to reduce over-pumping and increase rainfall capture.

Can result in water and energy savings on par with that of Zero-Grade.

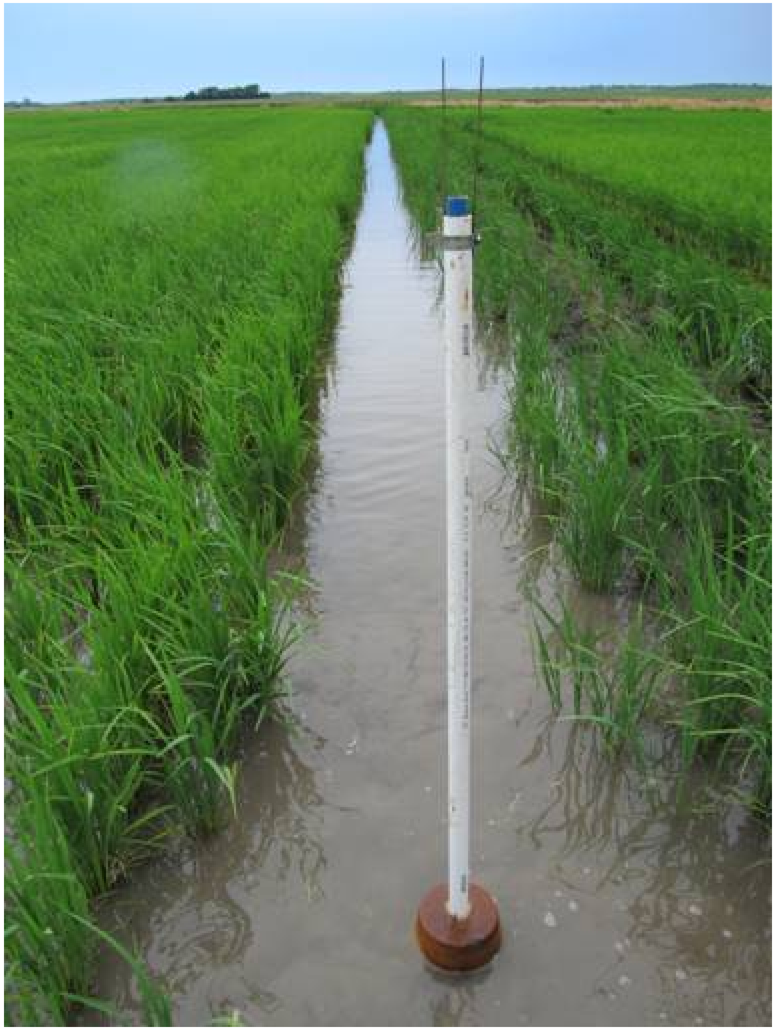


Every inch of water not pumped or captured as rainfall saves ~ 0.7 gal diesel per A.

Systematic Approach to Water Conservation

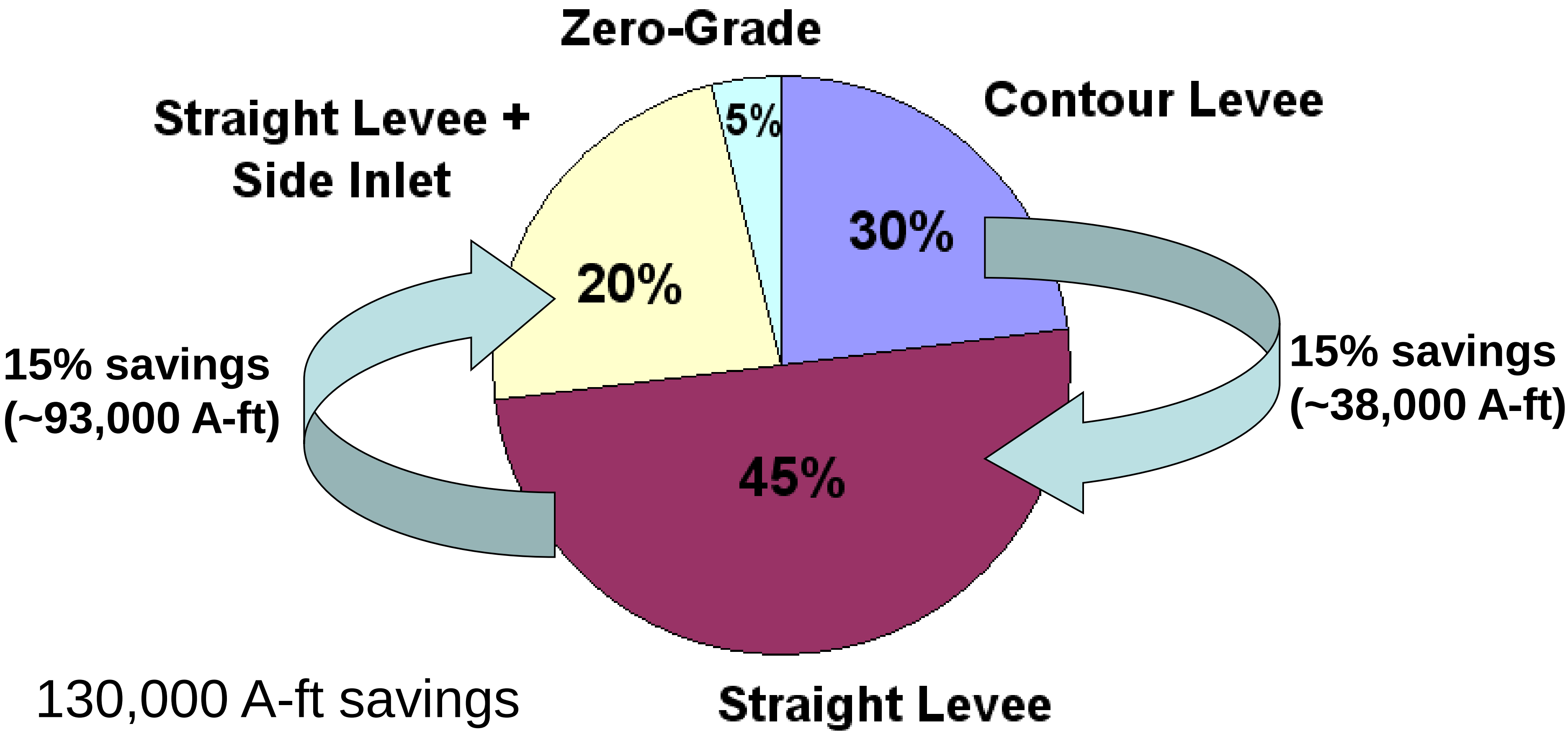


Thank you!




Kline-2009 Field B
38 Acres, 8 paddies, Cocodrie, Sharkey Clay

Estimated Adoption Rates for Rice Irrigation Systems in MS (2009)



130,000 A-ft savings

Sources: MSU Extension Service grower surveys; rice consultants

Appendix E.3
Markets for GHG reductions
Nick Martin, Winrock International
Rice focus group meeting
December 6, 2011

Markets for GHG reductions

Nick Martin, Winrock International

Rice focus group meeting

December 6, 2011

WINROCK INTERNATIONAL

Winrock International Institute for Agricultural Development

Non-profit organization that works in the U.S. and around the world to empower the disadvantaged, increase economic opportunity, and sustain natural resources

- Rockefeller family tradition of agricultural research and extension, yield improvement, global food security
- Seeking ways to connect farmers to new markets, enhance competitiveness

→ Can GHG reductions be a means to secure new revenues, reduce costs, improve performance?

What is an offset?

- *General/voluntary market*: GHG reduction or removal used to compensate for emissions elsewhere
- *Compliance market*: project-based GHG reductions occurring in unregulated sectors, used by regulated entity for compliance
- Denominated in tons CO_2 equivalent
- Meeting specific criteria laid out in protocols
- Verified, registered, serialized and retired

“Cap and Trade”

Market-based mechanism to reduce emissions cost-effectively by allowing compliance flexibility

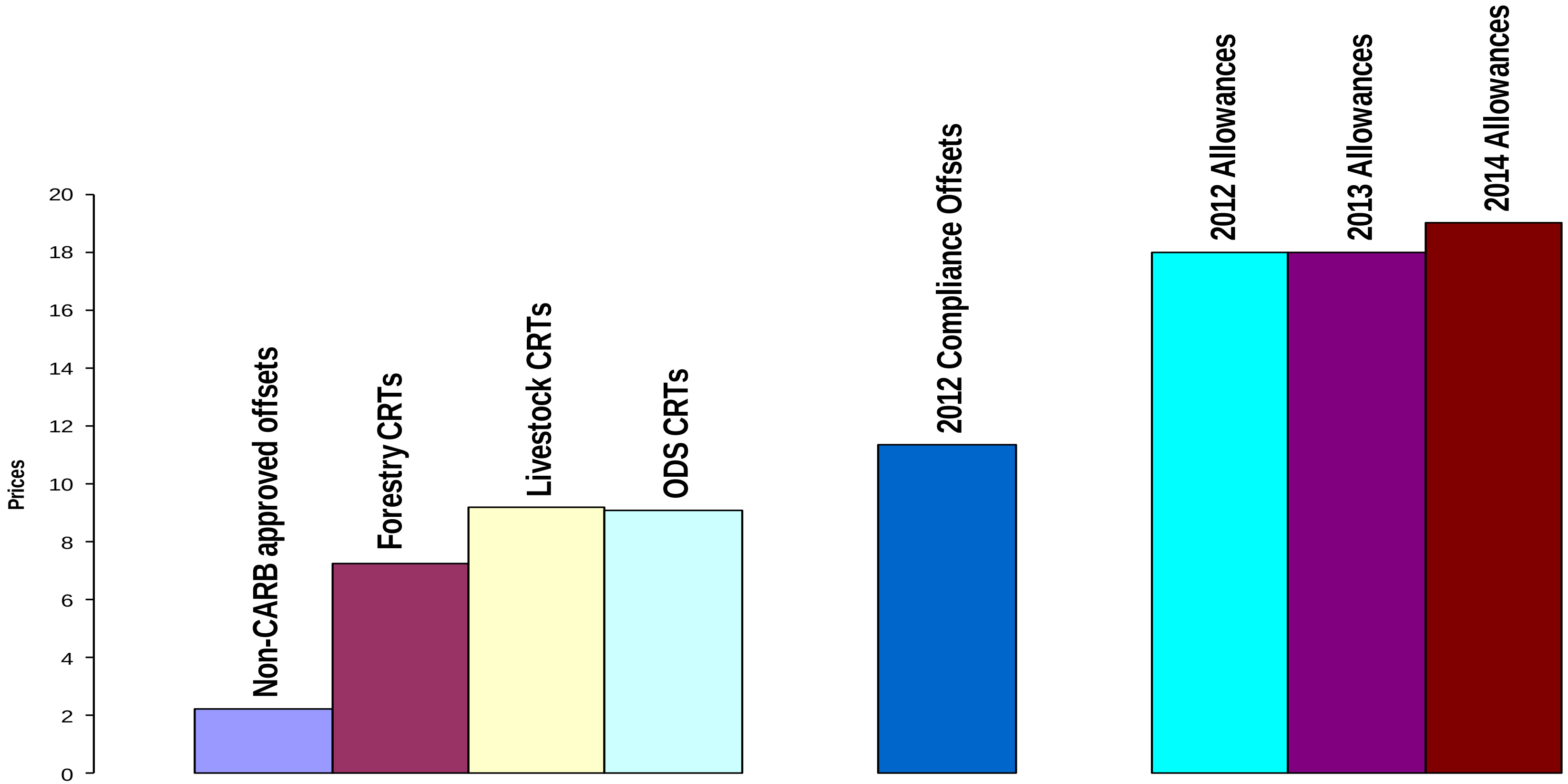
- Government sets declining cap on emissions for specific sectors
- Regulator creates allowances and distributes (via allocation or auction)
- Each year regulated entities must hold allowances = annual emissions
- Can reduce emissions on system; purchase allowances from companies that can reduce more cheaply; or purchase and retire offsets

WINROCK INTERNATIONAL

California offset market

- Power sector and large industrial emitters capped 2013, transportation and fuels 2015
- Up to 8% of these sources' annual compliance obligations can be met with offsets (200 million tons 2013-2020)
- All offsets must use California Air Resources Board-approved protocols
  - Offset supply short of demand under current 4 protocols
  - CARB strongly focused on agriculture for additional protocol approvals in 2012
- Offsets even now trading at \$7-10/ton CO_2e
  - Should increase as cap tightens, allowance prices increase, and additional sources come under the cap and compete for offsets

Recent California market pricing



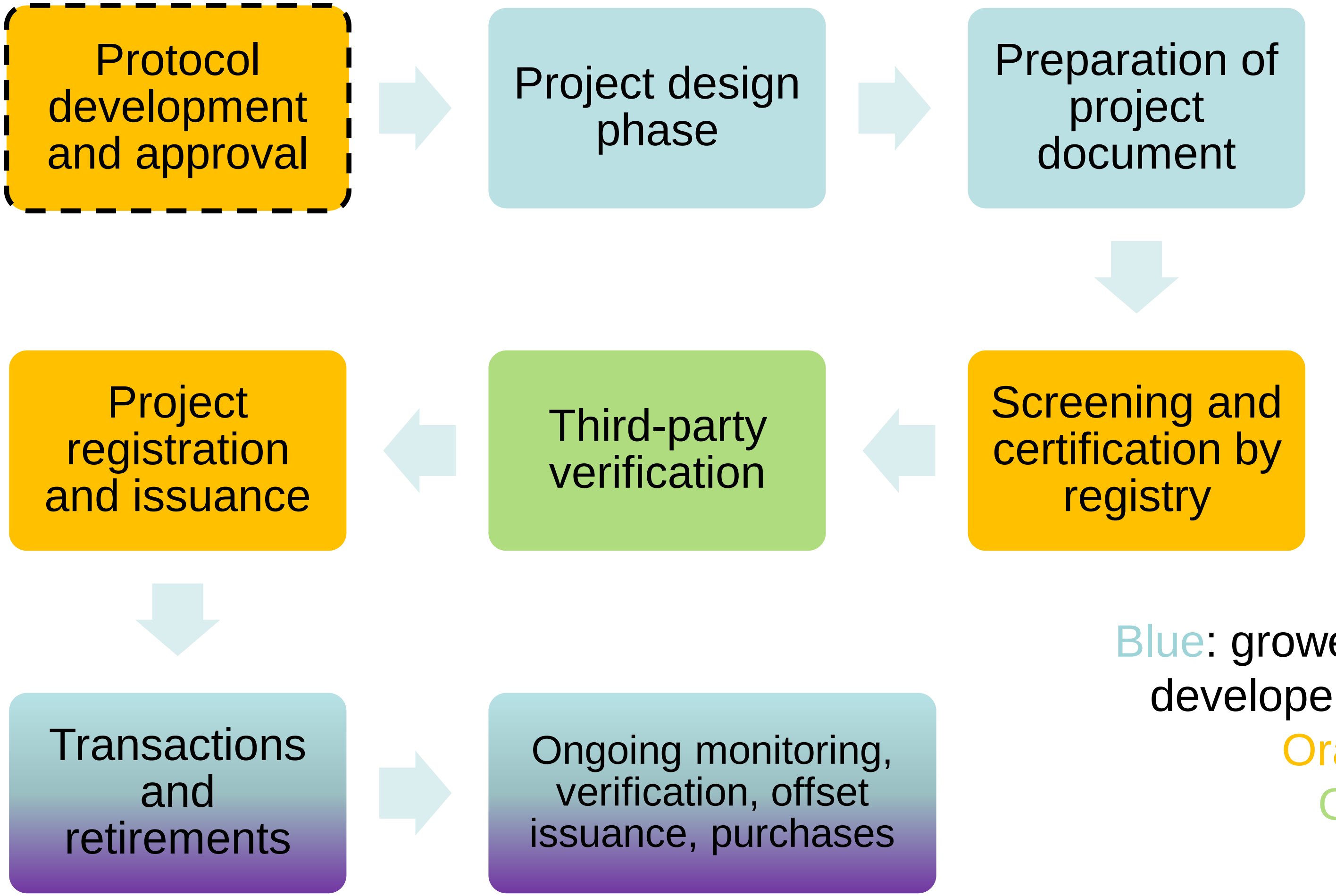
Typical agricultural offset types

- Reduce tillage / switch to no-till
- Add winter cover crop, eliminate summer fallow
- Switch to short-rotation woody crops or grasses for biofuels
- Change fertilizer N management – rate, source, placement, timing, nitrification inhibitors, slow-release – to reduce N_2O emissions
- **Implement various rice management changes to reduce CH_4 or CO_2**
- Manure management systems: methane digesters, manure solids separation, etc.
- Change grazing management: rotational grazing, feed additives, shorten livestock lifecycle, change from confined feeding to grass-fed
- Convert marginal/degraded croplands or grasslands to higher-carbon state
- **On-farm energy efficiency, reduce fossil fuel use, switch to low-carbon fuels, use less water or other inputs**

CIG project: *Demonstrating GHG reductions in California and Midsouth Rice Production*

- Implement pilot projects with willing growers on subset of practices discussed today
- Adapt ACR rice protocol to Mid-South, including calibration of DNDC model
- Develop more user-friendly producer interface and data management tools
- Assess waterfowl habitat impacts
- Evaluate replication potential in LA, MO, MS, TX
- Liaise with CARB on protocol approvals

Steps in the process



Blue: grower and project developer / aggregator
Orange: registry
Green: verifier
Purple: buyer

Parties involved

Party	Basic roles
Grower	• Implements modified practice and provides data on baseline and project • Retains title to GHG reductions unless transferred to project developer

Parties involved

Party	Basic roles
Grower	• Implements modified practice and provides data on baseline and project • Retains title to GHG reductions unless transferred to project developer
Project developer (aggregator)	• Interfaces with grower to collect necessary data (confidentially if preferred) • Prepares project documentation , submits to registry, works with verifier • May take offset title and market offsets • May aggregate many growers to reduce transaction costs and diversify risk

Parties involved

Party	Basic roles
Grower	• Implements modified practice and provides data on baseline and project • Retains title to GHG reductions unless transferred to project developer
Project developer (aggregator)	• Interfaces with grower to collect necessary data (confidentially if preferred) • Prepares project documentation , submits to registry, works with verifier • May take offset title and market offsets • May aggregate many growers to reduce transaction costs and diversify risk
Registry	• Publishes offset protocol • Reviews and accepts project documents, verification reports • Issues offsets; provides serialized tracking of transactions and retirements

Parties involved

Party	Basic roles
Grower	• Implements modified practice and provides data on baseline and project • Retains title to GHG reductions unless transferred to project developer
Project developer (aggregator)	• Interfaces with grower to collect necessary data (confidentially if preferred) • Prepares project documentation , submits to registry, works with verifier • May take offset title and market offsets • May aggregate many growers to reduce transaction costs and diversify risk
Registry	• Publishes offset protocol • Reviews and accepts project documents, verification reports • Issues offsets; provides serialized tracking of transactions and retirements
Verifier	• Third-party auditing against requirements of program and protocol • Delivers opinion on whether GHG assertion is without material discrepancy

Parties involved

Party	Basic roles
Grower	• Implements modified practice and provides data on baseline and project • Retains title to GHG reductions unless transferred to project developer
Project developer (aggregator)	• Interfaces with grower to collect necessary data (confidentially if preferred) • Prepares project documentation , submits to registry, works with verifier • May take offset title and market offsets • May aggregate many growers to reduce transaction costs and diversify risk
Registry	• Publishes offset protocol • Reviews and accepts project documents, verification reports • Issues offsets; provides serialized tracking of transactions and retirements
Verifier	• Third-party auditing against requirements of program and protocol • Delivers opinion on whether GHG assertion is without material discrepancy
Offset buyer	• Purchases and uses offsets for voluntary, pre-compliance, or speculative purposes • Retailer… Chevy… Walmart… Southern California Edison… fund

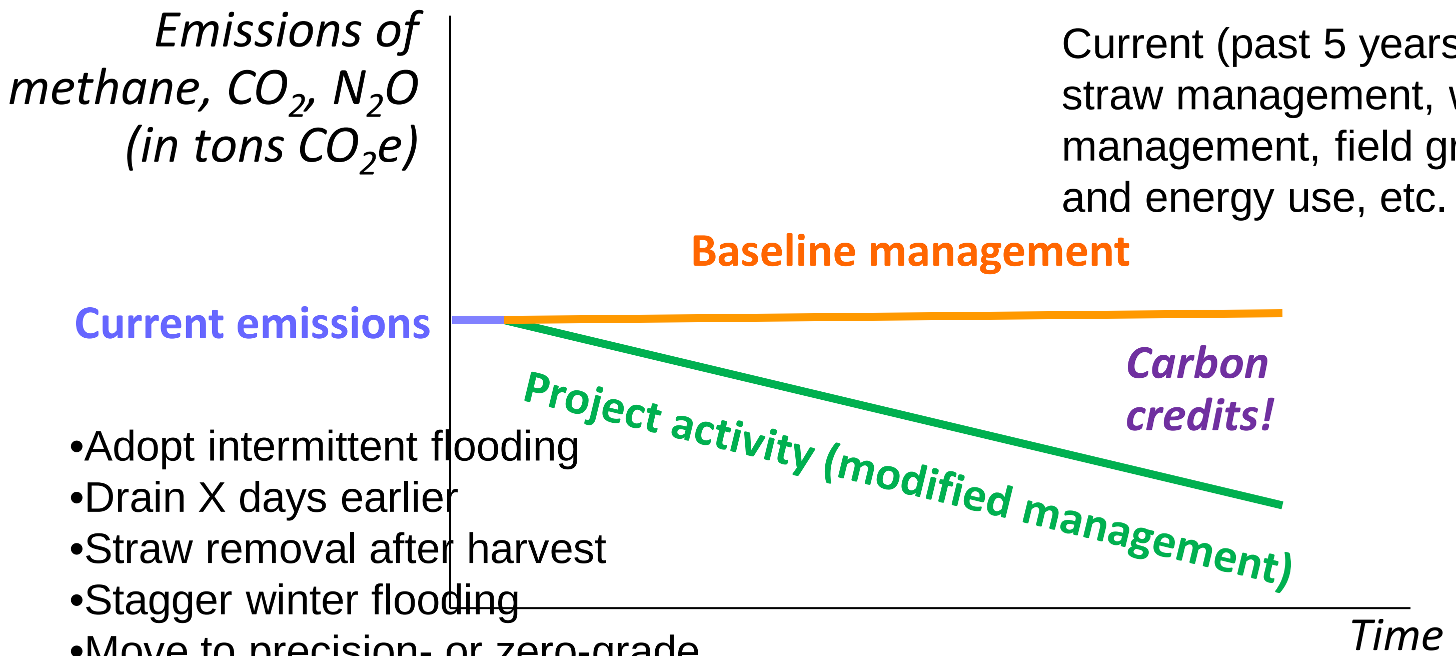
Protocols, project requirements, and revenue potential…
or,
Is the juice worth the squeeze?

Nick Martin, Winrock International

Rice focus group meeting

December 6, 2011

Baseline vs. project activity



Current (past 5 years) flood dates, straw management, winter water management, field grading, water and energy use, etc.

- Adopt intermittent flooding
- Drain X days earlier
- Straw removal after harvest
- Stagger winter flooding
- Move to precision- or zero-grade
- Use faster-maturing hybrid variety
- Improve efficiency of diesel pumps
- Etc.

WINROCK INTERNATIONAL

Additionality in offset protocols

- Activity is not "business as usual"
- GHG offset market had a role in incentivizing adoption of the practice – even if only one of several factors
  - Diesel and other input cost savings, less water, EQIP payments…
- Trying to reduce emissions through a flexible market-based system – have to be able to show the incentive provided by offset market is achieving a real environmental result

Protocol for voluntary emission reductions in rice systems

- Translates offset quality criteria into specifics that can be verified
- Sets project boundary (minimum 5 fields / 1,000 acres)
  - Aggregation likely but not mandatory
- Establishes baseline (what would happen on project fields in absence of project, based on last 5 years' management)
- Describes project activity (modified practices)
- Uses DNDC to model soil C dynamics, CH_4 and N_2O emissions in baseline and project
- Provides all equations to calculate emission reductions
- 3 pre-approved practices for California; module in development for Mid-South

Calculating methane reductions

- DNDC process-based simulation model of carbon and nitrogen biogeochemistry
- Outputs: emissions of GHGs (nitrous oxide, methane, CO_2) for baseline and project
- Inputs:
  - Management data: cultivar planted, yields, planting and harvesting dates, flooding depths, flooding and draining dates, residue management, fertilization dates and amounts
  - Information on soils, precipitation, etc. specific to project
  - Many default values or can be pre-loaded in model

Offset volume projections *(preliminary)*

Baseline:

- Planting Apr 15
- Harvest Sep 1
- Flood 4-6 weeks after planting
- Flood May 20 to Aug 10
- Fertilizer 200 units N/ac (80/40/40/40)
- Rice yield 180 bu/ac
- Leave 100% straw
- Winter flood Nov 15 to Feb 15
- Disk before planting
- Roll after harvest to incorporate stubble

Practice	Preliminary conservative estimate of GHG reductions (tCO_2e per acre)
Drain 2 weeks earlier	1
Remove 85% of straw	0.2
Reduce winter flood from 3 months to 1.5 months (could be staggered across fields)	0.3
Mid-season drain (14 day drain 21 days after initial flood)	0.7

Forward looking statements disclaimer

The numbers on the following slides contain forward-looking statements. These statements may be identified by words such as “expects,” “anticipates,” “estimates”… blah blah blah blah… subject to certain uncertainties and risks… blah blah blah blah… actual results may be materially different… blah blah blah blah blah blah …

Please take these numbers as preliminary educated estimates – not completely out of the air, but not the rigorous numbers that will eventually be generated in the pilot projects.

Potential offset revenues from reducing methane *(indicative only)*

Assumptions:

- 20,000 acre project (multiple fields aggregated)
- 2012 voluntary market price = $5
- 2012 California market price = $10
- 2015 California market price = $20
- Verification cost $30,000
- Typical registry fees (e.g. $0.20/ton transacted)
- Aggregator fronts all project costs and risk
- 50-50 profit sharing with aggregator initially

Practice	Per acre revenue to participating producers, net of all costs		
offset price -->	$5/ton	$10/ton	$20/ton
Drain 2 weeks earlier	$1.60	$4.10	$9.10
Remove 85% of straw	$0.00	$0.18	$1.18
Reduce winter flood	$0.00	$0.67	$2.17
Mid-season drain	$0.88	$2.63	$6.13

Reduce water use 20% and improve diesel efficiency 10% *(indicative only)*

Assumptions:

- 20,000 acre project
- 40 gal diesel per acre-foot pumped
- 4 acre-feet per acre over growing season (sandy soil)
- In baseline, 3.2 million gallons diesel per year; in project, 2.3 million
- GHG emissions from diesel at 10.21 kg CO_2e/gal (EPA)
- Same CO_2 price assumptions as above

Acreage	Per-acre revenue to participating producers, net of all costs		
offset price -->	$5/ton	$10/ton	$20/ton
20,000 ac	$0.42	$1.57	$3.85

Reduce water use 20% and switch to grid-connected electricity *(indicative only)*

Assumptions:

- 20,000 acre project
- 4 acre-feet per acre over growing season (sandy soil)
- In baseline, 3.2 million gallons diesel per year; in project, no diesel but 29 million kWh electricity
- GHG emissions from electricity at grid rate for east Arkansas
- Same CO_2 price assumptions as above

Acreage	Per-acre revenue to participating producers, net of all costs		
offset price -->	$5/ton	$10/ton	$20/ton
20,000 ac	$1.67	$4.10	$8.98

Further information

Nicholas Martin

Chief Technical Officer, American Carbon Registry

nmartin@winrock.org

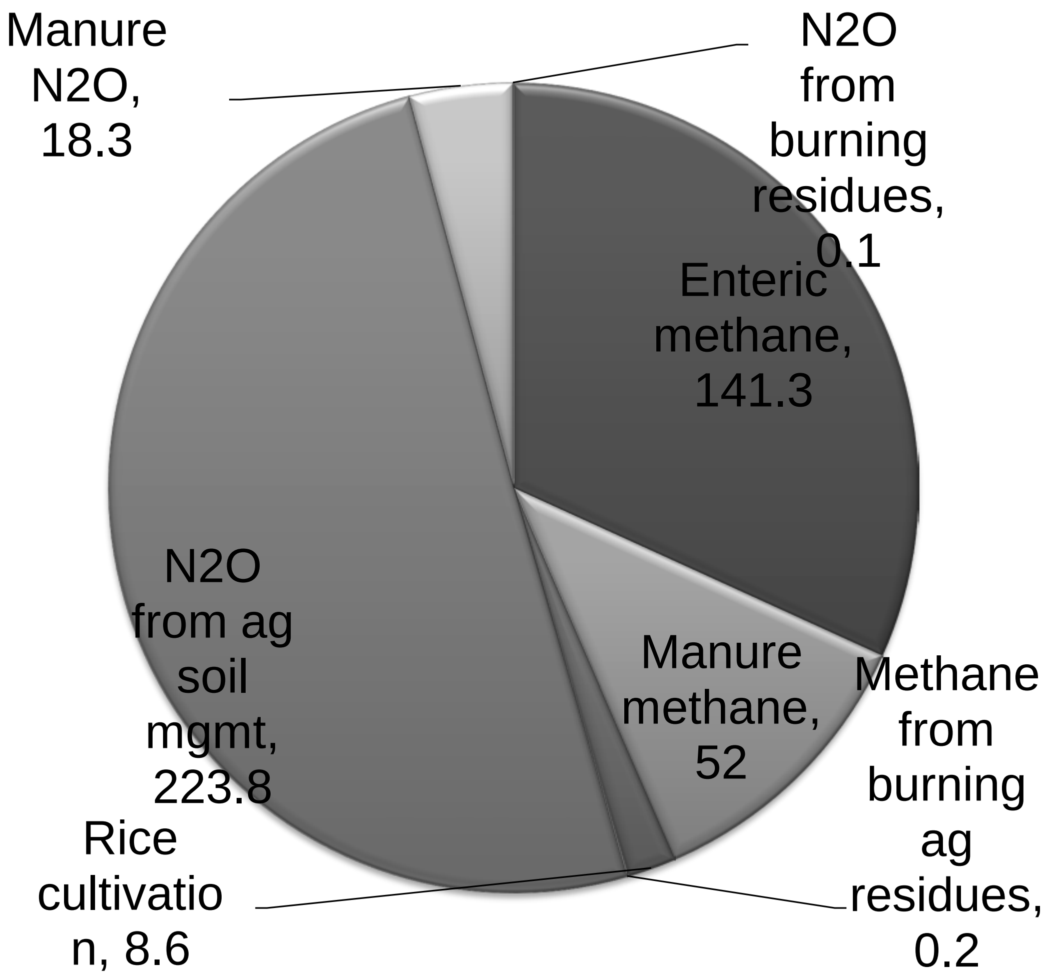
www.americancarbonregistry.org

(703) 842-9500

Conservation Innovation Grants – 2011 Greenhouse Gas round

- Special-purpose round focused on creating viable on-the-ground models for agricultural GHG mitigation
  - Pilot projects combining measured and verified GHG reductions with existing USDA conservation programs
  - Test protocols, learn lessons from growers, register projects on voluntary market registries
  - Grower feedback and lessons to inform NRCS programs
- $7.4m to nine projects in 24 states (plus $10m EQIP)
  - Fertilizer N management (3), soil carbon (1), rice (1), beef and dairy (2), grasslands (1), forestry (1)

Methane and N_2O emissions from U.S. agriculture, 2010



- Agriculture = 6.5% of US GHG emissions
- Leading sources N_2O from fertilizer and methane from livestock
  - Dominated by beef (101 MMT) and dairy (33 MMT)

GHG potential for various ag practices

Practice	Potential (tCO_2e per acre per year	Potential area (million acres)
Reduce N rate 15%	0.36	168
Change fertilizer source (ammonium to urea)	0.42	91
Slow-release fertilizer	0.11	230
Change placement	0.37	156
Change timing	0.20	131
Nitrification inhibitors	0.63	227
Winter cover crops	1.57	162
Change rice water management	1.81	3.2
Lower-GHG rice cultivars	0.76	3.2
Rotational grazing on pasture (soil C only)	1.17	103

Offset quality criteria

Additional	Reductions are beyond regulations, beyond common practice, beyond business-as-usual
Real	After-the-fact, measurable GHG reductions
Permanent	Atmospheric benefit is permanent, or reversal risk is assessed and mitigated to make non-permanent offsets fungible with other offsets, on-system reductions and allowances
Net of leakage	Emission increases outside project boundary, due to project, are mitigated
Verified	Reductions are verified by an approved, accredited third party Rules complied with and GHG assertion is without material discrepancy
Serialized	Transparent accounting and tracking ensures same reduction used only once

DNDC model inputs

Input Category	Code	Input	Units	Mandatory / Optional	Data Source			
					Project records	*Measured*	*Look-up*	*Default*
Location	***L1***	GPS location of stratum	decimal °	M		X		
Climate	***CI***	Atmospheric background NH_3 concentration	µg N/m^3	M				X
	C2	Atmospheric background CO_2 concentration	ppm	M				X
	C3	N concentration in rainfall	mg N/l or ppm	M			X	
	C4	Daily meteorology	multiple	M		X	X	
Soils	***S1***	Land-use type	type	M	X			
	S2	Clay content	0-1	M		X	X	
	S3	Bulk density	g/cm^3	M		X	X	
	S4	Soil pH	value	M		X	X	
	S5	SOC at surface soil	kg C/kg	M		X	X	
	S6	Soil texture	type	M		X	X	
	S7	Slope	%	M		X		
	S8	Depth of water retention layer	cm	M		X	X	
	S9	High groundwater table	cm	M		X	X	
	S10	Field capacity	0-1	M		X		X
	S11	Wilting point	0-1	M		X		X
Cropping system	***CR1***	Crop type	type	M	X			
	CR2	Planting date	date	M	X			
	CR3	Harvest date	date	M	X			
	CR4	C/N ratio of the grain	ratio	M		X	X	
	CR5	C/N ratio of the leaf + stem tissue	ratio	M		X	X	
	CR6	C/N ratio of the root tissue	ratio	M		X	X	
	CR7	Fraction of leaves and stem left in field after harvest	0-1	M		X		
	CR8	Maximum yield	kg dry matter/ha	M	X			
Tillage system	***T1***	Number of tillage events	number	M	X			
	T2	Date of tillage events	date	M	X			
	T3	Depth of tillage events	6 depths†	M	X			
N Fertilizer	***F1***	Number of fertilizer applications	number	M	X			
	F2	Date of each fertilizer application	date	M	X			
	F3	Application method	surface / injection	M	X			
	F4	Type of fertilizer	type*	M	X			
	F5	Fertilizer application rate	kg N/ha	M	X			
	F6	Time-release fertilizer	# days for full release	M	X			
	F7	Nitrification inhibitors		M	X			
Organic Fertilizer	***O1***	Number of organic applications per year	number	M	X			
	O2	Date of application	date	M	X			
	O3	Type of organic amendment	type	M	X			
	O4	Application rate	kg C/ha	M	X			
	O5	Amendment C/N ratio	ratio	M				X
Irrigation System	***I1***	Number of irrigation events	number	M	X			
	I2	Date of irrigation	date	M	X			
	I3	Irrigation type	3 types‡	M	X			
	I4	Irrigation application rate	mm	M	X			

Information needed for DNDC

- Growers’ management records (“critical management parameters”) for past 5 years and for project:
  - Rice cultivar planted, yields, planting and harvesting dates, flooding depths, flooding and draining dates, residue management, fertilization dates and amounts
- “Non-critical input parameters” unaffected by project:
  - Soil characteristics (organic matter, texture, pH, etc.)
  - Actual weather, precipitation etc. during growing season
- Lot of inputs, but many can be defaults; optionally measured to reduce uncertainty; or built into front-end interface tool

GROWER Survey Responses

Below are Survey Reponses collected from growers. Grower names have been removed for privacy.

June 2015|NRCS Conservation Innovation Grant 69-3A75-11-133

Survey Response: Grower A

June 10, 2015

Why did you join the pilot project?

There didn’t seem to be any risk and he didn’t mind the challenge. The farm was already doing AWD, so it was a no-brainer.

What were the highlights of participating in the project?

It forced him to be a better record keeper, which is a weakness for farmers. There’s power in data.

What would you tell other farmers considering participating in a carbon project?

He’s waiting to see how it goes before saying anything either way. They haven’t received any real feedback to date.

What did you observe on the fields when you implemented a given practice such as alternative wetting and drying?

He was doing AWD before they were even thinking about it, he stumbled on it accidentally and it returned the biggest yield he had seen at that point.

How can we improve the process moving forward?

He’d like to have a form for the growers to remind them what types of records they need to keep.

Is there any other feedback that you would like to share?

It’s important to have patience and provide the right documentation.

Survey Response: Grower B

June 10, 2015

What are your thoughts about participating in this pilot rice project?

He's enjoyed the education on AWD outside of the paperwork. They're pushing the water management stuff as far as possible.

Why did you join the pilot project?

Grower B saw Dennis give a talk on conservation and he was instantly interested.

Were there any complications collecting the data that you didn't foresee?

No, he didn't know what to expect.

What were the highlights of participating in the project?

What would you tell other farmers considering participating in a carbon project?

It's all about the money. With AWD, there's less water usage, which equates to less money out the door. They'll want to know what their efforts are worth.

What did you observe on the fields when you implemented a given practice such as alternative wetting and drying?

How can we improve the process moving forward?

He doesn't know. We're still developing the process, but he would like to know very clearly what things need to be documented.

Is there any other feedback that you would like to share?

Any additional notes:

Automation for data collection (e.g. water depth sensors) is key to reducing the burden on the farmer.

Also, there's been no communication of the project's status to the farmers which makes it hard for them to have an opinion on any part of the process.

Survey Response: Growers C and D

June 11, 2015

What are your thoughts about participating in this pilot rice project?

They're excited about the research aspect.

Why did you join the pilot project?

They strive to do the best they can and be good stewards of the land.

Were there any complications collecting the data that you didn't foresee?

It's time consuming. The soil websites are hard to navigate – they had to call the university for unsuccessful help. He says the soil websites are terribly slow.

Were there any complications that you did foresee, and if so, how did you overcome them?

No.

What were the highlights of participating in the project?

Learning about what they're doing for the environment and being able to make a living give them a good feeling. There's a lot of personal satisfaction with this work.

What would you tell other farmers considering participating in a carbon project?

Nothing yet – they want to see some money first.

What did you observe on the fields when you implemented a given practice such as alternative wetting and drying?

They use less water (~20% less). They participated in a rice verification study through the university where it was observed that they used 17.5 acre inches of water and the next closest participant was using 36 acre inches.

Is there any other feedback that you would like to share?

They still need to figure out how to manage the AWD process across 125 fields as the timing isn't in sync yet.

Any additional notes:

- They need clarification if there are multiple options to choose from in the model (i.e. soil types). They don't know which soil classification to choose from if there are 4 different types of soils on the field.
- They need a process for data collection.
- Data can bog you down when their job is to farm.

Survey Response: Grower E

June 09, 2015

What are your thoughts about participating in this pilot rice project?

Why did you join the pilot project?

Grower E has always been at the cutting edge of rice farming to improve efficiencies, which can reduce operational costs.

Were there any complications collecting the data that you didn’t foresee?

The unknowns – knowing whether it’s worth your time and how much time you’ll need to expend.

Were there any complications that you did foresee, and if so, how did you overcome them?

He wasn’t worried about these complications since they’ve been implementing the practices on a smaller scale.

What were the highlights of participating in the project?

They observed increased root health with AWD.

What would you tell other farmers considering participating in a carbon project?

He would speak to the [unseen to date] economic benefits.

What did you observe on the fields when you implemented a given practice such as alternative wetting and drying?

In theory it’s less water usage. In reality, it’s hard to measure but they’re hoping to get a better data set this year.

Another benefit is the root health – some varieties of rice (fall autodeclans) force this activity due to lack of oxygen which requires earlier drainage.

The primary risk with AWD is that you’ll decrease your yield.

How can we improve the process moving forward?

Clearer goals moving forward.

Is there any other feedback that you would like to share?

It took a while to get any traction. It’s taken them a few years to figure out the structure. He wants to be more part of the process and less removed from the decision making aspects. He wants to be involved in the implementation development process.

They want the coop to be farmer led.

These last few years have given them the ability to experiment and figure out what works. They're hoping that moving forward; they've worked out most of the bugs.

Any additional notes:

Questions growers will have to figure out if they have enough water to keep the field(s) flooded. Additionally, they have found that they need a larger volume of water for AWD, which results in extra effort.

The grant was instrumental in providing the impetus for something that wouldn't have happened otherwise. It got them to this point where he feels they can go out to other farmers and demonstrate that this is worth their while.

He believes that this is the proving ground for other agricultural offset mechanisms and that the efforts will lead to something positive.

Any additional notes from agronomists participating in the project, Dr. Merle Anders & Dr. Joe Massey.

Merle:

- The process needs to be more transparent for the people on the ground.
- In regards to record keeping, further clarification of what data is needed once vs. what is needed during each year needs to be provided.

Joe:

- The growers need further guidance on how to prove land ownership.
- Agrees that clarification is needed, but in particular, he'd like to better understand what inputs are truly required for the DNDC model.

Conservation Innovation Grant Experiences from the Mid-South
White River Irrigation District | July 2015

July 2015 |NRCS Conservation Innovation Grant 69-3A75-11-133

Introduction

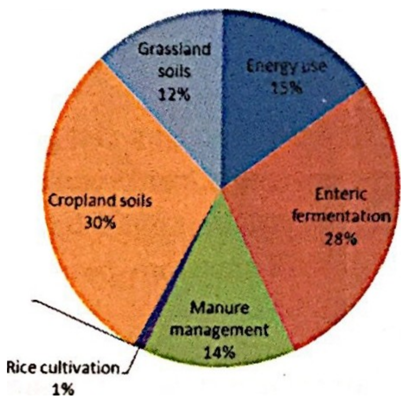
This document was prepared for the 2011 Conservation Innovation Grant supporting the development and implementation of a carbon trading protocol for rice production. This document only addresses efforts in the mid-South to engage, educate and support rice growers who are interested in piloting a rice management carbon offset project, and efforts to inform the development of both the voluntary rice management methodology by the American Carbon registry (ACR) and the Compliance Rice Protocol by the California Air Resources board (ARB). The work was performed by a core team comprised of representatives from Mississippi State University, Arkansas State University, the Agricultural Research Service, University of Arkansas Cooperative Extension Rice Experiment Station and the White River Irrigation District (WRID). Many other individuals and specialists have been involved over time but the key personnel of the mid-South rice team include Dr. Michelle Reba, Dr. Joe Massey, Dr. Merle Anders, Dr. Earl Vories, and Dennis Carman. Robert Parkhurst of the Environmental Defense Fund (EDF) provided invaluable service and acted as a liaison between us and ARB. Additional guidance has been provided throughout the project for feedback, training, suggestions, directions and clarification of methods from personnel from Winrock International and ACR, EDF and Terra Global Capital.

We have relied very heavily on input and support from pilot growers in Arkansas and Mississippi that have provided direct assistance, formal training, sharing of their institutional knowledge and suggestions on how to make the proposed practices work.

At the start of this 3 - 4 year process there were no clearly identified project procedures or formally established greenhouse gas (GHG) quantification methods. Training materials did not exist and the protocols or methods were in the initial process of being formulated. WRID's role was to provide the organization structure and local interaction between the "carbon trading structure" and the growers who are ultimately the decision makers and carbon credit generators.

Setting: This document must be viewed in the context that this has been a **3-4 year journey** to explore the potential for a Carbon Trading Program that would influence rice producers to reduce GHG emissions during the rice growing cycle. It is written from the grower and field implementation perspective. We started with many more questions than answers. Those questions concerned **"big picture" issues** that are represented by grower questions or statements such as:

1. Is global warming real or is it a manufactured deal for some other purpose?
2. Why Me? Why rice growers? Although important to the US and Global Economy and world strategic issues, we have a very small, generally regional footprint. Agriculture produces less than 10% of the total GHG emissions and rice growers are 1% of that 10%. Are we being targeted?
3. Some of the lead organizations promoting this effort have not historically supported voluntary approaches to environmental issues in agriculture. Are we to trust the motives of the organizations involved?



4 "The California Cap and Trade Program seems to be a key driver of this initiative. Why would anyone in California want to pay Arkansas rice growers to change their conservation practices? That makes no sense so I have to be a suspicious of the motives."
5 What about the science? Do you guys know what you are talking about and how it all works?
6 Where are the land grant institutions and Universities on this issue? It appears to include different recommendations than we have been told to follow to successfully grow rice.
7 Other than you local guys we trust and have worked with previously, everyone else involved appears to be unfamiliar with rice growing in general and mid-South resources in particular. How can these people make reasonable decisions or recommendations without knowing the basics of growing rice?
8 What about Riceland, Producers Mills, and the rice industry organization's representatives in general? Are they for or against this?
9 What Conservation Practices are you proposing? What management changes are you asking me to do?
10 We have successfully grown rice for four generations using the conventional methods. What guarantee can you give me that these proposed changes will not increase disease, reduce yield, reduce my grain quality, increase my management time, or increase my risk of failure. Will this increase or reduce my income potential?
11 What records do I have to keep? Who will have access to those records? How can I be assured that any records or information I provide will not be used against me?
12 Who owns any credits I generate?
13 What payment levels are available and what do I have to do to participate? How is the money divided?

These are fair and reasonable questions demanding fair and responsible answers. After 3 years of hard and dedicated work we have been able to answer some of these questions but many of the larger policy and programmatic issues remain. There are many basic questions yet to be answered, mostly in the programmatic arena.

Our general responses are shown below.

1 *Is global warming real or is it a manufactured deal for some other purpose?*
Global warming is real. Global temperatures are rising as well as the temperatures of the ocean. This has significant issues for the short term and long term sea levels, weather patterns, and potential impacts on our food supply. Some individuals argue that this global warming is not "manmade" but part of a natural process. That may be but does it really matter? We need to address this issue in a reasonable, common sense manner. Rice projects are one way of achieving greenhouse gas reductions and avoiding regulation.

2 *Why Me? Why rice growers? Although important to the U.S. and global economy and world strategic issues, we have a very small, generally regional footprint. Agriculture produces less than 10% of the total GHG emissions and rice growers are 1% of that 10% being targeted?*
The rice industry specifically and agriculture as a whole is not being targeted. In fact, agriculture and forestry are two areas where solutions have been identified that can help mitigate global warming. Rice production is identified as one of the areas for early action because the acres involved are relatively limited and focused in the mid-South and California. Additionally, rice GHG is generally in the form of methane which is one of the more potent greenhouse gases.

3 *Some of the lead organizations promoting this effort have not historically supported voluntary approaches to environmental issues in agriculture. Are we to trust the motives of the organizations involved?*
We have found the individuals and groups we are working with, specifically the

Environmental Defense Fund and Winrock International/American Carbon Registry to be nothing but dedicated to making the voluntary market and carbon trading process work. They are working hard to provide a solution to global warming that works without regulations. Why? Global warming is real. Global warming must be addressed. Regulations are recognized as a non-option politically for a large percentage of the United States and/or world. So a dedicated effort is being made to bring market concepts to GHG reduction in rice production. The aforementioned organizations understand that the market provides a universal incentive to reduce emissions and create other environmental benefits.

4 *"The California Cap and Trade Program seems to be a key driver of this initiative. Why would anyone in California want to pay Arkansas rice growers to change their conservation practices? That makes no sense so I have to be a suspicious of the motives."*
Everyone knows that California has its own way of doing things. California has the world's 7th largest economy and significant air quality issues. California has passed a Cap and Trade law that outlines specificgoals for reducing Greenhouse Gases from major industries that will guide them and their industries as this significant resource issues is addressed. Part of this effort recognizes the global implications of this issue given GHG emissions have no political boundaries. If a ton of carbon is reduced, it offsets a ton of carbon produced somewhere else. Rice producers are one of the unregulated areas that offsets can be purchased. If it makes more economic sense to reduce GHG production by rice producers in the mid-South, that is where it should occur.

5 *What about the science? Do you guys know what you are talking about andhow it all works?*
We believe we understand the science and where we can make the most impact. The three areas where greenhouse gas reductions have the most potential involve irrigation water management, nutrient management, and energy management. We know that greenhouse gases can be reduced if we practice alternate wetting and drying (AWD) during the growing season. We also know that emissions are reduced when nitrogen application rates are reduced and/or applied with a one-time application. We know that practicing AWD reduces water use with a direct decrease in energy used for pumping water, much of which is powered by diesel equipment.

6 *Where are the land grant institutions and Universities on this issue? It appears to include different recommendations than we have been told to follow to successfully grow rice.*
That is true. There can be a difference in the recommendations. The pioneers in this effort are promoting conservation practices and management methods that will influence emission reductions. These differences are reasonable and will be "adjusted" as we successfully apply practice and management changes. There is always a risk with something new. We are encouraging growers to try the process on a portion of their rice fields and decide for themselves.

7 *Other than you local guys we trust and have worked with previously, everyone else involved appears to be unfamiliar with rice growing in general and mid-South practices in particular. How can these people make reasonable decisions or recommendations without knowing the basics of growing rice?*
Much of the information, research, and recommendations we are promoting has been developed in the mid-South by specialists directly associated with local climate and production methods. We are partners. However, at times it is difficult to communicate why certain programmatic issues or measurement technologies simply don't work in the mid-South conditions when the other partners don't understand the basic techniques. It takes cooperation.

8 *What about Riceland, Producers Mills, and the rice industry organizations in general? Are they for or against this?*
That is officially unknown. We don't know what they are thinking. Riceland and producer cooperatives are aware of this effort as are representatives of rice growing associations. Nothing negative has been expressed. Individuals in leadership positions have been supportive of all conservation efforts and expressed positive thoughts about helping increase grower income potentials.

9 *What Conservation Practices are you proposing? What management changes are you asking me to do?*
Our initial discussion included all of the eligible activities under the ACR Rice Protocol: removal of rice straw from the field after harvest; early drainage at the end of the growing season; intermittent flood during the growing season (AWD) and; increase water and/or energy efficiencies. Ways to achieve water and energy efficiencies include, but are not limited to: converting contour levees to precision or zero grade; use of side inlet/poly piping systems; use of more efficient diesel pumps; switching from diesel to electric pumps; and use of soil moisture sensors to tailor flood levels to water needs. Project proponents who implement practices that decrease nitrogen applications concurrently with these practices will also be able to combine this methodology with other ACR protocols in order to optimize emission reductions in addition to the reduced methane emissions. As this effort progressed the message became more specific given market realties, difficulty in measurement methods, record keeping demands and other uncertainties that are as yet resolved. That message has generally been focused on planting using normal tillage equipment and timing. We will encourage a one-time nitrogen application at a slightly reduced rate, but we do not focus on that point currently. We do focus on obtaining at least one AWD cycle about 20 days after the initial flood. We are focusing on **keeping adequate records**. We are focusing on converting contour levees to zero grade or precision leveled fields but we have found that practice is usually driven by other factors. However, individuals implementing those practices are good candidates for carbon projects. We could have greater participation but the price of carbon and the relatively small amount of tons produced under the ARB Rice Project Protocol will limit grower buy-in. The ARB protocol should recognize energy reductions. There is a mismatch between the voluntary and compliance program, the price of carbon and potential reductions.

10 *We have successfully grown rice for four generations using the conventional methods. What guarantee can you give me that these proposed changes will not increase disease, reduce yield, reduce my grain quality, increase my management time, or increase my risk of failure. Will this increase or reduce my income potential?*
No, we cannot guarantee you these proposed changes will always be successful. We will tell you that we have demonstrated significant water savings reductions when AWD is practiced resulting in reduced pumping costs. We have maintained yields and eliminated the mid-season fertilizer application. We know precision leveled fields or zero graded fields are easier to manage and save significant amounts of water. We have not seen increased diseases and research seems to be showing a reduced potential, we have been able to maintain yields. We are not telling you the carbon payment is enough to drive the decision making process. It is not. However if you consider a combination of water savings (reduced pumping costs), reduced fertilizer costs, and a small incentive payment from carbon sales, it appears to offer additional income potential. Try some of your acres and check it out for yourself. We believe it is worth the risk.

11 *What records do I have to keep? Who will have access to those records? How can I be assured that any records or information I provide will not be used against me?*
As to the records needed, initially we told the growers we needed things like dates for tillage, planting, water application times and depths, fertilizer application dates and rates and similar data. As time and the learning curve progressed the records needed have not become any clearer

and maybe even more confusing as the ARB moves to adopt their Rice Protocol. The degree and detail required as well as verification procedures remain unclear.

In regards to who will have access to the records, we continue to tell growers that only the project developer or the “aggregator” responsible for selling the credits, the project verifier and the registry program will have access to full records. It remains a real concern that any records, especially with the limited number of initial participants with geographic data recorded, could be easily obtained and used by others to single out the growers. We don’t have a good answer yet. We can’t guarantee that the records won’t be used against the farmers however we’re doing everything we can to prevent misuse and protecting the records.

12 *Who owns any credits I generate?*
The grower does until they sell them or enter into an agreement with an aggregator/project developer to broker your credits.

13 *What payment levels are available and what do I have to do to participate? How is the money divided?*
Initially our response was that we don't know for sure but we believe it will be in the $7 - $8 per acre range given the early science that indicates implementation of AWD reduces greenhouse gases by roughly one ton of carbon per acre. We do not know about what levels, if any, there may be for fossil fuel reduction or water savings. As time progressed the $7 - $8 per acre goal appeared to be optimistic. The only offer to date that has been available was a total of $10 per ton of carbon with $6.50 going to the grower. This did include consideration for fossil fuel reduction however methods for determining those credits have not been clearly defined.

We have answered many of the technical and science questions and have concluded that there is great potential to reduce GHG production during rice growing. There are many unanswered questions concerning the policies, procedures, regulatory intent, and program implementation methodologies that are in the hands of federal and state policy makers and/or organizations interested in the environmental credit market.

Emission Reductions in California Rice Management Systems

Version 4-0

July, 2015

Terra Global

Table of Contents

Table of Contents 2
A. PROJECT OVERVIEW 1
A1. PROJECT TITLE 2
A2. PROJECT TYPE 2
A3. PROOF OF PROJECT ELIGIBILITY 2
A4. LOCATION 4
A5. BRIEF SUMMARY OF PROJECT 6
A6. PROJECT ACTION 7
A7. *EX ANTE* OFFSET PROJECTION 8
A8. PARTIES 9
B1. APPROVED METHODOLOGY 10
B2. METHODOLOGY JUSTIFICATION 11
B3. PROJECT BOUNDARIES 11
B4. IDENTIFICATION OF GHG SOURCES AND SINKS 11
B5. BASELINE 12
B6. PROJECT SCENARIO 14
B7. REDUCTIONS AND ENHANCED REMOVALS 14
B8. PERMANENCE 14
C. ADDITIONALITY 15
C1. REGULTORY SURPLUS TEST 16
C2. COMMON PRACTICE TEST 16
C3. IMPLEMENTATION BARRIERS TEST 17
C4. PERFORMANCE STANDARD TEST 18
D. MONITORING PLAN 19
D1. MONITORED DATA AND PARAMETERS 20
E. QUANTIFICATION 25
E1. BASELINE 26
E2. PROJECT SCENARIO 28
E3. LEAKAGE 30

E4. UNCERTAINTY 30
E5. REDUCTIONS AND REMOVAL ENHANCEMENTS 31
E6. EX-ANTE ESTIMATION METHODS 32
F. COMMUNITY & ENVIRONMENTAL IMPACTS 34
F1. NET POSITIVE IMPACTS 35
F2. STAKEHOLDER COMMENTS 35
G. OWNERSHIP AND TITLE 37
G1. PROOF OF TITLE 38
G2. CHAIN OF CUSTODY 38
G3. PRIOR APPLICATION 38
H. PROJECT TIMELINE 39
H1. START DATE 40
H2. PROJECT TIMELINE 40
Appendices 42
Appendix A 43

A.
PROJECT OVERVIEW

A1. PROJECT TITLE

Emission Reductions in California Rice Management Systems

A2. PROJECT TYPE

The project type is Agricultural Land Management

A3. PROOF OF PROJECT ELIGIBILITY

This project uses the methodology *Voluntary Emission Reductions in Rice Management Systems version 1.0*, which was formally approved by the American Carbon Registry (ACR) in May 2013. The following applicability criteria were met to as required by the protocol.

1. The project encompasses 5,389 acres, exceeding the 1,000 acre requirement.
2. The California Regional Calibration Module version 1.0 shows that the Denitrification-Decomposition model (DNDC) has been successfully calibrated to the proposed project activities in California's Rice Growing Region.
3. All rice Fields included in the Project have been cropped under rice flooded conditions for at least two out of five years preceding project start.
4. Detailed management data was gathered on each rice field for three of the five years preceding the start of the project. For each field it is known whether the Project Activities were conducted for each of the five years preceding project start.
5. No field in the Project contains soils organic carbon content in the top 30 cm greater than 3%.

The proposed project meets the eligibility requirements of the ACR Standard, as specified in Chapter 3 of Version 4.0 of the Standard, dated January 2015. Each eligibility requirement is addressed individually below and elaborated upon further throughout the Plan. All proposed offset credits (i.e. those in this Plan and those developed at any point in the future) shall meet these eligibility requirements.

- **Start Date** – The project activities were initiated on a range of years based on the specific field. The earliest known activity start was April 1, 2007, thereby satisfying the eligible Agriculture Forestry and Other Land Use (AFOLU) project start date of January 1, 2000 or later.
- **Minimum Project Term** – There is no minimum project term required, as per the American Carbon Registry Standard v4, due to the fact that there is no risk of reversal subsequent to crediting since emission reductions are credited on a yearly basis for each field.
- **Crediting Period** – In compliance with the Voluntary Emission Reductions in Rice Management Systems, v1.0, the crediting period is 5 years and can be renewed in 5 year increments. The crediting period for this project starts in Nov 1, 2011 and ends in Oct 31, 2016. While some project activities were adopted in participating fields starting in 2007, these fields were bundled with all others in the project for ease of accounting/aggregation. Thus, to be conservative and meet the requirements for all acres included in the project we are applying for Nov 1, 2011 to be the first year of the crediting period. Additional documentation will be provided to ACR reflecting the fundamental goal of environmental sustainability, including reducing GHG emissions on these fields at the time in which practices were initiated on field.

- **Real** – Though this GHG Plan includes ex-ante emission reductions, the Project Proponent is only seeking GHG offset credits for emission reductions after they have been verified. Therefore, only after-the-fact quantifiable and verifiable GHG removals are accounted for.
- **Emission or Removal Origin** – The Project Proponent, Terra Global, is the aggregator for rice producers in California. Terra Global executes agreements with all farmers in the project. Under the agreement, the project's participating rice producers assign rights to the emission reductions to Terra Global, who supports the validation and verification of ERTs, manages the sale of ERTs on behalf of the farmers and facilitates the distribution of revenue to participating farmers. This project only claims emission reductions from direct emissions not from indirect emissions and meets the criteria defined in the Standard.
- **Offset Title** – All farmers in the project have legal title to the offsets produced under the project, based on the fact that they are responsible for the implementation of the practices that generate the offsets on land where they have title. No chain of custody documentation is needed as offsets have never been generated or sold in the past.
- **Land Title** – All farmers in the project have legal, undisputed title to the land on which the offsets are generated. Terra, the Project Proponent and ACR Account Holder, will provide documentation and attestation of clear, unique, and uncontested title to the verifiers.
- **Additional –** The GHG emission reductions and removal enhancements are additional, as they exceed those that would have occurred in the absence of the Project Activity and under the business-as-usual scenario. Determining the Baseline Scenario and demonstrating additionality is performed on each individual field and for each of the eligible Project Activities under the methodology *Voluntary Emission Reductions in Rice Management Systems v1.0* and the *Voluntary Emission Reductions in Rice Management Systems – California Module*. Fields implementing Project Activities that have an adoption rate in the Rice Growing Region of less than or equal to 5% of total acres in the Project's Rice Growing Region may establish the baseline using a Common Practice Baseline approach. The Project Activities that are applied minimally across the rice region are automatically additional if they pass ACR's regulatory additionality test. The Project Activities in this project that have an adoption rate in the Rice Growing Region of 5% or less are dry seeding and baling.

  Fields that implement a practice with an adoption rate greater than 5% of the total acres of rice in the Project's Rice Growing Region use a Field-Specific Baseline which is determined based on historical practices that define the business-as-usual for that field. All fields with Field-Specific Baseline associated with the project explicitly demonstrated additionality using the ACR three-pronged test. All fields passed the test, as the practices in each field: 1) exceed regulatory/legal requirements; 2) go beyond common practice; and 3) overcome at least one of three implementation barriers: institutional, financial or technical. Early drainage has an adoption rate greater than 5% in the Rice Growing Region.
- **Regulatory Compliance** – There are no regulatory compliance requirements associated with any project activities on fields. If any field agronomic management activities, such as straw burning, occur on the participating fields then they will follow all relevant regulations in the jurisdiction in which the Project is located.
- **Permanent** – Emission reductions achieved through this project are on a yearly basis, dependent on the practices adopted in a given year and using field specific agronomic data in the quantification

methodology. These emission reductions from changes in rice management in a given year are permanent and cannot be reversed, regardless of future changes in management.

- **Net of Leakage** – Possible leakage effects due to activity shifts are quantified and deducted from the GHG benefits. The project monitors crop yields every harvest, and any significant negative effects on yield will be monitored and quantified.
- **Independently Validated and Verified** – According to ACR rules, the project benefits will be validated and verified by an ACR approved independent auditor.
- **Community and Environmental Impacts** – The project is expected to have overwhelming positive effects on California's environment including reduced localized methane production combating climate change. The Project Proponent has carefully identified any potential negative effects associated with the Project Activities.

  The practice of baling rice straw could potentially have a negative effect in that additional nutrients, specifically potassium, can be lost from the field. Farmers monitor nutrient input, which is calibrated into the DNDC model to measure any additional emissions associated with nutrient loss due to baling. Annual monitoring data of any loss in yield or loss in nutrients due to baling will be recorded on an annual basis.

  The proposed Project Activity of early drainage can reduce late season water diversion water from California streams and rivers. The Project Activity of dry seeding allows farmers to plant early in the rice growing season and allows for improved managed water flow on fields. This can enable farmers to effectively manage a limited water supply to maximize the acres that can be planted with a limited amount of water. Both community and environmental impacts are expected to be net positive.

A4. LOCATION

The project encompasses 39 fields located across Sutter, Colusa, and Glenn Counties in California's Sacramento Valley. **Figure 1** shows the locations of the various project counties. Geo-referenced boundaries of the fields will be shared with the third-party verifier to validate; however, these boundaries and shape files will not be provided in the Plan due to the confidentiality of those boundaries.

Sutter County is recognized for having one of the richest soils in the state of California. The county's average high temperature during the summer is 97˚F and an average low temperature during the winter of 39.2˚F. The average annual rainfall is 22 inches, and there is typically no snow.[1] It is one of the counties with access to surface and subsurface water supplies, and this enables an extended growing season. The combination of such conditions makes the county one of the most productive in the state, with approximately 90% of its total land acreage being used for agricultural purposes. Rice has historically been the most common crop in the county, followed by orchards, and row and field crops. There are more than 40 individual soil units found in the county. The most common are capay, clear lake, conejo, oswald, and olashes.[2] In 2010, under the Williamson Act, 65,247 acres were protected as agricultural land. Economic

[1] Information from the Sutter County Climate and Weather Section accessed on July 24, 2015 in www.suttercounty.org

[2] Information from https://co.sutter.ca.us/pdf/cs/ps/gp/documents/eir/06-08_Geo_Seismic_and_Mineral.pdf. Consulted on July 24, 2015.

incentives have been introduced to prevent other developments, mainly due to the high importance of the agricultural sector in the economic development of the county.[3]

Glenn County is divided into two major sections; the eastern side is steeper and is defined as the coast range while the western side is on the Sacramento Valley and has an elevation of approximately 100 feet above sea level. The eastern third of the county is the most important for farmland, where production is predominantly for external consumption, whereas the center of the county produces more for local consumption.[4] The average temperature for the county during the summer is 74˚F, and the average winter temperature is 46˚F. Annually, Glenn has an average precipitation of 23.20 inches and reports an average of 0.53 inches of snow per year.[5] Agriculture continues to be the primary source of economy for the county. There are more than 1,100 farms throughout the county, mainly along the Interstate 5[6], on the basin floor. The main products include prunes, rice, almonds, milk products, and livestock.[7] Colusa County has an average maximum temperature of 74˚F during the summer and an average temperature of 46˚F during the winter. The county's annual average precipitation is 22.26 inches and has on average of 0.38 inches of snow. The eastern side of Colusa is characterized by unique and prime farmland, while the central portion has a special local importance in the agricultural farmland. Overall, 75% of the county is agricultural, and such usage is protected by several policies to protect one of the major sources of its economy.[8] Among its leading farm commodities are rice, almonds, tomatoes, cattle and calves, wine grapes, and sunflower seeds.[9]

[3] Information from Chapter 6.3 Agricultural resources

[4] Information from Chapter 7. Geology, Soils, and Seismicity

[5] Information from webpage http://www.usa.com/glenn-county-ca-weather.htm. Website consulted on July 27, 2015.

[6] Information from website http://www.countyofglenn.net/visitors/. Website consulted on July 27, 2015.

[7] Information from website http://www.countyofglenn.net/visitors/; http://www.countyofglenn.net/govt/departments/ag/documents/2013CropReportpdf.pdf; and http://www.countyofcolusa.org/index.aspx?NID=229. Websites consulted on July 27, 2015

[8] Information from Colusa County General Plan. Chapter 2. Information from website http://www.countyofcolusa.org/DocumentCenter/View/2719. Website consulted on July 27, 2015.

[9] Information from http://www.countyofcolusa.org/DocumentCenter/View/3014. Consulted on July 27, 2015.

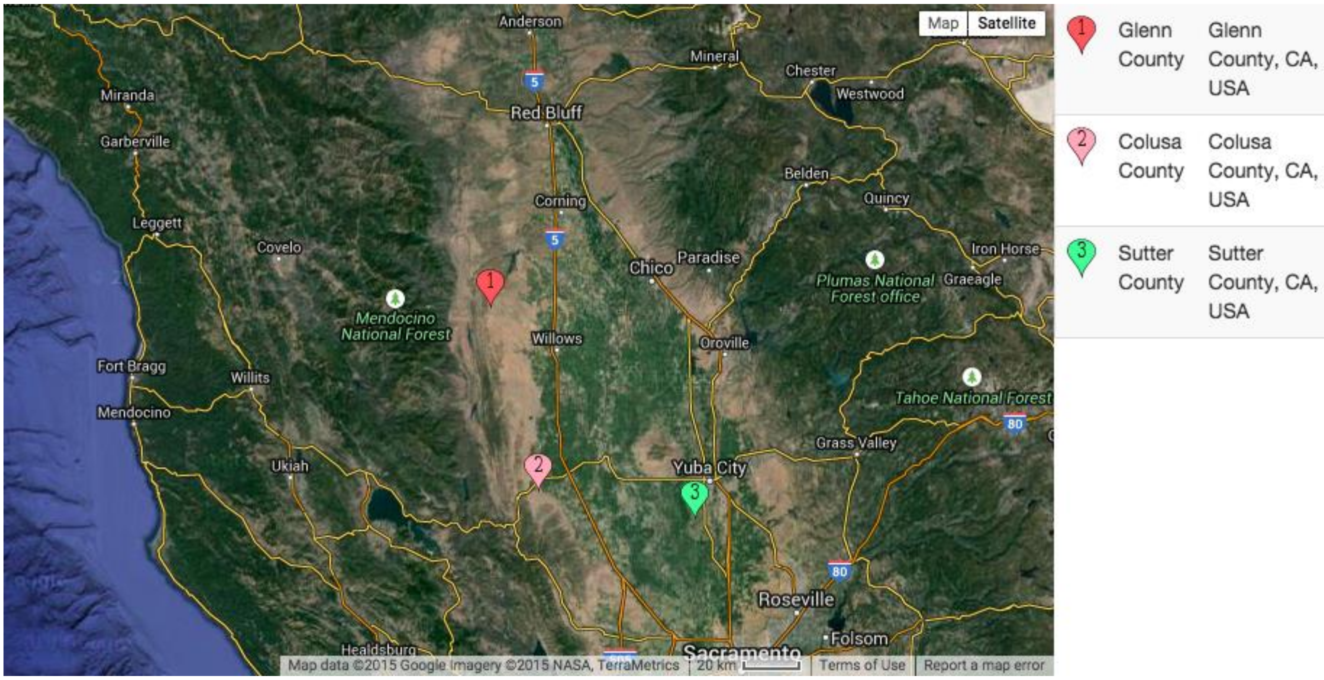


Figure 1. Project Counties

A5. BRIEF SUMMARY OF PROJECT

In California, rice producers have been leaders in adopting new practices and technologies to improve productivity and continue operating sustainability in a changing climate. California is the second largest rice-producing state in the United States, producing rice on approximately 585,000 acres and contributing $774 million to the state's economy. The Project's participating farmers are truly taking an innovative approach to land management, sustainable food systems, and combating climate change.

Terra Global Capital, LLC has been working with Environmental Defense Fund, and the California Rice Commission with funding support from the USDA, to develop high standard protocols, using rigorous science-based models, to account for GHG reductions and lay the groundwork for rice producers to generate GHG offset credits. The GHG emission reductions produced through voluntary changes in rice farming practices may be sold to provide income streams to farmers and encourage lower GHG rice production in California. The reduced GHG emissions produced, as well as the other environmental benefits generated from changes in rice farming practices such as water conservation, will contribute to the long-term sustainability of agricultural practices in the U.S.

The Project aims to support farmers in the changes to rice farming practices that will produce GHG emission reductions and other environmental benefits. This initial group of rice farmers in California is participating in the first validation and verification of the offsets under ACR. The voluntary management practices that will be undertaken by farmers include; early drainage, dry seeding and baling as is relevant and practical for a specific field. Additional management practices may be considered in the future, based on farmer interest and carbon market eligibility. This Project encompasses 4 participating farmers, with

39 unique fields, and 5,389 acres for California. A further goal of the Project is to solicit additional rice farmers in the U.S. to adopt the lower emission management practices and join this program.

A6. PROJECT ACTION

Flooded rice fields are a source of atmospheric methane (CH_4). Flooding results in anaerobic soil conditions, which triggers anaerobic decomposition of organic matter by methanogens, releasing CH_4 as a by-product. The amount of CH4 produced is proportional to the duration of flooding, both during the growing season and outside the growing season during the winter months, is impacted by the rice cultivar and the availability of crop residues and organic matter.

Currently, the most frequently used technique for straw management in California is chopping and/or disking with winter flooding and often times rolling; the second most common technique is chopping and/or disking without winter flooding; and the third is burning in the fall and/or spring for disease control.[10] The University of California Cooperative Extension estimated that by 2007 winter flooding occurred in 60% of the area, incorporation without winter flooding happened in 27%, and rice straw burning was practiced in only 13%. However, before 1990 burning was the most common post-harvest straw management technique. It was only after 1991 that the practice was abandoned and left, mainly for disease control purposes. Approximately 3 to 5% of the rice acreage has straw baled to be used afterwards for different purposes.[11]

This project enables the proponent to voluntarily generate CH_4 emission reductions by (1) removing rice straw from the field after harvest and before winter flooding, (2) replacing water seeding with dry seeding, and (3) draining water off the field earlier at the end of the growing season. Reducing winter flooding acreage in the California Rice Growing Region cannot be used for crediting under this version of the module. The definitions for each of the project activities, consistent with the approved methodology, are provided below.

Straw baling and Removal – Rice straw residue resulting from harvest is typically left on agricultural fields. However, rice straw can be removed by baling. Baled straw can be sold, though the market is small. Rice straw can be used for erosion control, animal bedding, as an alternative feed for cow and calf producers or for other uses.

Dry seeding – A seeding method that involves broadcasting or drilling dry seeds into dry or moist, non-puddled soil. Dry seeding often allows for quicker land preparation and reduces the irrigation water required for crop establishment. Dry seeding can occur through spreading seeds onto the soil surface and transferring soil on top of the seeds or by drilling seeds into a prepared seedbed, a practice known as “drill seeding”. Alternatively, seeding normally occurs by distributing seeds on inundated fields using small airplanes, a practice known as “water seeding” or “wet seeding”.

[10] University of California Cooperative Extension. 2007. Sample Costs to Produce Rice, Sacramento Valley, Rice Only Rotation. Available online at http://coststudies.ucdavis.edu/en/current/
[11] California Rice Commission. 2009. Environmental and conservation balance sheet for the California rice industry. Available online at http://calrice.thewebhounds.com/Environment/Balance+Sheet/Chapter+4+-+Air+Quality.htm

Early drainage - Early Drainage is defined as terminating water applications and draining a field at least 5 days earlier than the drainage date under conventional management ("Conventional Drainage Date"). Since there is not one single procedure to determine the Conventional Drainage Date that is used by all producers across all Rice Growing Regions, the procedure to set the Conventional Drainage Date as used by a specific participating grower shall be recorded in the GHG project plan.

An overview of the participating growers and the level of project activity adoption is provided below in **Table 1. Summary of Project Activities**.

Table 1. Summary of Project Activities

Producer	Number of Fields	Total Acres	Project Activities		
			Straw Baling	Early Drainage	Dry Seeding
Producer 1	26	3,833			X
Producer 2	4	333	X		
Producer 3	6	1,055	X	X	
Producer 4	3	168	X	X	
Total:	**39**	**5,389**			

A7. *EX ANTE* OFFSET PROJECTION

The total projected GHG emission reductions are estimated at 5,445 tons of CO_2e over the five years included in this crediting period. This estimate was based on the literature and is further described in Section E6. EX-ANTE ESTIMATION METHODS. In addition, a spreadsheet entitled GHG Estimate for GHG Project Plan is sent to the VVB to demonstrate how the calculation was completed. Please see Table 2 for the full breakdown of GHG emissions reductions on a yearly basis and on a Project Activity basis.

Table 2. Estimated Emission Reductions for Project Activities on a Yearly Basis

		Project Activity						
		Straw Baling		Early Drain		Dry Seeding		Total Project Reductions (tCO2eq)
Project Year	Year	Acres	GHG Emission Reductions (tCO2eq)	Acres	GHG Emission Reductions (tCO2eq)	Acres	GHG Emission Reductions (tCO2eq)	
1	2012	1,556	93.36	1055	63.3	3,833	958.25	1,114.9
2	2013	366	21.96	89	5.34	3,833	958.25	985.6
3	2014	1,556	93.36	1,055	63.3	3,833	958.25	1,114.9
4	2015	1,556	93.36	1,055	63.3	3,833	958.25	1,114.9
5	2016	1,556	93.36	1,055	63.3	3,833	958.25	1,114.9
							Total:	5,445.2

A8. PARTIES

The project proponent retains full responsibility for planning, implementing and maintaining the Emission Reductions in California Rice Management Systems Project. Main contact for the Project Proponent is:

Leslie L. Durschinger
Founder, Managing Director
Terra Global Capital
220 Montgomery Street, Suite 608
San Francisco, CA 94104
1.415.400.4491

Participating Growers identity are confidential but full contact information will be shared with the third party verifier.

Other partners:

Robert Parkhurst
Agriculture Greenhouse Gas Markets Director
Environmental Defense Fund
123 Mission Street
San Francisco, CA 94105

Paul Buttner
Manager of Environmental Affairs
California Rice Commission
1231 I Street, Suite 205
Sacramento, CA 95814

Randall Mutters
County Director, Farm Advisor
Cooperative Extension Butte County
2279-B Del Oro Avenue
Oroville, CA 95965

B.
Methodology

B1. APPROVED METHODOLOGY

This project uses the methodology *Voluntary Emission Reductions in Rice Management Systems version 1.0* approved May 2013 and *Voluntary Emission Reductions in Rice Management Systems – California Module version 1.0* approved May 2013 (located at: http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems).

B2. METHODOLOGY JUSTIFICATION

This methodology was chosen and followed given the agricultural crop grown and associated land use, and the Project Region. The project takes place on the California Sacramento and San Joaquin Valley Rice Growing Region where rice has been historically grown.

B3. PROJECT BOUNDARIES

The Project Region is defined as the California Rice Growing Region, which includes the Sacramento and San Joaquin Valleys. The project area for this crediting report is limited to three counties within this rice growing region: Sutter, Colusa, and Glenn Counties (see A4. LOCATION). This project includes 39 individual rice fields and each field boundary is included in the project boundary for where the primary emission reductions are being generated. Exact field boundaries provided in kml are available for the Validation/Verification Body (VVB). In order to protect individual farmer privacy, these geographic coordinates will remain confidential and will not be made available in this public document.

Each field is considered a separate strata, as defined in the methodology, and is considered a separate unit to the grower. A field is defined as a contiguous parcel of land with homogeneous irrigation management for the historical years. At the end of the five growing seasons the crediting period can be renewed with an updated baseline conformant to the requirements of the methodology in *Section 12.4 Project Renewal and Baseline Update.*

B4. IDENTIFICATION OF GHG SOURCES AND SINKS

Per the methodology, the Project modeled and accounted for all GHG sources that are likely to result in a significant increase in GHG emission or decreased carbon storage in the baseline scenario relative to the project scenario on all Participant Fields.

The GHG sources included in both the baseline scenario and project scenario include CO_2, CH_4 and N_2O resulting from soil microbial activity related to metabolizing soil carbon, root exudates, and soil mineral nitrogen. It is expected that the project activity of straw baling can result in significant changes in CO_2 emissions due to the removal of biomass from the field after harvest. In addition, flooded rice fields are a significant source of CH_4 which must be included in this project. Finally, N_2O is a significant source related to fertilizer application, which can vary based on project activities and must therefore be accounted for. The other major GHG source for both the baseline and project scenarios is from straw burning which results in a significant source of CO_2 and CH_4 if straw is burned.

Other sources of GHG emissions related specifically to the project scenario include alternative uses of straw and increased production and transportation of N, P and K fertilizer. When straw baling is adopted as a project activity and is then used for a variety of applications, it can result in increased CO_2 for the fuel used to collect the straw and increased CH_4 if the rice straw decomposes anaerobically. It is not anticipated that the use or decomposition of rice straw will result in a significant source of N_2O. Also related to the project activity of straw baling, fertilizer application may be increased to replenish soil nutrients lost through straw removal thereby contributing significant amounts of CO_2, CH_4 and N_2O.

B5. BASELINE

The Baseline Scenario in this project is developed on an individual field basis. The Baseline Scenario represents what would have occurred on the field had the Project Activities not been adopted. Per the methodology, only a Baseline Scenario with agricultural land uses can be accepted, conversion to non-agricultural land use is not allowed as a Baseline Scenario.

Two possible methods for determining the Baseline Scenario are provided in the methodology with a specific set of requirements for each option. If the implemented Project Activity has an adoption rate less than or equal to 5% of the rice acres in that specific Rice Grower Region, then a Common Practice Baseline may be used and that activity is automatically additional, given that the practice exceeds legal/regulatory requirements applicable for that rice field. Fields which implement a Project Activity with an adoption rate greater than 5% of the rice acres in that specific Rice Growing Region must use a Field-Specific Baseline and must demonstrate additionality (please see section C. ADDITIONALITY below).

Per the California Module, it was determined through discussions with industry experts (expert opinion) that the Project Activity of straw baling has an average adoption of 4% of the California rice acres per year. As well, the adoption of dry seeding in California is estimated to be less than 4%. Based on the above information both straw baling and dry seeding have an adoption rate of less than 5% and can use the Common Practice Baseline. Whereas early drain has an adoption of more than 5% in the California Rice Growing Region and a Field-Specific Baseline must be used when this practice is adopted on a field.

For each of the fields in the project a baseline type was chosen conformant to the requirements of the methodology, as shown in Table 3 below.

Table 3: List of Fields Activity and Baseline

Field	Project Activity 2012	Project Activity 2013	Applicable Baseline
1-1	Dry Seeding	Dry Seeding	Common Practice Baseline
1-2	Dry Seeding	Dry Seeding	Common Practice Baseline
1-3	Dry Seeding	Dry Seeding	Common Practice Baseline
1-4	Dry Seeding	Dry Seeding	Common Practice Baseline
1-5	Dry Seeding	Dry Seeding	Common Practice Baseline
1-6	Dry Seeding	Dry Seeding	Common Practice Baseline
1-7	Dry Seeding	Dry Seeding	Common Practice Baseline
1-8	Dry Seeding	Dry Seeding	Common Practice Baseline
1-9	Dry Seeding	Dry Seeding	Common Practice Baseline
1-10	Dry Seeding	Dry Seeding	Common Practice Baseline

Field	Project Activity 2012	Project Activity 2013	Applicable Baseline
1-11	Dry Seeding	Dry Seeding	Common Practice Baseline
1-12	Dry Seeding	Dry Seeding	Common Practice Baseline
1-13	Dry Seeding	Dry Seeding	Common Practice Baseline
1-14	Dry Seeding	Dry Seeding	Common Practice Baseline
1-15	Dry Seeding	Dry Seeding	Common Practice Baseline
1-16	Dry Seeding	Dry Seeding	Common Practice Baseline
1-17	Dry Seeding	Dry Seeding	Common Practice Baseline
1-18	Dry Seeding	Dry Seeding	Common Practice Baseline
1-19	Dry Seeding	Dry Seeding	Common Practice Baseline
1-20	Dry Seeding	Dry Seeding	Common Practice Baseline
1-21	Dry Seeding	Dry Seeding	Common Practice Baseline
1-22	Dry Seeding	Dry Seeding	Common Practice Baseline
1-23	Dry Seeding	Dry Seeding	Common Practice Baseline
1-24	Dry Seeding	Dry Seeding	Common Practice Baseline
1-25	Dry Seeding	Dry Seeding	Common Practice Baseline
1-26	Dry Seeding	Dry Seeding	Common Practice Baseline
2-1	Straw Baling	Straw Baling	Common Practice Baseline
2-2	Straw Baling	Straw Baling	Common Practice Baseline
2-3	Straw Baling	N/A	Common Practice Baseline
2-4	Straw Baling	Straw Baling	Common Practice Baseline
3-1	Straw Baling & Early Drain	N/A	Common Practice Baseline[12] for straw baling and Field-Specific for Early Drain
3-2	Straw Baling & Early Drain	N/A	Common Practice Baseline for straw baling and Field-Specific for Early Drain
3-3	Straw Baling & Early Drain	N/A	Common Practice Baseline for straw baling and Field-Specific for Early Drain
3-4	Straw Baling & Early Drain	N/A	Common Practice Baseline for straw baling and Field-Specific for Early Drain
3-5	Straw Baling & Early Drain	N/A	Common Practice Baseline for straw baling and Field-Specific for Early Drain
3-6	Straw Baling & Early Drain	N/A	Common Practice Baseline for straw baling and Field-Specific for Early Drain
4-1	Straw Baling	Straw Baling & Early Drain	Common Practice Baseline for straw baling and Field-Specific for Early Drain
4-2	Straw Baling	Straw Baling	Common Practice Baseline
4-3	Straw Baling	Straw Baling	Common Practice Baseline

Further details regarding the management parameters included in the DNDC model are discussed in E1. BASELINE.

[12] It is stated in the methodology Section 6.1 that for rice fields on which multiple Project Activities are implemented simultaneously, the Baseline Scenario may be partly Common Practice and partly Field-Specific

B6. PROJECT SCENARIO

The project scenario reflects the adoption of project activities on Participant Fields. As described in A6. PROJECT ACTION, the eligible Project Activities that result in emission reductions from flooded rice production are straw baling and removal, dry seeding and early drainage. Please see Table 3: List of Fields Activity and Baseline for a list of Project Activities on a per field basis.

B7. REDUCTIONS AND ENHANCED REMOVALS

Atmospheric methane (CH_4) is produced in rice fields due to the microbial decomposition of organic matter by methanogens. This happens when the fields are flooded and the methanogens, a class of soil bacteria, start the decomposition of the matter under the anaerobic conditions in the soils once the oxygen in the soil pores is depleted. The organic matter decomposed originates from organic amendments, plant residues, or root exudates. Because the anaerobic process starts once oxygen is depleted, the amount of CH_4 emitted will be proportional to how long the fields have been flooded and will vary based on the rice cultivar and the availability of crop residues and organic matter.

This project intends to reduce CH_4 emissions through the implementation of the Project Activities, including the removal of rice straw after harvest, early drain, and/or dry seeding. The removal of rice straw after harvest can limit the CH_4 produced by limiting the amount of organic matter available for decomposition. Draining the field at least 5 days before a conventional date reduces the number of days that the soil is in anaerobic conditions, thereby resulting in lower CH_4 emissions.[13] Dry seeding provides an opportunity to delay flooded conditions on the field, thereby again reducing the total amount of time the soil is under anaerobic conditions.

All emission reductions with respect to the calculating net GHG is further discussed in E5. REDUCTIONS AND REMOVAL ENHANCEMENTS.

B8. PERMANENCE

Emission reductions achieved through this project are on a yearly basis, dependent on the practices adopted in a given year and using field specific agronomic data in the quantification methodology. These emission reductions from changes in rice management in a given year are permanent and cannot be reversed, regardless of future changes in management. For this reason there is no risk of reversal and is not accounted for.

[13] Champagne, E.T., Bett-Garber, K.L, Thompson, J., Mutters, R., Grimm, C.C., McClung, A.M. 2005. Effects of Drain and Harvest Dates on Rice Sensory and Physicochemical Properties. Cereal Chemistry Journal. 82(4):369-374.

C.
ADDITIONALITY

The Project Activities of straw removal after harvest and dry seeding pass the approved performance standard proposed in the California Module and all Project Activities pass the Regulatory Surplus Test. The three-pronged test to demonstrate additionality will be completed for the Project Activity of early drain alone.

C1. REGULTORY SURPLUS TEST

The Emission Reductions in California Rice Management Systems Project encourages the voluntary adoption of Project Activities such as straw baling, early drain and dry seeding to reduce CH_4 production on flooded rice fields in the California Rice Growing Region. At the time of the Grower Agreements for the participating fields in this project, no mandates or legal restrictions were in place on these lands that hindered or removed the right for an individual to adopt these voluntary management practices on their fields. In addition, at this time there is no existing law, regulation, statute, legal ruling, or other regulatory framework in effect requiring any of the Project Activities or its associated GHG emissions reductions to be implemented on the participating fields.

California introduced The Connelly-Areias-Chandler Rice Straw Burning Reduction Act in 1991, mandating the phase out of rice straw burning in the Sacramento Valley. Starting in 2001 a permitting system that regulates the magnitude and frequency of rice straw burning was implemented. Any participating growers who do perform straw burning in the practice years received the appropriate permit and followed the permit guidelines on field.

C2. COMMON PRACTICE TEST

Rice producers in the California growing region must drain their fields in preparation for harvest. Soils must be completely drained in order to accommodate the heavy harvesting equipment, preventing deep ruts in the soil and/or cause the equipment to get stuck in mud. Mud during harvest not only decreases efficiency, it may cause serious damage to valuable equipment and ruts the field. However, drain date can impact the quality and yield of the rice crop. Determining a drain date must be done on an individual field and is dependent on the following; a) soil characteristics, such as clay content and water draining capacity, b) the rice cultivar grown which dictates the rate of maturity, and c) the weather conditions of the growing season and drain period such as high temperature and north winds which can increase evapotranspiration and impact crop maturity.[14] Specifically in California, rice is typically harvested at <24% average moisture content of the grains on the panicles, usually in the 18-21% range. Therefore, field drainage is timed, based on the number of days required to drain the field, in order to harvest the crop while it is in the 18-21% range of moisture content of the grains on the panicles.

Research conducted in California demonstrates common medium grain varietals are resilient to drain dates 5 or more days earlier to conventional drain dates based on the date for 50% heading.[15] Yields for

[14] Water Management. 2009.University of California Rice On-line. Accessed online: http://ucanr.edu/sites/RiceTestSite/files/196582.pdf.
[15] Mutters, R.G.; Thompson, J.F. (2009). Rice Quality Handbook. University of California, Agriculture and Natural Resources. Publication No. 3514: 141.

all tested varieties were unaffected by the drain dates later than 10 to 14 days after 50 percent heading. Based on some of these field tested findings, draining 5 or more days earlier than a conventionally derived date has the potential to yield the same quality and quantity of grain. In addition, an early drain date also has the potential to reduce CH_4 production by reducing the number of days the field is in flooded, anaerobic conditions.

Through communications with Dr. Randall Mutters, County Director, Farm Advisor for Cooperative Extension Butte County, it is estimated for Butte County that on approximately 5-7% acres for which rice is grown early drain is adopted. While Butte County is not one of the counties included in this project, it is a county in the California Rice Growing Region and shares similar characteristics and culture as the other counties in the region, and can therefore be seen as representative of the region. At this time no surveys or research has been conducted to indicate a more concrete adoption rate for early drain. This approximation indicates that the practice is not widely adopted in the region. By definition, this practice is beyond what is typically done on rice producing fields on this region, since it requires draining 5 or more days before a conventional drain date for the field and region. It is believed that producers view this activity as risky due to the conventional belief that draining early can reduce production quality and quantity. As early drain is determined on a field basis and compared to a conventional drain date for that specific field, it can be seen as additional to business as usual.

C3. IMPLEMENTATION BARRIERS TEST

Institutional Barrier:

Rice producers in the California Region set drain date on a field basis, dependent on a variety of factors including soil type, rice variety planted and weather conditions. Extension agencies and common rice growing educational materials recommend and promote keeping water on the field as close to harvest as possible due to the risks to crop production quality and quantity.[16] One example comes directly from the University of California Rice On-line, which is made up of an interdisciplinary team consisting of UC Cooperative Extension specialists, faculty and farm advisors with the goal of providing rice growers with up-to-date guidelines and information on rice production in California. In their Water Management guide it is stated that "As important as making sure the ground is dry enough to support equipment is to make sure it is moist enough to finish the crop. Premature drainage will impede ripening and result in more chalk and light kernels. In addition, research has shown that milling quality is improved if the water is left on longer, including up to the time of harvest. Since harvesting in the water is not a practical option, the grower has to decide when to drain to optimize ripening." These messages encourage producers to delay drain date or plan for a drain date that results in the ground just being dry enough for harvesting machinery. The environmental benefits of draining 5 or more days earlier and the limited impact on yield and grain quality are not well understood and not included in producer extension or education. This lack of understanding and promotion at the extension level will limit the adoption of early drain by rice producers. In addition, early drain will face continued resistance from growers due to fear of lower grain

[16] Water Management. 2009. University of California Rice On-line. Accessed online: http://ucanr.edu/sites/RiceTestSite/files/196582.pdf.

quality, the risk of reducing the quality of production may outweigh any environmental benefits of the practice even when research shows that early drain does not impact yield quality for the varietals currently produced.

C4. PERFORMANCE STANDARD TEST

In accordance with the methodology, the California Module and ACR Standard v 4.0, all of the fields referred to in Table 3: List of Fields Activity and Baseline in B5. BASELINE, which meet the requirements of the Common Practice Baseline Scenario of implementing a Project Activity that has an adoption rate less than or equal to 5% of the rice acres in the Rice Growing Region are automatically additional, given that the practices exceed legal/regulatory requirements. As shown below in C1. REGULTORY SURPLUS TEST all of the Project Activities presented in this project pass the regulatory surplus test. For that reason, all fields which implemented removal of straw after harvest and/or dry seeding are automatically additional and do not need to pass a three-pronged test to demonstrate that the project activity is additional.

D.
MONITORING PLAN

D1. MONITORED DATA AND PARAMETERS

The following tables list the parameters to be monitored in the project according to the requirements given by the methodology. For all field specific management information, the individual farmer is responsible for monitoring and maintaining records. The aggregator will be responsible for all non-field management data (ie climate data) and organizing the information for the VVB.

Data or Parameter Monitored	Climate Data
Unit of Measurement	DNDC compatible climate data file
Description	Daily meteorological data files(s) in the plain text (i.e., ASCII) format for each year. Data files are written in format readable in the DNDC model.
Data Source	Weather Station
Measurement Methodology	If the project area is located in California, it is recommended to use weather data from the nearest CIMIS weather station (http://wwwcimis.water.ca.gov). National Climate Data Center (www.ncdc.noaa.gov/oa/ndcd.html) is another source of climatic data that can be used.
Data Uncertainty	Low level of uncertainty
Monitoring Frequency	Daily
Reporting Procedure	Source of the data shall be provided to the VVB so that the data can be independently retrieved by the VVB and compared to the data submitted at verification
QA/QC Procedure	Daily climate data must come from a weather station that is located maximally 50 miles away.
Notes	

Data or Parameter Monitored	Plant Time
Unit of Measurement	Date
Description	Planting month and day. A number from 1 – 12 for month; and a number from 1 to 31 for day.
Data Source	Agricultural statistical records, farmer records, or remote sensing procedures.
Measurement Methodology	
Data Uncertainty	The methodology states that if uncertainty is present in the data unit/parameter, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the Model Parameters; however Plant Time or Plant Date is not an input parameter that can be selected for the Monte Carlo Test in the DNDC Model.
Monitoring Frequency	Annually
Reporting Procedure	Interview with farmer and receipt from plane rental for planting if wet seeded field. This is a methodology deviation.
QA/QC Procedure	
Notes	

Data or Parameter Monitored	Harvest_time
Unit of Measurement	Date
Description	Harvesting month and day. A number from 1 – 12 for month; and a number from 1 to 31 for day.
Data Source	Agricultural statistical records, farmer records, or remote sensing procedures.
Measurement Methodology	
Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	Geo-tagged picture within 3 weeks after harvesting OR date-stamped receipt from the mill occurring within 2 weeks after the harvest date indicated in the Monitoring Report OR any other receipt or contractual information indicating the harvesting date
QA/QC Procedure	Please see the note above for Plant_time, this data parameter is not included as an option in the DNDC Monte Carlo Test.
Notes	

Data or Parameter Monitored	Yield
Unit of Measurement	t DM ha-1
Description	Crop productivity (i.e. rice productivity for rice) in the growing season
Data Source	Agricultural statistical records or farmer records.
Measurement Methodology	
Data Uncertainty	
Monitoring Frequency	Annually or per growing season.
Reporting Procedure	Signed affidavit of farmer OR interview with farmer by VVB OR date-stamped receipt from the mill indicating yield OR yield information on any other contract
QA/QC Procedure	
Notes	

Data or Parameter Monitored	Tilling Date/Period and Method
Unit of Measurement	Date -
Description	Date of tilling event. In case multiple tillage events are done throughout a period (e.g., for post-harvest straw residue management), it suffices to provide the dates of the first and last tillage events. Tilling method is to be provided as one of the following four methods: a. No-till (i.e., only mulching) (0 cm) b. Plowing slightly (5 cm) c. Plowing with disk or chisel (10 cm) d. Deep plowing (30 cm)
Data Source	Agricultural statistical records or farmer records.
Measurement Methodology	

Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	Signed affidavit of farmer OR interview with farmer by VVB
QA/QC Procedure	
Notes	

Data or Parameter Monitored	Fertilizer Date, Amount and Composition
Unit of Measurement	Date, kg N ha-1
Description	Date of fertilizer application, amount of fertilizer applied and chemical composition of fertilizer
Data Source	Agricultural statistical records or farmer records.
Measurement Methodology	
Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	Signed affidavit of farmer OR interview with farmer by VVB
QA/QC Procedure	
Notes	

Data or Parameter Monitored	CRHyi the amount of Crop Residue harvested in year y for individual Rice Field (optional – see comment below)
Unit of Measurement	t dry straw ha-1
Description	The amount of dry Crop Residue harvested and removed from the field through baling or any other means in year y for individual Rice Field
Data Source	Field measurement.
Measurement Methodology	Measure directly during baling or harvesting of the straw. Make sure to correct for any residual moisture content of the straw
Data Uncertainty	
Monitoring Frequency	Annually, any time baling occurs as part of a project activity
Reporting Procedure	Logging of baling equipment OR notes, contract, or agreement from or with baler or end-user of rice straw OR interview with baler or end-user of straw if contact information is provided
QA/QC Procedure	
Notes	The CRHyi parameter is not required to be monitored on the condition that fRHyi is provided. Specifically, crop residues can either be measured directly, as specified in this parameter, or may be calculated using equation [EQ 5]. In the latter case, fRHyi must be monitored or provided

Data or Parameter Monitored	fRHyi fraction of residue left after harvest (optional – see comment below)
Unit of Measurement	fraction
Description	A fraction of the above-ground crop residue left as stubble in the field after harvest for field i and year y.
Data Source	Field Measurement
Measurement Methodology	Measure either directly, or estimate using the cutter height used during harvesting using the relationship between cutter height and straw yield in Summers et al. (2001): [straw yield - % of maximum] = -2.95 * [cutter height - in] + 94.8 For example, if the cutter height was set to 4 in, the straw yield as a % of maximum is 83%, and the percentage left after harvest is 17%.
Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	Geotagged picture of stubble height OR contract with baler or end-user indicating end use of straw OR interview with baler or end-user of straw if contact information is provided
QA/QC Procedure	
Notes	This parameter is not to be monitored or provided when CRHyi is monitored. A default fraction of 0.10 for fRHyi may be used.

Data or Parameter Monitored	Flooding and Draining Dates
Unit of Measurement	Date
Description	Start and end dates for flooding and draining in Rice Fields. Dates shall be given in month and day combination. If start and end dates fall in different years, then year must also be provided.
Data Source	Agricultural statistical records, farmer records, or remote sensing procedures.
Measurement Methodology	
Data Uncertainty	The methodology states that if there is uncertainty in the data to include it in Monte Carlo, however, Flooding and Draining Dates are not included parameters when doing the Monte Carlo test on DNDC
Monitoring Frequency	Annually
Reporting Procedure	Geotagged pictures taken of field or pulled boards within one week of date provided in Monitoring Report OR remote sensing imagery within 2 weeks of dates provided in Monitoring Report OR observations from farm advisers OR records, observations, or interviews with the water districts confirming that no more water was required within 1 week of the date provided in the Monitoring Report Methodology deviation: Signed affidavit of farmer OR interview with farmer by VVB
QA/QC Procedure	
Notes	

Data or Parameter Monitored	End use of baled straw
Unit of Measurement	
Description	The end use for rice straw. Select from the following: a. Dairy replacement heifer feed b. Beef cattle feed c. Animal bedding d. Spread out on bare soils as erosion control e. Stuffed in netted rolls to prevent soil loss f. Mushroom production g. Fiberboard manufacturing h. None of the above. Describe end-use
Data Source	Farmer records
Measurement Methodology	
Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	Contact information of baler or end-user of straw shall be provided so that baler or end-user of straw can be contacted to verify end-use of straw.
QA/QC Procedure	
Notes	

Data or Parameter Monitored	Date of straw burning event
Unit of Measurement	Date
Description	The date of a burned event used for post-harvest straw management
Data Source	Farmer records
Measurement Methodology	
Data Uncertainty	
Monitoring Frequency	Annually
Reporting Procedure	
QA/QC Procedure	
Notes	

E.
QUANTIFICATION

E1. BASELINE

Per the methodology, the calculation of GHG emissions under both the Baseline and Project Scenarios must be evaluated using the DNDC model. This biogeochemical model can simulate carbon and nitrogen dynamics in agro-ecosystems and can be used to predict crop growth, soil carbon dynamics, nitrogen leaching and emissions from GHG including nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO2)[17]. In order for the model to predict GHG emissions from rice systems, it must first be calibrated for the local conditions; this is accomplished through the Regional Model Calibration step & Field-specific Model Calibration Step.

The steps for quantifying all relevant emissions or removals for the baseline scenario are as follows:

1) Identify critical and non-critical parameters
2) Calibrate the model
3) Create model simulation
4) Emission reduction calculations

The California Module v1 represents the Regional Calibration Module specific for the California Rice Growing Region. Within it includes the identification of all critical and non-critical management parameters for each of the Project Activities eligible in California, as shown in Table 4 below.

Table 4: List of Critical (C) and Non Critical (NC) Management Parameters for Project Activities for California Rice Growing Region

Management Parameter	Project Activity		
	Removal of Straw after Harvest	Dry Seeding	Early Drainage
Harvesting date	NC	NC	C
Fraction of residues left after harvest	C	NC	NC
Crop residue management (tillage) date	C	NC	NC
Crop residue management (tillage) method	C	NC	NC
Crop residue burning date (if burning was present)	C	NC	NC
Frequency of winter flooding	C	NC	NC
Start Date of the winter flooding period (if any)	C	NC	NC
End Date of the winter flooding period (if any)	C	NC	NC
Spring fertilization amount	C	C	NC
Spring fertilization date	C	C	NC
Spring fertilization application method	C	C	NC
Pre-plant field preparation (tillage) date	NC	C	NC
Pre-plant field preparation (tillage) method	NC	C	NC

[17] Li, C., 2000. Modeling trace gas 1312 emissions from agricultural ecosystems. Nutrient Cycling in Agroecosystems 58, 259–276.

Management Parameter	Project Activity		
	Removal of Straw after Harvest	Dry Seeding	Early Drainage
Planting date	NC	C	NC
Flooding date	NC	NC	NC
Fertilization amount during growing season	C	NC	NC
Fertilization date during growing season	C	NC	NC
Fertilization application method during growing season	C	NC	NC
Draining date	NC	NC	C

Critical management parameters are those used in the DNDC model that are directly or indirectly impacted by the Project Activities, whereas the Non-critical parameters are modeled agronomic parameters that are not influenced by the Project Activities.

The application of a Field-specific Baseline scenario compared to a Common Practice Baseline will impact the actual values used for Critical and Non-Critical parameters for the baseline scenario. When using the field specific baseline, the Critical Management Parameters are set to the values of the management during at least three out of five years preceding the Project Start Date, if rice was only grown in two out of the five years then that is sufficient. For the Common Practice Baseline the Critical Management Parameters are set to the actual management from at least 5 fields within the same rice growing region on which the common practice management is done. The management data was reviewed by 3 independent peer reviewers such as farm advisors, extension agents or academic scientists. The contact information for these reviewers will be provided to the VVB.

The critical management parameters are fixed Ex-ante and used for all the Ex-post baseline calculations. The Non-Critical Parameters of the Ex-post calculations for Common Practice and Field-specific baselines are set to the actual values monitored during the period being reported and verified.

Once the various management parameters, based on the Project Activity and Baseline Scenario, are determined they are entered into the DNDC model along with weather and soil data. The weather data originates from a weather station within 50 miles from the field location. In this project, soil data was not available from individual field testing, for that reason soil data was accessed through SSURGO, as specified through the methodology in Section *7.3.2 Soil Data.*

Prior to running DNDC model for the Baseline Scenario, the DNDC model must first be calibrated on a field level. For this step the 3 years of historical field data, or 2 years if rice was only grown for 2 out of the five years, is run through the model and actual field yield and modeled yield are compared. Following the steps described in Section 7.4.2 Field-specific Model Calibration, the model is tuned to predict the recorded yields for those historical years before the start of the project with a maximal relative Root Mean Squared Error (RMSE) of 10% of the observed means.

Once field calibration is achieved the Baseline Scenario, including a 20 year historical period, is run through the DNDC model. The historical period is used to equilibrate the DNDC model in certain variables such as the sizes and the quality of the different carbon pools, and the inorganic nitrogen contents of soil pore water. The 20-year Historical Period is set by using the management parameters of at least three out of five years before the start of the Crediting Period, unless only two years of data are available, and repeating the five years four times to create the full 20-year Historical Period. To see the full list of parameters included in the DNDC model please see Appendix A for the template .dnd input file specific to the California Module.

For each rice field, separate Baseline Scenario model simulations are conducted. Using the DNDC model results the following emissions equation is applied (conformant to EQ3 of the protocol).

$$BE_{yi} = \frac{44}{12} * [CO2 - C]baseline, y, i + 310 * \frac{44}{28} * [N2O - N]_{baseline,y,i} + 21 * \frac{16}{12} * [CH4 - C]_{baseline,y,i}$$

Where:
BE_{yi} = Baseline emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1} yr^{-1}]
$[CO2 - C]baseline, y, i$ = Baseline carbon dioxide flux rate from changes in SOC content in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]
$[N2O - N]_{baseline,y,i}$= Baseline nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha^{-1}]
$[CH4 - C]_{baseline,y,i}$ = Baseline CH_4 flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

E2. PROJECT SCENARIO

As stated in the section above, E1. BASELINE, the Project emissions of CO_2, CH4 and N_2O are determined based on the DNDC model. Each individual rice field has a separate model simulation for the Project scenario and the related input parameter file for the DNDC model (.dnd file) will be provided to the VVB. For the Project scenario, the DNDC model will already have been calibrated for field conditions in the Baseline Quantification and would not need to be repeated.

The steps for quantifying all relevant emissions or removals for the Project scenario are as follows:

1) Identify critical and non-critical parameters
2) Create model simulation
3) Emission reduction calculations

Similarly to the Baseline scenario, the Critical and Non-Critical Management Parameters are determined based on the Project Activity implemented on the individual field and year. Please see Table 4 for the full list of Critical and Non-Critical Parameters for the Project Activities specific for the California Rice Growing Regions, as stated in the California Module.

All Critical and Non-Critical Management Parameters for the 20-year Historical Period for the Project scenario simulations must be identical to the Model Parameters for the Historical Period for the Baseline Scenario, except for Projects that are using a Common Practice Baseline. Projects that are using a Common Practice Baseline use the historical field-specific management for the Historical Period for the Ex-ante Project scenario simulation. After the start of the Crediting Period, only the Critical Management Parameters are allowed to be different between the Baseline and Project scenarios. For Ex-post Project scenario calculations, values for the Critical Management Parameters must be set using farming records and empirical data of the Project Activities actually implemented.

The weather data for all Baseline and Project scenarios are accessed through the closest weather station within 50 miles of the individual field. For the 20-year Historical Period the weather data corresponding to the five years of field management data are repeated four times to fill out the 20-year period. For all ex-post Baseline and Project scenarios the actual weather data for the Project years must be used. As well, the same soil data used in the Baseline scenario are used for the Project scenario for an individual field.

For each rice field, separate Project Scenario model simulations are conducted. Using the DNDC model results the following emissions equation is applied (conformant to EQ4 of the protocol).

$$PE_{yi} = \frac{44}{12} * [CO2 - C]_{project,y,i} + 310 * \frac{44}{28} * [N2O - N]_{project,y,i} + 21 * \frac{16}{12} * [CH4 - C]_{project,y,i}$$

Where:
PE_{yi} = Project emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1} yr^{-1}]
$[CO2 - C]_{project,y,i}$ = Project carbon dioxide flux rate from changes in SOC content in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]
$[N2O - N]_{project,y,i}$= Project nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha^{-1}]
$[CH4 - C]_{project,y,i}$ = Project CH_4 flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

Project Specific Calculations

When the Project Activity of straw baling and removal is implemented on a field, the end uses for rice straw must be explicitly identified so that any potential increase in emissions due to the removal and subsequent end use of rice straw can be accounted for. Baling rice straw potentially increases emissions during swathing, raking or baling operations, but will reduce emissions related to the avoidance of post-harvest chopping and disking. In addition, depending on the end-use of the baled straw, additional off-field emissions potentially occur. For this project, the default emission factors found in Table 6 of the methodology were used corresponding to the actual end up of the baled straw for each field and for each year. The end use options were: dairy replacement heifer feed, beef cattle feed, animal bedding, spread out on base soils as erosion control, stuffed in netted rolls to prevent soil loss, mushroom production, use in fiberboard manufacturing. The resulting emission factor, OFEF (Off-field Emission Factor) was applied to the full emission reduction calculation, further discussed in E5. REDUCTIONS AND REMOVAL ENHANCEMENTS. OFEF is relative to CRH_{yi}, the amount of Crop Residue harvested in year y for individual field in units of dry straw ha^{-1}. Specific for this Project, the CRH_{yi}, was calculated using the following equation:

$$CRH_{y,i} = \frac{1}{0.4} * \frac{1}{1000} * CRP_{y,i} * f_{RHyi}$$

Where:
$CRH_{y,i}$ = Crop residue harvested in year y for individual Rice Field i [t dry matter ha^{-1}]
0.4 = Average carbon content of rice straw [kg C kg^{-1} dry matter]
1000 = Conversion factor from kg to t.
$CRP_{y,i}$= Carbon in crop residue produced in year y for individual Rice Field i [kg C ha-1 yr-1]
f_{RHyi} = Fraction of residue left after harvest for field i and year y

In addition to OFEF, another factor related to the Project Activity of straw baling and removal is Increased Fertilizer Emission Factor (IFEF). Removing rice straw from a Rice Field removes a significant amount of nutrients. This nutrient removal must be compensated by increasing fertilization. This increase in fertilization is associated with an increase in GHG emissions from fertilizer production and fertilizer transportation. Emissions from fertilizer transportation are assumed to be negligible, but emissions from fertilizer production are not. For this Project the provided IFEF of 44.7 kg CO_2e (tons dry straw)$^{-1}$ from the methodology will be applied to the final emission calculation.

E3. LEAKAGE

While it is predicted that project activities will have minimal impact on yield, potential leakage will be monitored and calculated. Per the methodology, Ex-ante calculations will assume a negligible level of leakage due to Project Activities on yield. However, for Ex-post calculations the impact of Project Activities on yields and potential leakage will be calculated using actual yields according to the procedures in Section 12.1 of the methodology. If the Project Activities lead to statistically significant decrease in the rice yield totaled over all participating Rice Fields, compared to the available yields of at least three of the five years before the Project Start Date, credits must be discounted according the methods described in Section 12.1 of the methodology. This deduction is necessary to account for potential market leakage effects. Yields are normalized against seasonal variations in yields using yield statistics obtained by the NASS or NRCS.

E4. UNCERTAINTY

There are two sources of uncertainty which must be accounted for and quantified as part of the emission reduction calculations; uncertainty related to the input data and the structural uncertainty related to the DNDC model's capacity to simulate the project fields. In the case of this project the structural uncertainty parameters have already been determined through the development of the California Module v1-0 and are described below.

The California Module determined the various parameters required in the Structural Uncertainty equation based on the comparison of modeled and field measured emissions applying the various project activities. This uncertainty deduction, when applied, ensures that simulated emission reductions will be conservative at a confidence level of 90%. The resulting structural uncertainty equation and estimated parameters are listed below.

$$u_{struct} = s\sqrt{2n(1-p)} * t_{inv}(0.90, k)$$

Where:
u_{struct}= Absolute deduction for structural uncertainty for the whole Project Area [kg CO_2-eq]
s = 51.3 (estimated based on the 9 pairs of measured and simulated fluxes presented in Table 3 of the California Module v.1)
p = 0.06 (estimated based on the daily flux data of the fields and seasons as presented in Table 3 of the California Module v.1)
k = 9
n = Project Area size in ha
t_{inv} (0.90, k) = 1.36 for k=11

Any uncertainty due to the input parameters was assessed using a 1,000 draw Monte-Carlo analysis for both baseline and project scenarios. The Monte-Carlo analysis is a tool included in the DNDC model. Per the methodology, the distribution parameters which were required to be included in the analysis were described in Table 7 of the methodology. Based on the analysis, a relative input uncertainty factor for each field was calculated as the value corresponding to the 10% quantile for the distribution of emission reductions divided by the mean of the emission reductions.

Both sources of uncertainty were combined for a total uncertainty deduction, described below.

$$u_i = \frac{u_{struct}}{\sum_{i=1}^{nrFields} Ai\ (PE_{yi} - BE_{yi})} + u_{input,i}$$

Where:
u_i = Uncertainty Deduction factor for individual Rice Field [-]
u_{struct}= Absolute deduction for structural uncertainty for the whole Project Area [kg CO_2-eq]
$nrFields$ = Number of individual Rice Fields included in the Project area
Ai = Size of individual Rice Field [ha].
PE_{yi} = Project emissions in year y for individual Rice Field [kg CO_2- eq ha^{-1}]
BE_{yi} = Baseline emissions in year y for individual Rice Field [kg CO_2- eq ha^{-1}]
$u_{input,i}$ = Relative input uncertainty factor [-]
As per ACR requirements, no uncertainty deduction is required if the half-width of the resulting combined confidence interval is within 10% of the mean at 90% confidence.

E5. REDUCTIONS AND REMOVAL ENHANCEMENTS

Net reductions in GHG emissions were calculated following the methods outlined in detail in preceding sections E1-E4. Using the DNDC model, Project scenario and Baseline scenario emissions were derived for each of the two reported growing seasons. Deductions for leakage and uncertainty, described in E3. LEAKAGE and E4. UNCERTAINTY respectively, were applied to the final emission reduction calculation. The calculation used for the GHG emission reductions for year *y* (*ERy*) for the project, in accordance to EQ. 8 of the methodology, is as follows:

$$ER_y = \sum_{i=1}^{nrFields} A_i\left[u_i\left(PE_{yi} - BE_{yi}\right) - CRH_{yi}\left(OFEF_{yi} + IFEF\right)\right] - E_{leakage}$$

Where:
ER_y = GHG emissions reductions and/or removals in year y
$nrFields$ = Number of individual Rice Fields included in the Project area
A_i = Size of individual Rice Field [ha].
u_i = Uncertainty Deduction factor for individual Rice Field
PE_{yi} = Project emissions in year y for individual Rice Field
BE_{yi} = Baseline emissions in year y for individual Rice Field
CRH_{yi} = Crop Residue harvested in year y for individual Rice Field defined in Section 8.3.2 [t dry straw ha-1]
$OFEF_{yi}$ = Off-Field Emission Factor in year y for individual Rice Field [kg CO2-eq t-1 dry straw]
$IFEF$ = Increased Fertilizer Emission Factor [kg CO2-eq t-1 dry straw]

E6. EX-ANTE ESTIMATION METHODS

The estimated GHG emission reductions reported in A7. *EX ANTE* OFFSET PROJECTION were determined based on the research presented in a study by the University of California Agricultural Issues Center.[18] The study assessed the economic and GHG benefits of a number of agronomic management practices for rice production in California. The GHG emissions were determined using the DNDC model under the supervision of William Salas of Applied GeoSoluations. For each scenario, the model was run for a 10 year simulation with one year having straw burning for disease management. The first 2 years of the simulation were discarded to initialize the crop litter pools, and the subsequent 8 years of results were averaged. Within the 8-year average data, including one year with burn, represents about 13 percent burning, which closely mirrors the current multiyear average.

The scenarios assessed included a Baseline, 1) Rice straw incorporation and winter flooding, 2) Rice straw incorporation without winter flooding, 3) Rice straw removal without winter flooding, 4) Rice straw removal and winter flooding, 5) Drill seeding, 6) Mid-season drainage beginning 35 days after planting, 7)Mid-season drainage beginning 45 days after planting. For the purposes of our project, the scenarios which were included in the GHG estimate were the Baseline, scenario 4 – Rice straw removal and winter flooding and scenario 5 – Drill seeding. Unfortunately this study did not include early drain as a management practice, therefore the most conservative emission value was used. The Baseline scenario

[18] Garnache, C., Rosen-Molina, J.T., Sumner, D.A. 2010. Economics of Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley. University of California Agricultural Issues Center. Available at: http://aic.ucdavis.edu/publications/AICRiceReport.pdf

represented the closest approximation to the current typical practices employed by growers in the Sacramento Valley. The field agronomic management practices were taken from the 2007 UCCE study.[19]

The resulting emissions from each scenario were presented in the report as CH_4, N_2O and dSOC and were converted to carbon dioxide equivalency (CO_2e). The following equation was applied to calculate the estimated GHG emission reduction.

$$ER_y = (BE_{y,pa} - PE_{y,pa}) * n$$

Where:
ER_y = Emission reductions in year y for the acres implementing a specific Project Activity, pa (tCO2eq)
$BE_{y,pa}$ = Baseline scenario emissions for year y
$PE_{y,pa}$= Project scenario emissions for year y for a specific Project Activity
n = Number of acres implementing that particular Project Activity in year y
To see the full calculation please see the included spreadsheet, GHG Estimate for GHG Project Plan.

[19] University of California Cooperative Extension. 2007. Sample Costs to Produce Rice, Sacramento Valley, Rice Only Rotation. Available online at http://coststudies.ucdavis.edu/en/current/

F.
COMMUNITY & ENVIRONMENTAL IMPACTS

F1. NET POSITIVE IMPACTS

California is the second largest rice-producing state in the United States, producing rice on approximately 585,000 acres and contributing $774 million to the state's economy. This project takes place in Sutter, Colusa and Glenn Counties in California, working with 4 innovative and influential rice producers in their communities. This pilot project will not only provide any lessons-learned when moving forward with future rice emission reduction projects in the California Rice Growing Region, but will provide an opportunity to demonstrate the positive community and environmental impacts of participating in the GHG market.

As discussed in E3. LEAKAGE, the Project Activity of baling rice straw could potentially have a negative effect in that additional nutrients, specifically potassium, can be lost from the field. Farmers monitor nutrient input, which is calibrated into the DNDC model to measure any additional emissions associated with nutrient loss due to baling. Annual monitoring data of any loss in yield or loss in nutrients due to baling will be recorded on an annual basis. Any loss of yield will be monitored and accommodated for using the leakage calculation.

GHG emission reductions produced through voluntary changes in rice farming practices may be sold to provide income streams to farmers and encourage lower GHG rice production in California. The reduced GHG emissions produced, as well as the other environmental benefits generated from changes in rice farming practices such as water conservation, will contribute to the long-term sustainability of agricultural practices in the U.S. The Project Activity of dry seeding allows farmers to plant early in the rice growing season and allows for improved managed water flow on fields. This can enable farmers to effectively manage a limited water supply to maximize the acres that can be planted with a limited amount of water. Both community and environmental impacts are expected to be net positive overall.

F2. STAKEHOLDER COMMENTS

The California Rice Commission in conjunction with the Environmental Defense Fund, UC Davis and UC Extension held many discussions with farmers during the development of the ACR methodology to find GHG reduction solutions that truly worked for farmers. Many GHG protocols and methodologies have data and monitoring requirements that are unattainable for farmers and working farms. This project has taken comments from stakeholders seriously, and since the Methodology and gathering data for the GHG plan were done in conjunction, many comments summarized here were for both.

Farmer comments include that meeting the data requirements is still too difficult. For example, gathering five years of historical rice management data (gathering data from five past growing years) is too cumbersome. Monitoring data could be streamlined by on-ground sensors or using smartphone apps. Participating farmers have been in communication with project developers through farm visits, US Post, email and phone calls. Originally farmer agreements were written similarly to that of a crop insurance contract. Farmers, and those representing farmers, asked if the contracts could be revised for clarity and simplicity.

Wildlife concerns are that the rice growing region is in the Pacific Flyway, which is a critical habitat for migratory birds. This project worked closely with USDA-NRCS to identify if project activities negatively affected bird habitat. Winter flooding, is a common practice in the rice growing region that helps degrade biomass, incorporate rice stocks into the soil, reduces weeds, as well as provides habitat for birds during critical migratory periods. Originally no winter flooding was proposed as a Project Activity as methane production is very high during this period, and the reduced flood would be very climate beneficial. Through working with USDA-NRCS and other environmental agencies, this Project Activity was removed from the Project. There were also concerns about bailing reducing bird habitat, though there is insignificant research. The project will take any new findings into account as more research is conducted.

Environmental comments especially concerning water use have been overwhelmingly positive. The proposed Project Activity of early drainage can reduce late season water diversion water from California streams and rivers. The Project Activity of dry seeding allows farmers to plant early in the rice growing season and allows for improved managed water flow on fields. This can enable farmers to effectively manage a limited water supply to maximize the acres that can be planted with a limited amount of water

G.
OWNERSHIP AND TITLE

G1. PROOF OF TITLE

Terra Global is acting as the aggregator and holds the title for credits generated from the project. The farmer or association of owners have transferred offset title for the five-year crediting period to Terra Global through contractual agreements. Each farmer or association of owners (i.e. family farms) has direct ownership of each individual rice field. As the farmers have Land Title, they also have clear, unique, and uncontested offsets title. Farmers conduct practices on their own lands that reduce emissions associated with farming practices. Though activities such as till management, seeding and irrigation may be carried out by contracted individuals or entities, the practices carried out on each field are the decision of the farmers and therefore the associated emission reductions are owned by the farmers. Farmers or the association of owners agree to have Terra Global act as their aggregator for the five-year crediting period. In order to protect the confidentiality of individual rice farmers, contractual agreements between Terra Global and producers are provided directly to the VVB.

G2. CHAIN OF CUSTODY

This is the first time this project, or credits generated from this project, has been listed on any GHG emissions trading systems. No credits have been sold previously.

G3. PRIOR APPLICATION

The project proponents have not applied for GHG emission reduction or removal credits through any other GHG emissions trading systems. Credits generated through this project are unique, verifiable and voluntary.

H.
PROJECT TIMELINE

H1. START DATE

The project start date, reflecting when project activities were first initiated on a few individual fields is April 1, 2007. Discussions around AB32 in California and the potential for the agricultural sector to contribute to reduced GHG emissions were topics that UC Davis, UC Extension, and the California Rice Commission started having with the rice growing community prior to 2007. In 2007 the Environmental Defense Fund in partnership with the California Rice Commission were awarded a USDA Conservation Innovation Grant (CIG) with the goal of identifying, refining and developing innovative practices to reduce greenhouse gas emissions on rice farms in addition to providing environmental benefits associated with water quality, air quality and wildlife habitat. These practices were field tested on rice growing fields in California's Sacramento Valley. Throughout this project rice growers in California were included in discussions, education and outreach about various management practices including straw baling after harvest and dry seeding. In 2010 Terra Global was contracted by the Environmental Defense Fund and the California Rice Commission to initiate work on developing an emission reduction methodology for rice production in California and the Mid-south through VCS. This initial project was based on the California Rice Commission having extensive conversations with rice farmers in the California Rice Growing Region about potential practices and having them start to adopt practices to determine viability for the protocol.

While these activities were being adopted on field as early as 2007, the requirements of the future ACR protocol were not known until further into the process, including the historical data records requirements. For this reason, the participating growers did not have the eligibility requirements required to get credits starting from when practices were initially adopted. The included farmers heard about the project, became engaged through these programs, and helped shape the ACR Rice Protocol which was publically released in May 2013.

The project Start Date, April 1, 2007, is more than two years prior to the date of listing, March 2014. Evidence that GHG mitigation was an objective as of the Start Date is stated above with the CIG project being initiated in 2007[20] and the continued work around reducing GHG emissions from rice production. Growers were aware that this project may be awarded well in advance since they were consulted during the pre-proposal and full proposal stage. Discussions about what practices could be applied on field to reduce GHG emissions from rice productions were well underway by the time the grant was awarded.

H2. PROJECT TIMELINE

The project timeline was designed to optimize farmer engagement, and to present a similar contractual agreement and timeline to other farmer contracts, such as fertilizer agreements and crop insurance.

Farmers engaged in the project commit to being involved for five years, which is the crediting period. The project is specifically designed to generate credits when emission reductions take place and not restrict farmers into making management decisions that may reduce GHG, but jeopardize yields or income. GHG

---

20 http://www.nrcs.usda.gov/wps/portal/nrcs/cigsearch/national/programs/financial/cig/cigsearch/?svsn=National&awardYear=2007

credits are generated when practices are carried out that truly reduce emissions. For example, farmers are not contractually required to carry out the practice, nor are they required to grow rice during the crediting period. This helps farmers optimize market, environmental and climatic conditions to do what they know best; grow food to feed America.

Verification can happen at any time during the Project Crediting Period, but verifies each voluntary project vintage year within the Crediting Period. A vintage year, as specified in the methodology Section 5.3, is characterized by starting immediately after a harvest and end immediately after a subsequent harvest. This time frame captures the resulting GHG emissions from all project activities. The Project Activity of straw baling happens early in the vintage year, while dry seeding and early drain happen during the growing season. A farmer can carry out one or more of these activities to generate emission reductions.

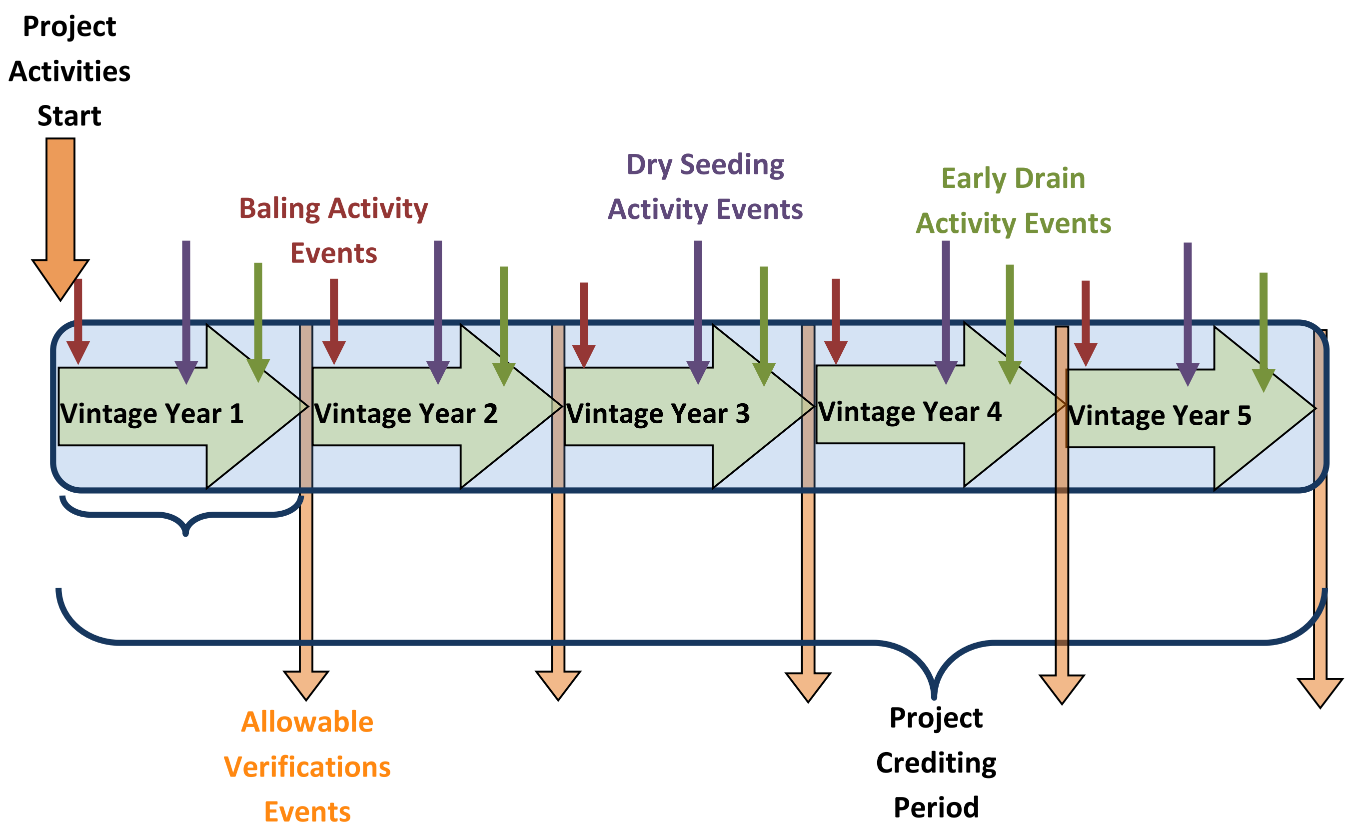


Figure 2. Project Timeline

Appendices

Appendix A

Sample .dnd input file for the DNDC Model, specifically created for the California Module.

Line	DND Parameter	Selection procedure for value
1	Input_Parameters:	
2	--	
3	Site_data:	Leave blank
4	Simulated_Year:	24
5	Latitude:	Use latitude of project area
6	Daily_Record:	0
7	--	Leave blank
8	Climate_data:	0
9	Climate_Data_Type:	Fix at 1
10	NO3NH4_in_Rainfall	1
11	NO3_of_Atmosphere	0.06
12	BaseCO2_of_Atmosphere	Fix at 350
13	Climate_file_count	Leave blank
14	1	No default
15	Climate_file_mode	1
16	CO2_increase_rate	0
17	--	
18	Soil_data:	0
19	Soil_Texture	Empirical soil measurements
20	Landuse_Type	2
21	Density	Empirical soil measurements
22	Soil_pH	Empirical soil measurements
23	SOC_at_Surface	Empirical soil measurements
24	Clay_fraction	Empirical soil measurements
25	BypassFlow	Fix at 0
26	Litter_SOC	Fix at 0.01
27	Humads_SOC	Fix at 0.003
28	Humus_SOC	Fix at 0.987
29	Soil_NO3(-)(mg N/kg)	Fix at 0.5
30	Soil_NH4(+)(mg N/kg)	Fix at 0.05
31	Moisture	Fix at 0.405
32	Temperature	No default
33	Field_capacity	Empirical soil measurements
34	Wilting_point	Empirical soil measurements
35	Hydro_conductivity	Empirical soil measurements
36	Soil_porosity	Empirical soil measurements
37	SOC_profile_A	Provide soil information
38	SOC_profile_B	Provide soil information
39	DC_litter_factor	Fix at 1
40	DC_humads_factor	Fix at 1
41	DC_humus_factor	Fix at 1

42	Humad_CN	Fix at 10
43	Humus_CN	Fix at 10
44	Soil_PassiveC	Fix at 0
45	Soil_microbial_index	Fix at 1
46	Highest_WT_depth	Fix at 9.99
47	Depth_WRL_m	Fix at 0.3
48	Slope	0
49	Use_ION_file	0
50	--	
51	Crop_data:	0
52	Rotation_Number	No default
	REPEAT FROM 20 YEARS BEFORE START OF CREDITING PERIOD UNTIL 10 YEARS AFTER START CREDITING PERIOD:	
53	Rotation_ID	No default
54	Totalyear	No default
55	Years_Of_A_Cycle	No default
56	YearID_of_a_cycle	No default
57	Crop_total_Number	No default
58	Crop_ID	No default
59	Crop_Type	No default
60	Plant_time	Exact date required, ex. 5 1
61	Harvest_time	Exact date required, for example 9 11
62	Year_of_harvest	1
63	Ground_Residue	1 if no baling is applied, otherwise 0.25 or empirical measurement
64	Yield	Exact data required
65	Rate_reproductive	0.044
66	Rate_vegetative	0.015
67	Psn_efficiency	0.4
68	Psn_maximum	47
69	Initial_biomass	12.5
70	Cover_crop	0
71	Perennial_crop	0
72	Grain_fraction	0.6
73	Shoot_fraction	0.3
74	Root_fraction	0.1
75	Grain_CN	30
76	Shoot_CN	65
77	Root_CN	65
78	TDD	3000
79	Water_requirement	508
80	Max_LAI	6
81	N_fixation	1.05
82	Vascularity	1
83	Tillage_number	Supply number of tillage events
	Repeat for all tillage events	

84	Tillage_ID	Index value running from 1 until the number of tillage events
85	Month/Day/method	Exact date required, for example 4 23 3
	End of tillage events	
94	Fertil_number	Supply number of fertilization events
	REPEAT FOR EACH FERTILIZATION EVENT:	
95	fertilization_ID	1
96	Month/Day/method	Exact date required, for example 4 30 1
97	Depth	15
98	Nitrate	0
99	AmmBic	0
100	Urea	0
101	Anh	130
102	NH4NO3	0
103	NH42SO4	0
104	NH4HPO4	0
105	Release_rate	1
106	Inhibitor_efficiency	0
107	Inhibitor_duration	0
108	Urease_efficiency	no default
109	Urease_duration	no default
	(end of fertilization event enumeration)	
141	Manure_number	0
142	Plastic_applications	no default
143	Ventilation	No default
144	Weed_number	no default
145	Weed_Problem	no default
146	Flood_number	3
147	Leak_type	1
148	Water_control	0
149	Leak_rate	0.08
	Repeat for Each Flooding Event	
150	Flooding_ID	1
151	Flood_Month/Day	Exact date required, for example 1 1
152	Drain_Month/Day	Exact date required, for example 1 31
153	Water_N	0
154	Shallow_flood	0
	(end of flooding event enumeration)	
168	Irrigation_number	Fixed at 0
169	Irrigation_type	Fixed at 0
170	Irrigation_Index	Fixed at 0
171	Grazing_number	Fixed at 0
172	Cut_number	Fixed at 0
	(end of crediting year enumeration)	
435	Crop_model_approach 0	-

Comparative Analysis of Alternative GHG Calculation Methods and Protocols

A review and comparison of rice cultivation carbon offset protocols

July 2015 | NRCS Conservation Innovation Grant 69-3A75-11-133

I. Introduction

Between February 2011 and June 2015, the Environmental Defense Fund (EDF) actively participated in and supported the development of five different carbon offset protocol modules with three different organizations. These protocols are: Climate Action Reserve's (CAR) *Rice Cultivation Project Protocol*, American Carbon Registry's (ACR) *Voluntary Emission Reductions in Rice Management Systems*, and the California Air Resources Board's (ARB) *Rice Cultivation Projects Compliance Offset Protocol*. The ACR protocol was divided into three different modules – one parent methodology, one methodology for California, and a third methodology for the Midsouth. Each of these protocols built on the experience from the previous version.

The ACR protocols have attracted significant interest by growers. As of June 2015, 21 farmers on more than 22,000 acres have signed up to generate offset credits from rice cultivation. The first credits are expected to be issued to the first California project by late summer or early fall 2015.

This report describes the history and process followed in the development of each of the rice protocols as well as provides a summary comparing the differences of the protocols approved by the three different organizations.

II. Voluntary Protocols

Climate Action Reserve – Rice Cultivation Project Protocol

Work on this protocol was initiated in February 2011 and version 1.0 was approved by the CAR Board of Directors on December 14, 2011. An updated version of the protocol was adopted on June 19, 2013. This protocol focused on implementation of two practices by California rice growers – draining a rice field 7 to ten days earlier than is their common practice, also called early drainage, and the baling and removal of rice straw at the end of harvest, also called baling. The protocol credits the reductions of methane and debits any increases in nitrous oxide or decreases in soil organic carbon.

Advising CAR staff on the protocol was a workgroup composed of twelve experts from diverse backgrounds:

California Rice Commission	NRG Energy
Carbon Solutions America	Terra Global Capital

Deloitte Consulting	Trinity Carbon Management
Environmental Defense Fund	UC Agriculture and Natural Resources
ibLaunch Energy, Inc.	U.S. Department of Agriculture, Natural Resources Conservation Service
National Wildlife Federation	U.S. Environmental Protection Agency

This workgroup met four times to discuss the protocol and advised CAR staff on key considerations, including performance standards, aggregation, wildlife habitat, and verification.

In addition to the workgroup, CAR held a public workshop on October 24, 2011 to solicit feedback on the protocol. Ten organizations provided public comments on the draft protocol. There were 89 comments in total which thoroughly covered every section except for Reporting and Record Keeping. These comments were incorporated into version 1.0 which was approved on December 14, 2011.

In 2013 CAR undertook a revision of the Rice Cultivation Project Protocol. The changes to version 1.0 of the protocol were focused around clarifications and updates such as eligibility criteria for fields which have received NRCS funding and clarification of on the quantification of leakage quantification. The updated version of the protocol, version 1.1, was approved by the CAR Board on June 3, 2013.

No projects have utilized this protocol for the development of voluntary carbon offsets.

American Carbon Registry – Rice Management Systems

In the fall of 2011, the California Rice Commission, EDF, Terra Global Capital, and Applied Geosolutions started work on a rice protocol to be submitted to the American Carbon Registry. This protocol was divided into three different modules and funded through two separate CIGs. The first module was a parent methodology which contains all the non-geographically specific information required to generate GHG reductions from rice cultivation. It includes definitions, identification of the project boundary, procedure for developing the baseline, and leakage considerations. This module was adopted by ACR on May 6, 2013.

The second module, which focuses on the California rice growing region and was developed in parallel with the parent module, contains 1) the specific practices which can be implemented on California rice fields, 2) the data required to be collected for these practices and 3) the details for calculating the structural uncertainty of the DNDC model. The DeNitrification DeComposition (DNDC) model is a biogeochemical model of carbon and nitrogen biogeochemistry in agro-ecosystems and can be used for predicting crop growth, soil temperature and moisture regimes, soil carbon dynamics, nitrogen leaching, and emissions of trace gases including nitrous oxide (N_2O), nitric oxide (NO), dinitrogen (N_2), ammonia (NH_3), methane (CH_4) and carbon dioxide (CO_2). The three practices allowed in the California region are baling, early drainage, and dry seeding. Baling and early drainage follow the same definitions as in the CAR protocol. Dry seeding is the practice of sowing dry seeds rather than aerially applying pre-germinated seeds. This module was adopted by ACR on May 6, 2013.

The third module was developed starting in January 2012 and includes rice grown in the Mississippi River Delta mainly in Arkansas, but extending into Mississippi and Missouri and Gulf Coast area of

Louisiana and Texas. Like the California module, this module focuses on the specific practices which could be implemented on rice fields in the Midsouth, the data required to be collected for these practices and the details for calculating the structural uncertainty of the DNDC model. The Midsouth module allows for the implementation of four different practices – baling, early drainage, increased water and/or energy use efficiency, and alternate wetting and drying. As is the case with the California module, baling and early drainage follow the same definitions as in the CAR protocol. Increased efficiency includes practices which ultimately decrease the use of fossil fuels from diesel pumps or farm equipment. Alternate wetting and drying is the practice of periodically flooding and then drying down a field throughout the growing season. This module was adopted by ACR in February 2014.

One of the unique aspects of the ACR protocols is that they allow the use of a common practice baseline. A common practice baseline allows the grower or project developer to use data from growers in the region who are not implementing the practice as the baseline. A common practice baseline is set at practices which are adopted by less than 5% of growers in a given rice growing region. This reduces the costs to gather data and develop the necessary documentation related to the project. In addition, it incentivizes growers to adopt practices, such as dry seeding, which reduce GHG emissions. Once the 5% adoption rate has been achieved, a field specific baseline must be used.

As of June 2015, three projects have been listed with ACR:

- **ACR205 – Emission Reductions in California Rice Management Systems** – was listed on March 5, 2014 and includes 4 farmers, with 36 unique fields, and 4,990 acres for California. This initial group of rice farmers in California is participating in the first validation and verification of offsets under the ACR methodology. The voluntary management practices that will be undertaken by farmers include: early drainage, dry seeding and baling.
- **ACR230 – Emission Reductions in Midsouth Rice Management Systems** – was listed on December 29, 2014 and includes 8 farmers, with 63 unique fields, and 3,000 acres in the Midsouth (Arkansas and Mississippi). The voluntary management practices that will be undertaken by these farmers include: early drainage, baling, intermittent flooding and increased energy and water use efficiency.
- **ACR231 – Emission Reductions in California Rice Management Systems 2 –** was listed on December 29, 2014 and includes 9 farmers, with 154 unique fields, and 14,223 acres in California. The voluntary management practices that will be undertaken by farmers include: early drainage, dry seeding and baling.

III. Compliance Protocol

ARB-Rice Cultivation Project Compliance Offset Protocol

Development of a compliance-based rice cultivation offset protocol was first proposed on May 17, 2012 by the Western Climate Initiative (WCI), a non-profit corporation formed to provide administrative and technical services to support the implementation of state and provincial greenhouse gas emissions trading programs. WCI consists of officials from the provinces of Quebec and British Columbia, and the

State of California who coordinate cap-and-trade developments for the three subnational governments. In a statement issued by WCI, they announced that partner jurisdictions would consider reviewing offset protocols including "municipal and industrial waste water treatment, forests (all project types), fertilizer application N2O emission reductions, rice cultivation, and enteric fermentation."

On March 28, 2013 ARB held a workshop entitled "Discussion of New Compliance Offset Protocols for the Cap-and-Trade Regulation." At that workshop ARB proposed development of a rice cultivation offset protocol and solicited comments from stakeholders. Seven different stakeholders submitted comments.

Following the workshop, ARB kicked off development of a rice cultivation protocol through the holding of four technical work group meetings on: May 10, July 19, October 1, and December 20, 2013. A brief summary of what was discussed in each of the workshops follows:

First Technical Working Group Meeting – May 10, 2013

This working group meeting focused on four items: the use of the DNDC model, verification approaches for crop-based protocols, aggregation of multiple growers into a single project, and the potential for leakage resulting from a rice cultivation offset protocol. Approximately 13 people attended in person and 18 via the phone.

ARB proposed developing a streamlined version of the DNDC model by simplifying the require input and consolidating the output files and developing customized links to databases like SSURGO (the Soil Survey Geographic database refers to digital soils data produced and distributed by the Natural Resources Conservation Service) and other weather station data. This proposal was met with broad support from attendees.

Significant discussion was held related to the aggregating multiple growers into a single project. This is important because it is not economical for any single grower to develop a project as the average reduction of methane is between 0.5 and 3.0 tons per acre per year.

Second Technical Working Group Meeting – July 19, 2013

The second technical working group meeting had eight items on the agenda, although the discussion focused on six of them: definition of an Offset Project Operator, verification sampling requirements, missing data provisions, DNDC model validation, remote sensing, and structural uncertainty of the DNDC model. Approximately 13 people attended in person and 18 via the phone.

The most detailed discussion involved the definition of the Offset Project Operator (OPO) who, according to the cap-and-trade regulations, has to have operational control of the practices implemented under the protocol. Concerns expressed included the temporary lease holders and the differentiation between the land owner and the person who farms the land. An additional concern raised was the level of disclosure of information by a grower. While many were comfortable with the disclosure of a farm's location, there was widespread concern with the disclosure of agronomic practices on the farm as they are considered confidential business information by the growers.

In addition to the OPO, ARB asked for comments on how to approach verification. This was a significant concern of stakeholders as verification is one of the largest costs associated with developing a project. ARB discussed approaches to sampling and one of the options was setting a specific sample size requirement. There are pros and cons of requiring a specific sample size and one of the largest cons is that the verifier would not have any flexibility if a specific verification sample size was written into the regulations.

Third Technical Working Group Meeting – October 1, 2013

At the third technical working group meeting, there were two primary items which were discussed: the timeline for bringing the protocol before the ARB Board for consideration and the potential environmental and ecological impact as a result of future implementation of this proposed protocol. Approximately 13 people attended in person and 13 via the phone.

ARB stated that they planning to take the rice cultivation protocol to the Board in the springtime of 2014 and staff were considering putting it on the agenda for both the March and April meetings.

The bulk of the discussion revolved around other environmental impacts which could occur as a result of implementing the practices being considered under the rice cultivation protocol – dry seeding, early drainage, alternate wetting and drying and baling. No concerns were expressed about the dry seeding practices.

For the early drainage practice, working group members felt that the practice has the potential to help mosquito abatement districts control mosquito populations as the protocol would reduce standing water. Concerns with the practice were moving water to places where mosquito populations would increase as well as the affect early drainage would have on late brood birds as the young birds would have to find alternative habitat if the field they were in was drained early.

The largest concern was with respect to the baling practice. A study conducted by Point Blue, a bird and ecosystem research nonprofit, and paid for under EDF's CIG found much reduced populations of waterbirds in fields that were baled, even if the fields were subsequently flooded after baling. Point Blue was concerned about a detrimental impact to waterfowl if ARB implemented baling as a practice in the protocol.

Fourth Technical Working Group Meeting – December 20, 2013

At the fourth and final technical working group meeting, there were three on the agenda: the timeline for bringing the protocol before the ARB Board for consideration, the results of Point Blue's study on the impact to waterbirds from baling and the data used to calibrate and validate the DNDC model. Approximately 16 people attended in person and 12 via the phone.

ARB updated the timeframe for consideration of the rice cultivation protocol by the Board stating that they intended to release a draft protocol in February 2014 and have the first consideration by the Board at their May meeting. They anticipated that the second hearing of the protocol, which is required for complex rulemakings such as the rice protocol, would be in the fall of 2014 and that the protocol would take effect in January of 2015.

After EDF and Point Blue gave a history and summary of the study, ARB recommended that baling not be included as a practice in the rice cultivation compliance offset protocol at this time. Stakeholders asked a number of questions about the study which included consideration of geese impact, hunting, incentive to flood after baling, and impacts of the drought on baling. After all the discussion, ARB reiterated that until additional research is conducted which shows that rice baling can occur without impacts to waterbirds, the practice would not be included in the protocol.

ARB Workshops on Rice Cultivation Projects Compliance Offset Protocol

Once the technical working group meetings wrapped up, ARB held two workshops to discuss drafts of the Rice Cultivation Projects Compliance Offset Protocol. The first was on March 17 and the second was on June 20, 2014.

At the March 17 workshop, ARB outlined the timeline for the development of the protocol and presented the eligibility criteria, project boundary, quantification methodology, early action timeframe, aggregation considerations, and verification considerations. ARB staff asked for feedback on the draft and 57 entities submitted comments. A large number of comments were driven by a group opposed to Reduced Emissions from Deforestation and forest Degradation (REDD) who were concerned that the rice protocol set a precedent for ARB's development of an international REDD protocol. Many of these comments were form letters. Among the stakeholders closely following the protocol, the majority of the comments can be summarized into two categories – aggregation and baling. Twelve organizations submitted comments on aggregation and encouraged ARB to find a way to include it in the final protocol. Four organizations asked ARB to include baling as a part of the protocol.

During the June 20 workshop, ARB outlined the key changes to the previous draft version of the protocol. These changes can be grouped into two categories – clarifications and updates. The clarifications included – sampling requirements, reporting requirements, documentation requirements, verification requirements, and baseline record requirements. The updates included – Monte Carlo simulations, structural uncertainty of the DNDC model, and monitoring parameters. A total of fourteen comments were submitted by stakeholders and these comments largely focused on specific edits and clarification to the draft protocol. However, multiple parties continued to lobby for the inclusion of baling in the protocol.

Board Consideration of the Rice Cultivation Projects Compliance Offset Protocol

On October 28, ARB released the latest version of the protocol along with a staff report which details ARB staff research and decisions. This draft yielded seventeen comments. The vast majority of the comments supported the rice protocol and provided final edits to the October 28 version. The protocol was put on the calendar for the December 20 Board meeting for the Board to hear the protocol for the first of two times. At the Board meeting, the Board voted unanimously to move the protocol forward to a final vote.

On May 20, ARB released the final version of the protocol for public comment. This final version yielded eleven comments with the majority of them focused on ensuring inclusion of early action projects to allow the 21 farmers on more than 22,000 acres to ability to convert their voluntary project to Early

Action offset projects which can be used in California's cap-and-trade program. At the June 25 Board meeting the Board voted unanimously to approve the rice protocol as drafted on May 20. In addition, Board Chairman Mary Nichols asked ARB staff to work with growers to find a way that all growers who voluntarily reduced emissions prior to approval of the protocol could find a way to generate carbon credits which could be used in California's cap-and-trade program.

IV. Summary Comparison Table

	Climate Action Reserve	**American Carbon Registry**	**California Air Resources Board**
Date originally approved	December 14, 2011	May 2013	June 25, 2015
Geography	California	California and the Midsouth	California and the Midsouth
Baseline approach	• Field-specific	• Field-specific • Common Practice	• Field-specific
Baseline rice cultivation time	5 years out of 6 years prior to start date	2 out of 5 years of historical data	2 years before the project start date
GHGs credited	• Methane	• Methane • Nitrous Oxide • Carbon Dioxide (both through fossil fuels and changes in SOC)	• Methane
Minimum project size	No minimum	1,000 Acres	No minimum
Crediting period	5 years renewable three times (20 years total)	5 years and renewable thereafter as long as adoption rate practices is < 50% of	10 reporting periods renewable twice
GHG reduction practices credited	• Dry Seeding • Baling	• Early Drainage • Dry Seeding • Alternate Wetting and Drying • Baling • Energy Efficiency	• Early Drainage • Dry Seeding • Alternate Wetting and Drying
Minimum fields receiving an in-depth audit	50%	20%	100%
Stacking	Payment stacking allowed with NRCS practices 344A and 329 provided they at the same time or after project initiation	Silent on payment stacking	Silent on payment stacking

V. Conclusion

Over the past four years, three different organizations developed offset protocols for rice growers in the United States. Each of these protocols built on the previous version while taking different approaches to key aspects of rice cultivation offset creation. The protocol developed by ACR was the most inclusive both in terms of practices allowed, geographic coverage, and GHGs considered. The applicability and interest of this protocol is evident through the three projects listed with ACR by 21 farmers on more than 22,000 acres.

The last rice protocol was developed by ARB and adopted for use on June 25, 2015. This is the first crop-based protocol included in a cap-and-trade program worldwide. While the ARB protocol does not include the breadth of practices or geography, it does send a strong signal to growers that reduction of GHGs through crop-based practices can generate an additional revenue stream through market-based programs.

Even though each of the protocols built on the prior version and ultimately resulted in the first crop-based protocol for a cap-and-trade program, there are still opportunities for improvement. None of the protocols completely handled risk-based and randomized verification and none them completely addresses stakeholder concerns related to aggregation. Fortunately, growers, developers, the carbon registries, ARB, and EDF are committed to furthering this work and demonstrating the success of this offset protocol as it sets such an important precedent for crop-based agriculture. The first credits from the first project are expected to be generated in the fall of 2015 and ARB has committed to funding a pilot to determining opportunities to implement cost-effective and environmentally rigorous verification of these first projects. The lessons learned through the development of the three protocols supported by this Conservation Innovation Grant demonstrate the value of an iterative process to developing innovative environmental markets.

Analysis of Rice Protocol Project Feasibility

An exploration of the technical feasibility, operational constraints, costs, and the resulting potential for implementation

July 2015 |NRCS Conservation Innovation Grant 69-3A75-11-133

Contents

I. Introduction 2

II. Project Feasibility 2

a. Technical Feasibility 2

Practice Risks and Mitigation 3

Improving Technical Feasibility 5

b. Social Feasibility 6

Challenges to Project Implementation 6

Optimal Project Participants 9

Farmer Interest 9

Improving Social Feasibility 9

c. Economic Feasibility 11

Carbon Credit Project Costs 11

Aggregation 12

Economics of Practice Implementation in California 15

Economics of Practice Implementation in the Midsouth 17

Improving Economic Feasibility 21

III. Conclusion 21

Appendix A- Why is Aggregation Necessary? 23

Appendix B- Aggregation Concerns and Solutions 25

I. Introduction

As a part of a Conservation Innovation Grant (CIG) from USDA entitled *Demonstrating GHG Emission Reductions in California and Midsouth Rice Production*, project partners have explored the feasibility of implementing methane-reducing practices across the California and Midsouth rice-growing regions. Partners piloted the American Carbon Registry's *Voluntary Emissions Reductions in Rice Management Systems Methodology* (here forward ACR Rice Methodology)[1] to generate carbon credits for the voluntary and compliance markets.[2] We have identified the barriers and challenges to scaling up this market and suggest opportunities to overcome the barriers and challenges. This report includes internal analysis, as well as significant input from pilot participants regarding project feasibility.

II. Project Feasibility

a. Technical Feasibility

Research conducted through a previous CIG (NRCS 69-3A75-7-87) demonstrated the technical feasibility of recommended practices for California. The results of that CIG were summarized in a Final Report submitted to NRCS in 2010.[3] That report laid the critical framework for understanding the economics of environmentally appropriate and carbon beneficial practices for California's Sacramento Valley. From that work, project partners embarked on a second CIG to develop a protocol to incentivize the adoption of three practices that have shown the most practicality for adoption within the region: dry (drill) seeding, early drainage, and baling (rice straw removal). The technologies for these practices are easily accessible and the impacts of implementation on emissions are quantifiable.

In parallel, project partners in the Midsouth made a list of rice cultivation practices that could reduce methane emissions. Through this CIG, Winrock International (Winrock), the White River Irrigation District (WRID), Applied GeoSolutions (AGS) and academic partners at the University of Arkansas, Mississippi State University, and the USDA Agricultural Research Service determined that alternate wetting and drying (AWD), early drainage, increasing water and/or energy use efficiency, and baling were all technically feasible for rice farmers in Arkansas, Louisiana, Mississippi, Missouri, and Texas.[4] A discussion on increased water and/or energy use efficiency is not included in this report because this practice is not included in the DNDC modeled emissions and project proponents wanted to focus on practices that, at the time, we believed would be accepted in the ARB Protocol. Dry seeding is already common practice in the Midsouth, and therefore, not an option as an emissions-reducing practice to

[1] Rice Management Systems, American Carbon Registry, accessed 28 May 2015 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems)

[2] In June 2015, the California Air Resources Board (ARB) adopted a protocol, entitled "Rice Cultivation Projects Compliance Offset Protocol" (here forward ARB Rice Protocol). The project undertaken piloted the standards of the ACR Rice Methodology. Several of the growers will be able to transition voluntary credits generated to compliance credits since the ACR Rice Methodology (with some modifications) is included as an Early Action protocol by the ARB. Therefore, the following analysis incorporates information from the experience of creating potential Early Action credits. For further discussion on the differences between protocols, refer to the Comparison of Protocols report, submitted by EDF in July 2015 for Conservation Innovation Grant 69-3A75-11-133.

[3] This report is available upon request.

[4] Originally, reduced winter flooding was also considered to be a technically feasible in the Midsouth, but was ultimately excluded from the ACR Rice Methodology due to potential impact on waterbirds.

generate carbon credits. Although not directly related to technical efficiency, when selecting practices to implement in the Midsouth, Winrock considered whether a practice change would provide additional environmental, social, or economics benefits to the farmer (such as reduced input costs), also known as co-benefits.

Practice Risks and Mitigation

While practices may be technically feasible, there may be production risks associated with practice implementation that should be taken into account. Project partners explored potential concerns associated with each of the practices to better understand decisions farmers would make when implementing a project. The enumeration of these risks is not meant to discourage their practice, but rather to inform and educate on the possible tradeoffs of participating. As with any type of practice implementation, the riskiness of practices will vary for each farmer. These risks were not quantified monetarily and incorporated into the below economic analysis. [5] Each GHG-abating practice presents risks to production that cannot be adequately captured in a quantitative analysis, but are discussed qualitatively below. These major risk factors could represent barriers to widespread adoption of the practices.

Drainage Practices (Early Drainage and Alternate Wetting and Drying)

If rice fields are drained too early (beyond what is recommended for the early drainage practice), there is a risk that yield will be negatively affected. California farmers interested in implementing this practice will work with a crop advisor or agronomist to determine the ideal date for early drainage, which is between 7 and 10 days before "normal" drainage, or the common practice of holding water on fields for a certain time to ensure proper crop development. Research has demonstrated that draining 7 to 10 days before the "normally" accepted date does not affect the proper crop development. A specific description of how to implement this practice has been written into the various carbon offset protocols to help farmers to avoid draining too early. This description focuses on the determination of fifty percent heading. In the Midsouth, farmers use the DD50 model for plant development and/or the yellow hull determination given the rice variety grown there to determine how early they can drain their fields.

Aside from yield impacts, the biggest perceived risk in the adoption of flood reduction practices, such as AWD, in the Midsouth relates to irrigation. Throughout most of the Midsouth, producers own water rights on their land, but often need pumped groundwater from wells for additional irrigation. Thus, irrigation systems are frequently implemented, owned and maintained by producers themselves. Pumping is usually powered by diesel generators. A foremost fear of producers is the inability to re-wet a field after drying (especially in the case of AWD). If pumps or any other component of their irrigation systems break down, producers could lose their entire crop by being unable to irrigate after a drying phase. Conversely, farmers who have implemented AWD have seen irrigation demand reduced by as much as 30% thereby reducing the demand and costs for pumping the water onto their fields.

[5] Developed with farmer and crop advisor consultation.

Baling

A perceived risk in baling is nutrient loss in soils. When left on the field to decompose over winter, rice straw and crop residues are an important mechanism for replenishing lost nutrients (most importantly nitrogen) in the soil. Baling rice straw removes this source of nutrients – which must be compensated for in the following season by increasing fertilizer levels. It can be difficult for producers to precisely gauge how much additional nutrients need to be added, and in turn a risk of under-fertilization is possible. Yield reductions or crop losses may result.

Dry (Drill) Seeding

Environmental Defense Fund (EDF), the California Rice Commission (CRC), and University of California Cooperative Extension experts explored the risks associated with dry seeding in California, as this practice is not common in the Sacramento Valley. There are nine specific risks that must be taken into account before a rice farmer decides to change from wet seeding to dry seeding.

1. Delayed planting

   It takes more time to seed fields through dry seeding. Using a seed drill, it is estimated that seeding takes place at a rate of 2 miles/hr. This roughly translates to a 25-day planting period for 2,000 acres. If there is a period of rainfall, followed by cool and cloudy weather, it can delay planting by another week or so in the time it takes to wait for the soil to be in good condition for dry seeding again.

2. Delayed maturation

   If planting time is heavily delayed, and for example, the planting ends in mid-June, there are substantial risks of falling behind the seasonal schedule. This would correspond to a late October harvest, which in turn may not allow time to incorporate straw into the soil ahead of the winter. Due to this, farmers will have to wait for the straw to dry out fully in the spring before they can plant again, further delaying the process for the next season. This may persist for several years and can be difficult to recover from.

3. More precise water management

   Care must be taken to ensure water is brought on and off the fields in an efficient manner. Draining must be carefully supervised as puddles in the fields during seedling growth can create problems. Seeds will not be able to emerge and survive as effectively if they are dry seeded and then flooded over for a period of time shortly thereafter.

4. Frequent field leveling

   Farmers have to use laser guided blades to ensure their fields are more level when they dry seed. This is to avoid puddles forming and their associated effect on potential yield loss (see point 3).

5. Weed development

Dry seeding may cause a shift of the weed population to predominately grasses, which increases the chance of red rice establishment.

6. Availability of irrigation water to accommodate repeated flushes during stand establishment

There is a risk that a period of drought can severely affect a crop when dry seeding. In these situations a farmer will flush the fields, in order to moisten the soil and protect the crop. Depending on the irrigation district policy in place, this water may not be available if the need for it was unforeseen. Significant stand thinning can occur if a farmer must wait several days before being able to flush the fields.

7. Planting depth

Dry seeding can lead to uneven planting depth (often associated with large colloid size that commonly remains after cultivation in high clay content soils). This unevenness may inhibit plant establishment or cause inconsistency in plant growth.

8. Alkaline (high saline) soils

There is a possibility for a buildup of salinity in the topsoil when dry seeding in saline soils. This is largely due to a greater amount of water evaporating off of the land surface, rather than penetrating downwards in the case of flooding. Extra care must be taken when leveling fields to not uncover deeper, highly saline soil layers. In general, dry seeding is liable to be less successful in areas with alkaline soils.

9. Capital expenditures on equipment and irrigation infrastructure upgrades

The largest capital expenditure item in dry seeding is the drill itself. These have a wide range of sizes, features and costs; a small drill can be purchased used for several thousand dollars while a new large one can cost up to one hundred thousand dollars. The choice of drill will largely depend on the size of the acreage it will be used on, among other things. A larger drill means planting can be carried out more efficiently, reducing the risk of a delayed planting schedule.

Irrigation infrastructure must be modern and in good condition in order to allow for rapid flushing of fields. For this reason, it is likely that infrastructure will have to be upgraded on farms where there have not been long-term investments and upgrades. Land ownership can also play a significant role here – infrastructure is often better maintained when farmers own their land, as opposed to when land is leased in very short-term contracts.

Improving Technical Feasibility

While the technical feasibility risks might seem overwhelming, experience has shown that growers have been willing to implement them. As of July 2015, 21 growers representing more than 22,000 acres, slightly less than 1% of all rice grown in the U.S., have begun implementing these practices. In addition, over time, it is likely that the technical feasibility will improve as more farmers implement these practices and learn how to mitigate the abovementioned risks. With increased adoption of these recommended practices, machinery companies will enhance or make improvements to the tools needed. Finally, carbon project developers can identify the least risky practices for any individual farmer based upon farm-specific characteristics. Given the results of the Maximum Abatement Potential analysis that simulated rice practice implementation throughout both rice growing regions, one can determine the optimal combination of practices for any area of land that maximizes the potential for greenhouse gas emissions (GHG) reductions.[6]

To improve the technical feasibility and reduce production risk associated with carbon mitigating practices, we recommend that NRCS advisors, cooperative extension, and other crop consultants receive information on the emissions reduction potential of practices, the cost of implementing the practices, and the potential revenue which could be generated through carbon markets. As uptake of these practices increases, farmer partners will continue to identify ways to facilitate appropriate implementation that minimizes production risks and maximizes implementation of the technically feasible practices.

b. Social Feasibility

Throughout the pilot project implementation, CRC, WRID, EDF, Terra Global Capital, and Winrock collected significant feedback from participants regarding social constraints and possible solutions. General concerns raised reflect the nascency of the market for agricultural carbon credits and a need for trusted agricultural advisors to understand and translate carbon market language into the agricultural world. Some farmers are hesitant to implement new practices because they do not understand or believe the science of GHG emissions mitigation, especially if scientists are not “local.”

To increase the likelihood of success for these types of projects, stakeholders from all viewpoints must continue to participate in conversations with rule development bodies, like the American Carbon Registry (ACR), and the California Air Resources Board (ARB) to improve upon protocol requirements and make them attractive to farmers. It has to be clear to farmers that participating in the compliance market is not equivalent to regulation of a farmer’s practices, but rather an opportunity to reward their exceptional, voluntary efforts.

To increase agricultural community buy-in for GHG mitigation, EDF, WRID and Winrock/ACR will continue to identify and educate agricultural carbon market advocates through ongoing conversations with trusted farm advisors, routine public communications about the opportunity to generate offsets, offering trainings on the carbon market, and establishing cooperatives that will ease many of the constraints outlined below.

Challenges to Project Implementation

Time Invested without Seeing Results

One of the primary barriers to project implementation is a clear financial incentive for farmer participation. Pilot participants have been diligently implementing the practices and the supporting data

[6] Report submitted as a part of NRCS CIG 69-3A75-11-133 final deliverables in July 2015.

collection procedures but have yet to see any carbon revenue from their investment. Therefore, at this time it is hard to make a convincing argument that a carbon project is worth their time and effort. However, the first credits from the pilot projects are expected to be generated and sold in the fall of 2015, which will reinforce the opportunity for farmers who may be considering project implementation and reassure those who have already implemented practices and are waiting for credit creation and revenue generation. With the first project verified and credits issued and sold, all parties involved will have results to reference and use as motivation for additional project creation.

Unclear Monitoring Requirements

Because ARB and ACR Rice Protocols are still relatively new and still evolving, pilot producers have received varying information regarding the monitoring requirements for participation. Given the nascency of the protocols, the range of options to meet the monitoring requirements has not yet been tested and farmers and developers are still identifying the most cost effective options. Farmers have not traditionally kept detailed records of all the parameters required by the protocols. Carbon projects require a high level of data collection and retention and so project participants are still finessing the balance between protocol requirements and the most practical process on the ground. Some farmers have expressed concern with a perceived lack of translation from the "carbon world" to the on-the-ground conditions, which makes it harder for a farmer to discern what is required and what is reasonable. Some are hesitant that the record keeping requirements will cost them more in time than they will generate in revenue.

Fortunately, monitoring requirements will become clearer and more streamlined over time with increased implementation of methane-mitigation practices for carbon credits. This will particularly be true once the first pilot project completes its initial verification and creates credits later this year. Based on the experience from the first projects, ACR plans to provide additional clarifications and recommendations for comprehensive monitoring for projects. As common in other markets, project developers will find creative ways to lessen the monitoring burden for farmers in ways that reduce the risks of inaccuracy and misstatement. As described above, a balance is needed to make data collecting and management feasible and still maintain high-quality assurance for the carbon market.

Environmental Credit Pricing and the Cost of Monitoring

It has been difficult to convey that the increased effort of record keeping, monitoring and reporting is worth the payoff if carbon is not adequately priced. Some farmers are pessimistic that they will not be paid enough for their efforts. Many farmers want to be good stewards of their land, but in order to conform to the carbon protocols they will need high market prices. As an example, an optimistic scenario payment levels will currently generate about $10 per acre, with net proceeds to the farmer of approximately $7 per acre. In the Midsouth, the typical cost for monitoring can exceed $5 plus the initial costs of monitoring equipment, yielding no financial return.

The ARB Rice Protocol requires significant monitoring including water depths and soil moisture, as well as images of the rice fields at different phases of management. While this high level of monitoring provides a marginal amount of surety in the data, it creates a significant barrier to entry for most farmers.

Therefore, the price of carbon is extremely important. It goes without saying that if the price of carbon credits is $20-$25 per ton then there will be significantly more participation than if the price stays at the current value of $10 per ton. The good news is that the “floor” price of allowances in the California cap-and-trade program increases annually at 5% plus inflation and, to date, the offset market has tracked those increases. Over time this effect will increase the interest and participation of farmers.

WRID, AGS, and academic partners have made substantial progress identifying remote sensing technologies that will lessen the time and cost of collecting the required monitoring information. These remote sensing technologies are becoming increasing prevalent as farmers are seeing value in the data collected by these tools. They are also extremely accurate. For example, Dry Seeding practices can be verified with 95% accuracy. In the near future, it is possible that publicly available satellite imagery can provide a large portion of the evidence needed to verify the implementation of eligible practices and field locations. Supplemental field-specific data is useful for farmers beyond the needs for carbon credit creation, as they can track critical on-farm outcomes for other programs, such as NRCS, independent research, or crop insurance. Furthermore, this data could prove useful in optimizing the farmer’s revenue as supply will be better understood than it currently is which will increase price stability. As with any technology, it is likely that the price for monitoring equipment and software will decrease over time.

Fear of Regulation

Additionally, farmers have expressed a fear that participating in carbon markets will lead to regulatory action (where a government will legally require reductions in emissions from rice cultivation). Some farmers believe that providing detailed information on emissions will provide the ARB with the data needed to place a cap on agricultural emissions since agriculture is the largest uncapped sector in California’s cap-and-trade system. EDF and Winrock, continue to assure farmers that carbon credits are a voluntary financial stimulus for environmental benefits that simultaneously reduces input expenses.

Programmatic Challenges- Conflicting Criteria

It should also be noted that Farm Bill Programs have moved toward relying much more heavily on crop insurance for farmer income protection. A key component of crop insurance availability is irrigation methods for rice production. In the Midsouth, farmers have expressed concern that the USDA criteria for obtaining crop insurance do not recognize AWD as an acceptable irrigation method. Therefore, farmers worry that they may not be eligible for crop insurance if they implement the practice change.

Another threat to the success of rice projects in the voluntary carbon market is that large corporations may feel like they can set “sustainability” requirements that do not meet the rigor of the practices that have been identified for the carbon market. Farmers may choose to participate in these voluntary, non-revenue generating opportunities that requires less rigor rather than participating in the carbon market where their contributions are measured and independently confirmed. Criteria for corporate sustainability programs may also conflict with carbon market requirements.

EDF, WRID, and Winrock are working with farmers on both sustainability and carbon market opportunities. We are advocating for rigorous standards in both programs and are working to eliminate conflicting recommendations that farmers are receiving about practice implementation.

Optimal Project Participants

Ideal project participants are farmers who are innovators and forward thinking. Typically, an optimal farmer will need to sufficient land (at least 1,000 acres) under their operational control in order to generate financial return from the creation of carbon credits.[7] More specifically, in the Midsouth, the farmers need to have either precision leveled or zero grade fields, or be capable and willing to make the transition to graded fields. WRID and Winrock are helping to identify and promote existing financial incentives to convert from contour levees to precision leveled fields or zero grade. This conversion will be a primary driver for increased participation in carbon markets in the Midsouth.

Some farmers are already doing some of the recommended practices without understanding all of the environmental benefits. For example, some farmers (and scientists or crop advisors) have been practicing AWD without understanding the GHG benefits. These farmers are valuable resources because they have experience implementing AWD. Their knowledge will reduce some of the production risks noted above for AWD. While these progressive farmers cannot be rewarded through the carbon market, their involvement with AWD will help inform the identification of other potential project participants.

Farmer Interest

Some farmers are participating in initial projects because they want to be better stewards of the land; they are true conservationists. Some of them want to improve their bottom line and can envision the future revenue stream. Regardless, farmers enjoy being viewed as part of the solution and not part of the problem. Additionally, participation helps promote a positive message that agriculture is proactive in improving soil, water, and air quality. Farmers are proud of their conservation efforts, what they do and why they do it. Others say they are interested simply for self-preservation; out of the fear that they have to do this, or they would otherwise face regulations that are not efficient or affordable (as mentioned above). Agricultural carbon market partners must learn to engage each type of farmer by appealing to the issues of interest and importance to them.

Improving Social Feasibility

Even with the concerns outlined above, there are 21 farmers on more than 22,000 acres in both California and the Midsouth who are participating in projects to develop carbon credits. Clearly, the social constraints are not insurmountable. There is an opportunity for U.S. rice farmers to have a positive impact on the environment, not only through GHG emissions reductions, but also biodiversity, water quality, and soil health improvements.

[7] Based on EDF's current economic analysis, a successful project will be aggregated with 4,000+ acres.

As a result of this CIG report, EDF, Winrock and WRID have identified three main opportunities to reduce the barriers mentioned above: carbon market education, marketing and communications, and enhanced economics.

Education

After the completion of this CIG, EDF, WRID, Winrock and other partners will continue to support agricultural carbon markets by identifying and educating agricultural carbon market advocates. Local partners are critical to the social acceptance of carbon market practices and participation since these partners can leverage existing relationships while bridging the divide between the carbon industry and growers. Therefore, by developing a straightforward environmental markets curriculum that removes market jargon and by holding targeted trainings, we expect that on-the-ground advocates will become well-versed in the process for carbon credit creation and become messengers and advocates of project development. Rice farmers, current partners and new project developers will be the first class for this curriculum. Once piloted, we intend to broaden the reach of these trainings to other stakeholders as well as other agricultural carbon market opportunities, such as nitrogen fertilizer management. This curriculum will be shared with NRCS staff and could potentially be distributed through the NRCS Climate Hubs.

Marketing and Communications

Traditional marketing efforts have not encouraged farmer participation. As a part of this CIG, advertisements were placed in the local paper to increase awareness and encourage involvement in carbon credit projects. Unfortunately these advertisements were ineffective; they did not yield any project participants. The Midsouth has had some traction from farmer developed articles in trade magazines, but the full carbon credit development process needs to be completed before an effective story can be published. By highlighting the success and support of carbon credit projects, interest in participation will increase.

There is an additional opportunity for farmers to leverage the quantified environmental benefits of these projects through marketing activities, which in turn could lead to charging a premium for their crops, further incentivizing participation. Farmers in the Midsouth are already developing a “green” standard in hopes to translate their efforts that into a financial return through increased commodity prices for their rice. In addition, project partners have considered reframing agricultural environmental messaging to emphasize the positive work that farmers are doing to mitigate and adapt to climate change.

Enhanced Economics

If the economics are right and the process is reasonable and simple enough, participation will naturally increase; positive returns will reduce many of the social feasibility concerns expressed above. Furthermore, if farmers have the capability of stacking or leveraging other voluntary credits (e.g. water or nutrient management opportunities) and can find a synergy between the documentation requirements for these different incentives, then farmer participation will most likely accelerate. Stacking of environmental credits has the potential to increase the attractiveness of multiple environmentally beneficial practices in rice production, including methane mitigation for carbon credits.

Optimizing funding incentives such as EQIP for conservation practices like AWD or early drainage will increase the likelihood of participation. Additionally, if the USDA cost shares a program such as EQIP, allowing for a more local focus for ranking criteria, and that can be flexible with funding opportunities, then participation would increase.

Results from the following economic feasibility analysis will inform agricultural carbon market advocates on how to engage with farmers who see carbon credits as a business opportunity.

c. Economic Feasibility

Farmers are interested in practices and programs that can increase their business' success and sustainability. As a part of this CIG, project partners investigated the costs of developing a project with rice farmers. Based on the current carbon market price and the rigorous offset standards, aggregation of multiple farmers into a single project is absolutely necessary for economic feasibility. Additionally, EDF explored the marginal abatement costs of each of the practices in both California and the Midsouth rice growing regions.

Carbon Credit Project Costs

Recognizing that developing a carbon offset project means participation in the voluntary or compliance market, certain transaction costs must be taken into account. These costs can be broken up into four categories: mitigation, project development, verification and credit transaction costs.

Mitigation Costs:[8] Total costs will vary by the combination of practices implemented and the farm-specific characteristics that affect the implementation of practices. The risks outlined above will also influence a farmer's decision to implement a certain practice. Taking that into account, the costs of project implementation can be low for practices like early drainage, since farmers simply undertake the same practice earlier than normal and no additional equipment is needed. AWD in the Midsouth and dry seeding in California may require unique equipment that farmers will invest in or lease. Other costs associated with the implementation of a practice include the cost of the time spent collecting data and evidence that supports that a practice took place. As explained above, this data collection cost can be a large barrier to farmer participation.

Project Development Costs:[9] Farmers will likely partner with a project developer that translates the eligible project activities into carbon credits. The project developer will calculate the emissions reductions, manage the data collection process, develop the necessary project documents, oversee the verification, retain the project records, and in some cases, broker the sale of credits. For this time and effort, the developer will typically take a portion of the revenue generated upon the sale of the credits. Project developers also shoulder a large portion of the carbon credit project risk and will put processes in place to mitigate these inherent risks.

[8] Mitigation costs are referred to as practice costs in the aggregation analysis below.
[9] Project development costs are referred to as administrative costs in the aggregation analysis below.

Verification Costs:[10] All projects must go through an independent, third-party verification before credits are issued in the voluntary or compliance market. While these costs may fluctuate depending on the verification body, the project type, the complexity of the management practices, and the size of the project, generally speaking, verification costs are the largest cost for project development, often as high as 50% from EDF's economic analysis (see below). As third-party verifiers become more familiar with agricultural projects, project developers implement and refine processes to reduce the risk of misstatement and farmers find easier monitoring mechanisms, verification costs will decrease as they have with other offset protocols such as forestry.

Transaction Costs:[11] Depending on the carbon registry that the project developer decides to use, there are various costs for creating accounts, listing projects, creating credits, and trading credits. Project developers involved in multiple projects listed on a single registry may be able to reduce costs given that certain fees are membership-based.

Aggregation

We have found that by aggregating or consolidating individual farmers into groups of projects, economies of scale can be found, reducing project development, verification, and credit transaction costs. Aggregation is accommodated by registries in the voluntary market, but has encountered some concerns from the compliance market. Further analysis of the benefits of aggregation has been submitted in other reports for ARB and NRCS. In April 2014, EDF and partners submitted two documents to ARB, entitled "Why is Aggregation Necessary?" and "Aggregation Concerns Identified by ARB" (Appendices A and B).

Carbon Credit Economic Analysis of Aggregation- California Example

To demonstrate the difference that project aggregation makes, below are three scenarios: no aggregation, 50% aggregation, and 100% aggregation.

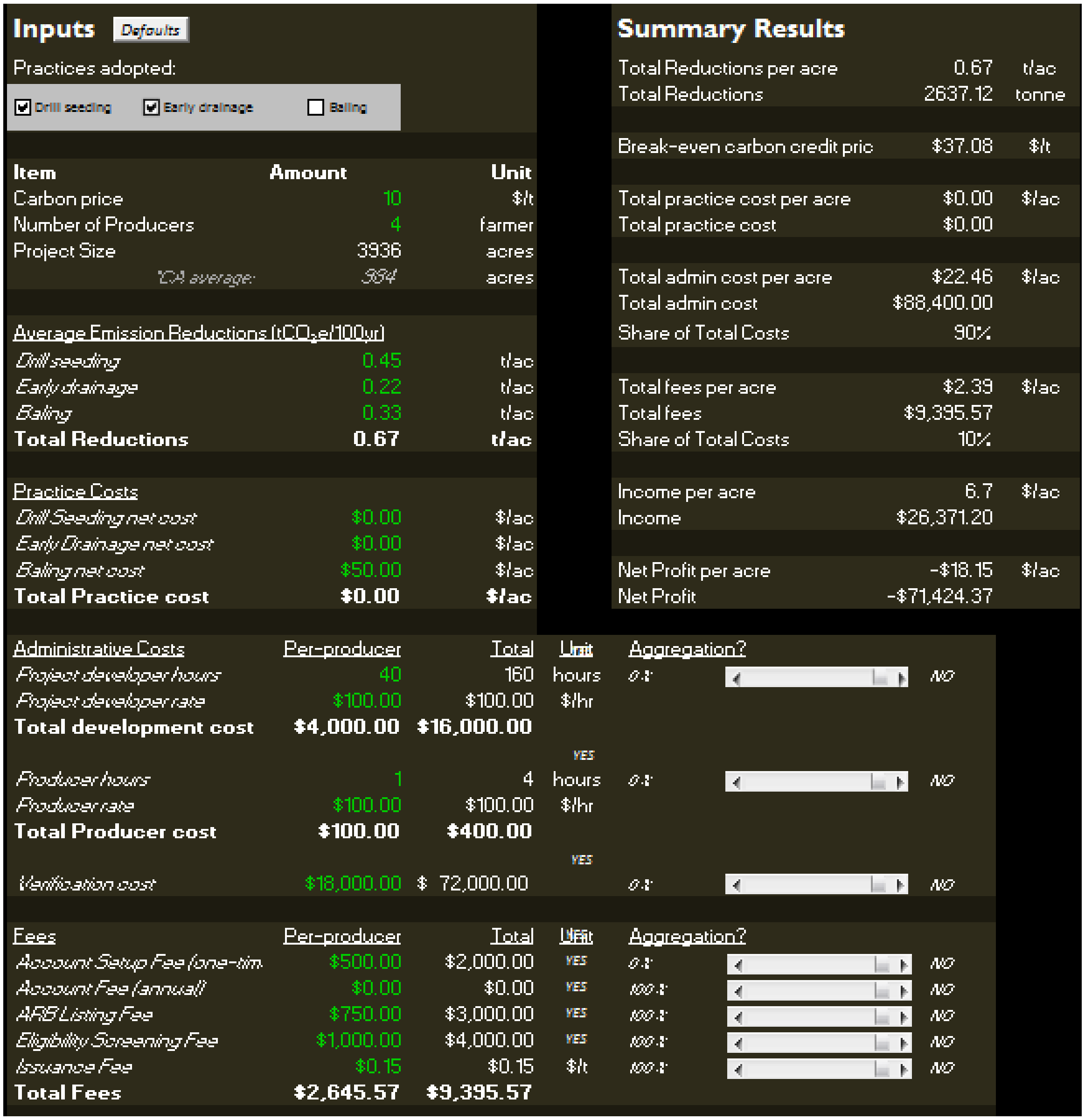
In all scenarios, we assumed:

- four farmers were participating and each implemented dry seeding and early drainage practices on 984 acres (which is the average acreage for rice farmers in California) for a total of 3936 acres enrolled
- a carbon price of $10 per ton
- total reductions for the dry seeding and early drainage practices were 0.67 tons of CO_2e per acre each year on average (fluctuations per field per year are expected)
- farmers already had dry seeding equipment and that there were no additional costs associated with implementing dry seeding

[10] Verification costs are referred to as administrative costs in the aggregation analysis below.
[11] Transaction costs are referred to as fees in the aggregation analysis below.

Scenario 1: No aggregation

For a scenario with no project aggregation, each project is implemented, listed, verified and registered independently of any other projects. Administrative costs and fees make these projects infeasible, with a break-even carbon credit price of $37.08 per ton of CO_2e.



Inputs Defaults

Practices adopted:

☑ Drill seeding ☑ Early drainage ☐ Baling

Item	Amount	Unit
Carbon price	10	$/t
Number of Producers	4	farmer
Project Size	3936	acres
CA average:	*984*	acres
Average Emission Reductions ($tCO_2e/100yr$)		
Drill seeding	0.45	t/ac
Early drainage	0.22	t/ac
Baling	0.33	t/ac
Total Reductions	**0.67**	**t/ac**
Practice Costs		
Drill Seeding net cost	$0.00	$/ac
Early Drainage net cost	$0.00	$/ac
Baling net cost	$50.00	$/ac
Total Practice cost	**$0.00**	**$/ac**

Summary Results

Total Reductions per acre	0.67	t/ac
Total Reductions	2637.12	tonne
Break-even carbon credit pric	$37.08	$/t
Total practice cost per acre	$0.00	$/ac
Total practice cost	$0.00	
Total admin cost per acre	$22.46	$/ac
Total admin cost	$88,400.00	
Share of Total Costs	90%	
Total fees per acre	$2.39	$/ac
Total fees	$9,395.57	
Share of Total Costs	10%	
Income per acre	6.7	$/ac
Income	$26,371.20	
Net Profit per acre	-$18.15	$/ac
Net Profit	-$71,424.37	

Administrative Costs	Per-producer	Total	Unit	Aggregation?	
Project developer hours	40	160	hours	*0%*	*NO*
Project developer rate	$100.00	$100.00	$/hr		
Total development cost	**$4,000.00**	**$16,000.00**			
			YES		
Producer hours	1	4	hours	*0%*	*NO*
Producer rate	$100.00	$100.00	$/hr		
Total Producer cost	**$100.00**	**$400.00**			
			YES		
Verification cost	$18,000.00	$ 72,000.00		*0%*	*NO*

Fees	Per-producer	Total	Unit	Aggregation?	
Account Setup Fee (one-tim	$500.00	$2,000.00	*YES*	*0%*	*NO*
Account Fee (annual)	$0.00	$0.00	*YES*	*100%*	*NO*
ARB Listing Fee	$750.00	$3,000.00	*YES*	*100%*	*NO*
Eligibility Screening Fee	$1,000.00	$4,000.00	*YES*	*100%*	*NO*
Issuance Fee	$0.15	$0.15	$/t	*100%*	*NO*
Total Fees	**$2,645.57**	**$9,395.57**			

Scenario 2: 50% aggregation

With fifty percent aggregation, we see significant improvements in economic feasibility. For this scenario, we assume that two separate project verifications take place (each representing half of the acreage) and the project developer still needs to invest a large amount of time per project. Also, two projects are listed and screened separately. In this scenario, the break-even carbon credit price is slightly more reasonable at $18.69 per ton of CO_2e.

Inputs Defaults

Practices adopted:

☑ Drill seeding ☑ Early drainage ☐ Baling

Item	Amount	Unit
Carbon price	10	$/t
Number of Producers	4	farmer
Project Size	3936	acres
CA average:	*984*	acres
Average Emission Reductions ($tCO_2e/100yr$)		
Drill seeding	0.45	t/ac
Early drainage	0.22	t/ac
Baling	0.33	t/ac
Total Reductions	**0.67**	**t/ac**
Practice Costs		
Drill Seeding net cost	$0.00	$/ac
Early Drainage net cost	$0.00	$/ac
Baling net cost	$50.00	$/ac
Total Practice cost	**$0.00**	**$/ac**

Summary Results

Total Reductions per acre	0.67	t/ac
Total Reductions	2637.12	tonne
Break-even carbon credit pric	$18.69	$/t
Total practice cost per acre	$0.00	$/ac
Total practice cost	$0.00	
Total admin cost per acre	$11.28	$/ac
Total admin cost	$44,400.00	
Share of Total Costs	90%	
Total fees per acre	$1.24	$/ac
Total fees	$4,895.57	
Share of Total Costs	10%	
Income per acre	6.7	$/ac
Income	$26,371.20	
Net Profit per acre	-$5.82	$/ac
Net Profit	-$22,924.37	

Administrative Costs	Per-producer	Total	Units	Aggregation?	
Project developer hours	20	80	hours	0%	NO
Project developer rate	$100.00	$100.00	$/hr		
Total development cost	**$2,000.00**	**$8,000.00**			
			YES		
Producer hours	1	4	hours	0%	NO
Producer rate	$100.00	$100.00	$/hr		
Total Producer cost	**$100.00**	**$400.00**			
			YES		
Verification cost	$18,000.00	$ 36,000.00		50%	NO

Fees	Per-producer	Total	Unit	Aggregation?	
Account Setup Fee (one-tim	$500.00	$1,000.00	YES	50%	NO
Account Fee (annual)	$0.00	$0.00	YES	100%	NO
ARB Listing Fee	$750.00	$1,500.00	YES	100%	NO
Eligibility Screening Fee	$1,000.00	$2,000.00	YES	100%	NO
Issuance Fee	$0.15	$0.15	$/t	100%	NO
Total Fees	**$2,645.57**	**$4,895.57**			

Scenario 3: 100% aggregation

Finally, in a scenario where all producers are aggregated into a single project, a single verification would be necessary. The project developer would find significant economies of scale by grouping multiple producers together and therefore would reduce the amount of time needed to spend processing documents. At this level, the break-even carbon credit price is $9.50 per ton of CO_2e, yielding $0.34 per acre or $334.56 total profit for each producer. Most importantly, projects experienced a 74% decrease in break-even costs and became financially feasible. This shows that, regardless of the numbers in this example, aggregation has a powerful impact on the solvency of any given project.

Inputs

Defaults

Practices adopted:

☑ Drill seeding ☑ Early drainage ☐ Baling

Item	Amount	Unit
Carbon price	10	$/t
Number of Producers	4	farmer
Project Size	3936	acres
**CA average:*	*984*	acres
Average Emission Reductions (tCO$_2$e/100yr)		
Drill seeding	0.45	t/ac
Early drainage	0.22	t/ac
Baling	0.33	t/ac
Total Reductions	**0.67**	**t/ac**
Practice Costs		
Drill Seeding net cost	$0.00	$/ac
Early Drainage net cost	$0.00	$/ac
Baling net cost	$50.00	$/ac
Total Practice cost	**$0.00**	**$/ac**

Summary Results

Total Reductions per acre	0.67	t/ac
Total Reductions	2637.12	tonne
Break-even carbon credit pric	$9.50	$/t
Total practice cost per acre	$0.00	$/ac
Total practice cost	$0.00	
Total admin cost per acre	$5.69	$/ac
Total admin cost	$22,400.00	
Share of Total Costs	89%	
Total fees per acre	$0.67	$/ac
Total fees	$2,645.57	
Share of Total Costs	11%	
Income per acre	6.7	$/ac
Income	$26,371.20	
Net Profit per acre	$0.34	$/ac
Net Profit	$1,325.63	

Administrative Costs	Per-producer	Total	Units	Aggregation?	
Project developer hours	10	40	hours	*0:1*	*NO*
Project developer rate	$100.00	$100.00	$/hr		
Total development cost	**$1,000.00**	**$4,000.00**			
			YES		
Producer hours	1	4	hours	*0:1*	*NO*
Producer rate	$100.00	$100.00	$/hr		
Total Producer cost	**$100.00**	**$400.00**			
			YES		
Verification cost	$18,000.00	$18,000.00		*100:1*	*NO*

Fees	Per-producer	Total	Units	Aggregation?	
Account Setup Fee (one-tim	$500.00	$500.00	YES	*100:1*	*NO*
Account Fee (annual)	$0.00	$0.00	YES	*100:1*	*NO*
ARB Listing Fee	$750.00	$750.00	YES	*100:1*	*NO*
Eligibility Screening Fee	$1,000.00	$1,000.00	YES	*100:1*	*NO*
Issuance Fee	$0.15	$0.15	$/t	*100:1*	*NO*
Total Fees	**$2,645.57**	**$2,645.57**			

Using this calculator,[12] identifying alternative scenarios with a variety of acreages, practices, and potential development costs, is simple. As demonstrated through this exercise, because of rice cultivation's small acreages and emissions reduction potential, aggregation is a necessity.

Economics of Practice Implementation in California

CIG project partners submitted a report in 2010 for NRCS grant NRCS 69-3A75-7-87 that outlined the economic costs for each of the proposed practices. For the current CIG (concluding in 2015), further analysis looked to the marginal abatement costs as an indicator of economic feasibility.

[12] This calculator is available upon request from EDF.

Marginal Abatement Cost Curves-California

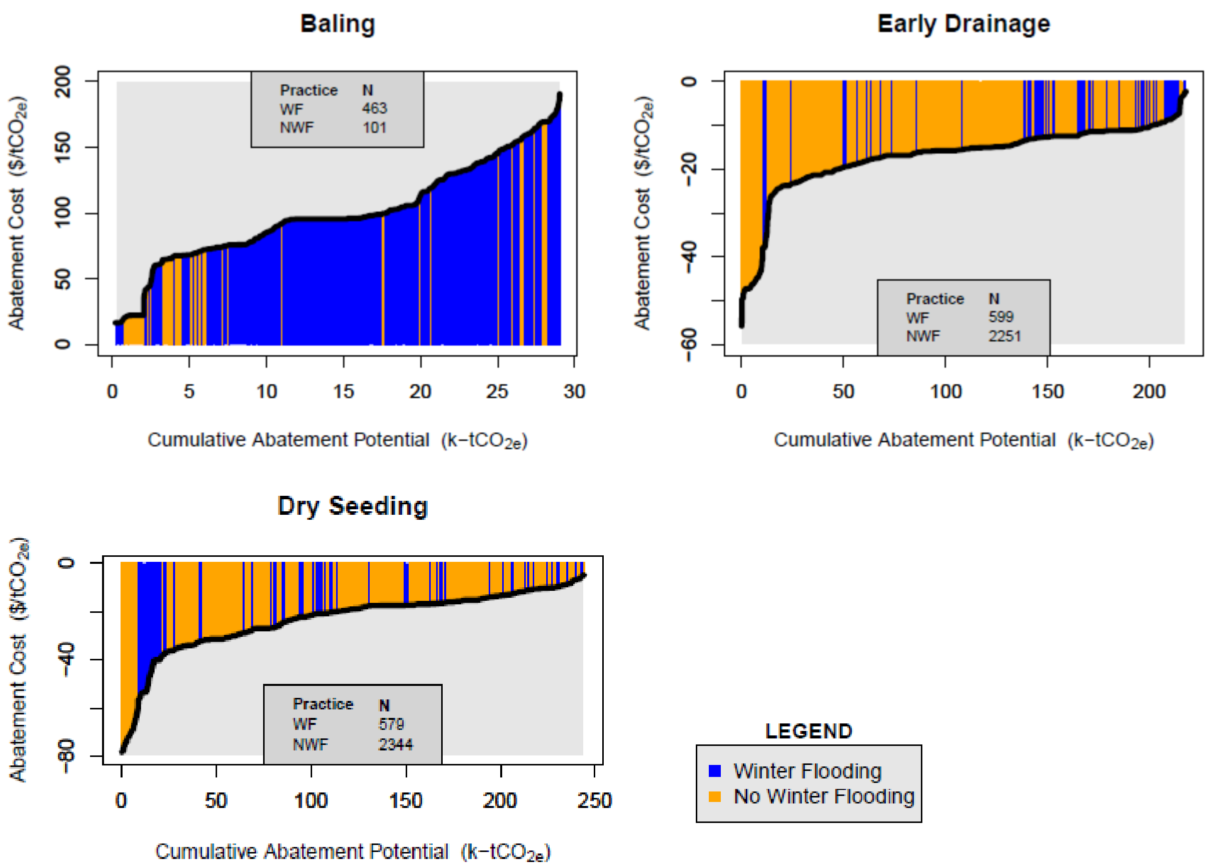
Our analysis builds on a prior study (UC Davis Agricultural Issues Center 2010) that estimates GHG emissions and yields for the majority of rice producing acreage in the state. This was performed using the DeNitrification-DeComposition (DNDC 2012) biogeochemical model: 6,316 fields were simulated for 16 farming practices, and parameters were calibrated to the Sacramento region and the Calrose rice variety. In our study, we estimate the abatement costs of a suite of specific practices. These are: dry seeding the rice fields, baling harvest residue, and hydroperiod adjustments (draining of fields in midseason, before harvest and/or reducing winter flooding).

We tabulate the cost of each management practice through a combination of literature (Mutters et al. 2004, 2007; Greer et al. 2012), farmer and farm advisor consultation. These costs are then combined with abatement estimates to generate marginal abatement cost curves (MACCs) for each practice. Our results indicate that four of the five practices have negative abatement costs with averages ranging from -\$29.45 to -\$0.45 /acre, while one practice, baling, has a positive average cost of \$120.53 /acre. One practice is accompanied with a significant decrease in yield (not depicted in the charts); for the others yields are maintained at similar levels.

Additionally, two of the practices represented here are not allowed to generate credits under the ARB Rice Protocol- no winter flooding and baling. No winter flooding is not included in the ACR Rice Methodology. After the initial CIG's completion in 2010, project partners decided not to pursue the practice of no winter flooding given the potential impact on waterbird habitat. A subsequent report by Point Blue indicated a potential impact to waterbirds from the baling of rice straw in California and was eliminated in the ARB Rice Protocol; however, it remains in the ACR Rice Methodology.

The MACCs show the cost of abating emissions, for each given practice (baling, early drainage, and dry seeding). These per-ton costs are then sorted in order of low to high while emissions are denoted in cumulative amounts, illustrating the trends in abatement costs across all fields. In the graphs below, blue lines depict fields that had a winter flooded (WF) baseline over 2008-2013, while orange lines were not winter flooded (NWF).

Figure 1: Marginal Abatement Cost Curves- California



Economics of Practice Implementation in the Midsouth

Most of the economic analysis for the Midsouth began in 2011 and continued throughout the implementation of the Midsouth pilot project. As with California, we investigated the marginal abatement costs as an indicator of economic feasibility.

Costs were identified for each type of field configuration: zero grade, straight levee, and contour levee. Zero grade fields are necessary for the implementation of AWD.[13]

[13] Costs vary a great deal depending on management. Key drivers behind some of these differences are seed type (pure line vs hybrid), plastic pipe and irrigation management depending on grading, and pump type (diesel vs electric). Budgets do not include land ownership/tenancy costs.

Item	Zero Grade	Straight Levee	Contour Levee
Direct Expenses			
Fertilizers	118.87	118.87	118.87
Pesticides	137.66	139.70	139.70
Planting	30.40	35.57	35.57
Hauling	57.40	54.60	51.80
Drying	65.60	62.40	59.20
Labor	33.93	40.89	65.82
Irrigation	55.10	78.30	95.70
Machinery/Fuel	98.47	123.82	144.13
Other	59.60	62.66	60.90
Overhead			
Irrigation	58.86	59.10	37.33
Machinery	51.81	54.12	59.74
Average total cost per acre	767.70	830.03	868.76

Figure **2**: Changes in Costs and Savings by Practice ($/acre)[14] **Practice**	**Costs**	**Savings**
Alternate Wetting and Drying		3.15 to 26.25
Early Drainage (7 days)		5.04 to 8.55
Early Drainage (10 days)		7.18 to 12.19
Baling	-50.00	

To estimate the cost savings, we made the following assumptions:

- Water obtained from groundwater well, pumped at a cost of $3.75/acre-inch using diesel powered machinery, $2.21/ac-in using electric machinery (weighted average of $2.90/ac).
- Reductions in water use:
  - AWD = 15 acre inches
  - ED7 = 2.28 acre inches
  - ED10 = 3.25 acre inches
- Additional costs for AWD include:

[14] MSU Rice Planning Budgets 2015, farmer & advisor consultation, informed by other regional cost budgets.

    - Side inlet polypipe for faster, safer irrigation is $14/acre if not already implemented
- There is a wide variability in baling costs. The scenario herein includes approximate costs for:
    - Small scale baling machinery, fuel and labor
    - Replacement of lost soil nitrogen

Marginal Abatement Cost Curves- Midsouth

In the Midsouth, there is a large variability in the sign and magnitude of marginal abatement costs, depending on the various combinations of practices adopted and site characteristics.

Baling practices show positive marginal abatement costs ranging from $10 to $20 /tCO2e. This shows that baling would not necessarily be economical at carbon prices of less than $10/ton. This can change in the case of higher carbon prices, or the ability to bale at a net cost lower than $50/acre. Reducing the cost of baling would be critical in the context of this protocol, considering the large share of reductions associated with this practice alone. It is important to remember that baling also presents risks of crop failure, in addition to potential environmental consequences such as waterfowl habitat and forage loss.

The subset of drainage practices exhibit negative abatement costs simply due to the assumed savings in irrigation costs, combined with the GHG reductions these provide. This suggests that drainage practices are able to provide a considerable incentive to producers, especially when combined with a carbon payment that may generate additional revenue. One must nonetheless keep in mind that these practices carry a greater risk of negative yield effects which are not readily quantifiable.

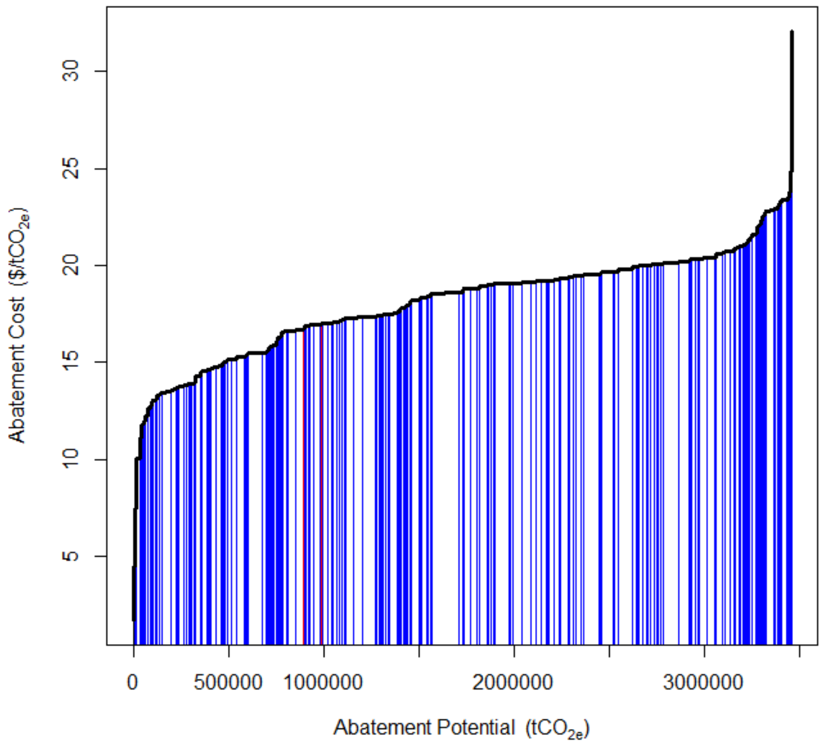
Below, the most abating combination of practices for each individual area are indicated by different colors on the MACCs (see key to the left of Figures 3 and 4). Possible practices include:

- Rotation (rs or rr): fields are either in a rice soy (rs) rotation or continual rice (rr)
- Flooding (awd or cf): fields are practicing AWD (awd) or continual flooding (cf)
- Drainage (ed7, ed10 or norm): fields drain 7 days earlier than normal (ed7), fields drain 10 days earlier than normal (ed10) or fields drain normally (norm)
- Rice straw removal (bale or nobale): fields are baled and rice straw is removed after harvest (bale) or rice straw remains after harvest and is incorporated back into the soil (nobale)
- Winter flooding (wf or nwf): fields are flooded during winter for bird habitat or rice straw decomposition (wf) or fields are not flooded during winter (nwf)

Figure 3: Marginal Abatement Cost Curve for Baling in Midsouth

- rs_awd_ed10_bale_nwf
- rs_awd_ed7_bale_nwf
- rs_awd_ed10_bale_wf
- rr_awd_ed10_bale_wf
- rs_awd_norm_bale_nwf
- rr_cf_ed10_bale_wf
- rs_awd_ed7_bale_wf
- rs_awd_norm_bale_wf
- rs_cf_ed10_bale_nwf
- rs_cf_ed7_bale_nwf
- rs_cf_norm_bale_nwf

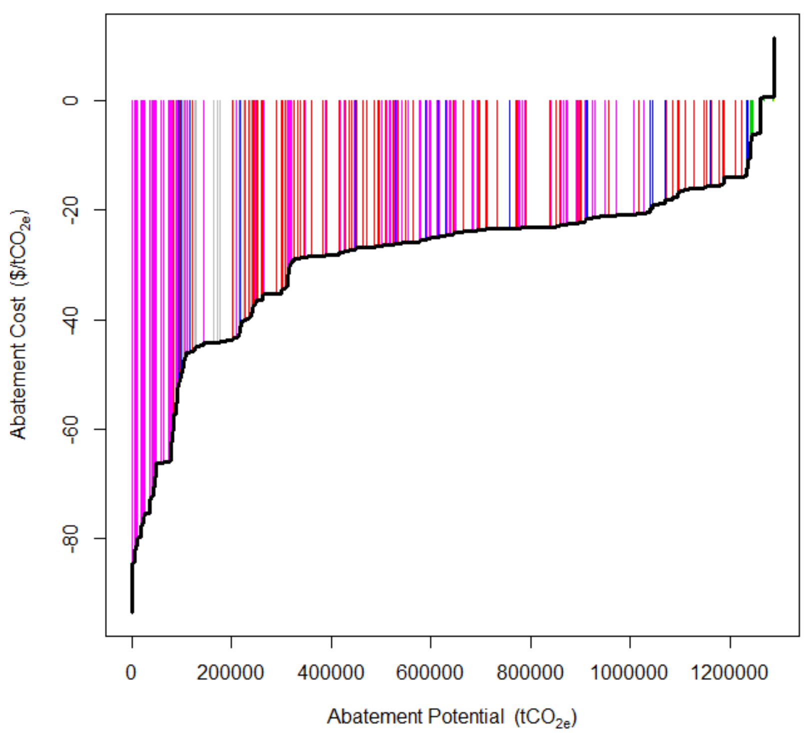
Summary -	Count
rs_awd_ed10_bale_nwf	248
rs_awd_ed7_bale_nwf	249
rs_awd_ed10_bale_wf	8
rr_awd_ed10_bale_wf	1
rs_awd_norm_bale_nwf	481
rr_cf_ed10_bale_wf	1
rs_awd_ed7_bale_wf	1
rs_awd_norm_bale_wf	3
rs_cf_ed10_bale_nwf	1
rs_cf_ed7_bale_nwf	3
rs_cf_norm_bale_nwf	1



- rs_awd_ed10_nobale_nwf
- rs_awd_ed7_nobale_nwf
- rr_awd_ed10_nobale_nwf
- rr_awd_ed7_nobale_nwf
- rs_awd_norm_nobale_nwf
- rr_awd_norm_nobale_nwf
- rr_cf_ed10_nobale_nwf
- rr_cf_ed7_nobale_nwf
- rs_awd_ed10_nobale_wf
- rr_awd_ed7_nobale_wf
- rr_awd_norm_nobale_wf
- rr_cf_ed10_nobale_wf
- rr_cf_ed7_nobale_wf
- rr_cf_norm_nobale_wf

Figure 4: Marginal Abatement Cost Curve for Drainage Practices (AWD and ED) in Midsouth

Summary -	Count
rs_awd_ed10_nobale_nwf	418
rs_awd_ed7_nobale_nwf	129
rr_awd_ed10_nobale_nwf	109
rr_awd_ed7_nobale_nwf	47
rs_awd_norm_nobale_nwf	201
rr_awd_norm_nobale_nwf	48
rr_cf_ed10_nobale_nwf	11
rr_cf_ed7_nobale_nwf	5
rs_awd_ed10_nobale_wf	4
rr_awd_ed7_nobale_wf	5
rr_awd_norm_nobale_wf	4
rr_cf_ed10_nobale_wf	13
rr_cf_ed7_nobale_wf	1
rr_cf_norm_nobale_wf	1



Improving Economic Feasibility

It is important to note that the MACC only looks at the cost to implement the practice and not to generate credits. As indicated above, aggregation is the best opportunity for improving the economic feasibility of rice cultivation offset projects to reduce methane from rice fields. Partnering emissions reductions with payments for other environmental co-benefits, such as nitrogen management for nitrous oxide reductions, habitat maintenance incentives, and water quality credits could increase the economic value and therefore, the potential for project implementation. However, payment stacking requires a cautious approach due to additionality issues, especially in combining emission reductions with other offset-type markets.

Reductions in the amount of time it takes to collect and process data will also decrease the administrative costs associated with project implementation. EDF and Winrock are investigating opportunities to streamline data collection, analysis and emissions modeling so as to minimize project development costs. Results from investments made by ARB (DNDC model improvements and a verification pilot program) will provide additional cost savings for new project developers interested in agricultural offsets from rice or other crops with emission mitigation protocols.

III. Conclusion

From this analysis, we believe that there is a potential for reductions in methane emissions from changing rice cultivation practices in California and the Midsouth. While significant technical, social and economic barriers remain, it is clear that opportunities abound for rice farmers, and eventually other crops, by reducing GHG emission and the creation of carbon offsets.

Analyses performed as part of this CIG indicate that improving the economic feasibility of projects will encourage the uptake of technically feasible practices. Production risks associated with technically feasible practices currently discourage implementation, but can be lessened with advisor guidance on the best practices to implement for each specific farm or field.

With greater economic incentives and production risks mitigated, innovative rice farmers will increase their participation and the carbon market will find it easier to overcome social barriers expressed by our pilot farmer partners. Main social constraints are fears of regulation, lack of market knowledge and confidence, and the substantial investments of time upfront without seeing benefits.

To address these barriers, we conclude that

- To improve the technical feasibility and reduce production risk associated with carbon mitigating practices:
    - carbon offset project developers must identify the least risky practices for any individual farmer based upon farm-specific characteristics, and
    - NRCS advisors, cooperative extension, and other crop consultants must receive information and training on the potential for these emissions reduction practices.

- To improve the social feasibility of carbon project implementation:
  - education is needed for all agricultural carbon market participants, from farmers and their crop advisors, to potential project developers and verifiers,
  - advocates of GHG mitigation practices must improve the attractiveness of participation by developing simple and clear messaging, and
  - EDF, ACR and others must continue to identify ways to reduce implementation costs by streamlining data collection and processing and to increase incentives for positive environmental outcomes.
- Given the economic feasibility outlined above:
  - scaling up implementation will require the aggregation of smaller projects into larger consolidated projects to reduce the costs associated with project development, verification, and credit creation,
  - in the Midsouth, water and energy efficiency practices may prove more profitable and attractive if farmers intend to only participate in the voluntary market.

We look forward to continuing our joint efforts to enhance the overall project feasibility of agricultural environmental markets. Carbon offsets from agriculture are an important voluntary incentive to increase GHG mitigation and meet global mitigation goals. Pilot implementation of these practices demonstrates that farmers are willing and interested to make a difference on their fields. We applaud the first 21 farmers reducing methane emissions on over 22,000 acres across the United States and look to them as examples of what is to come.

Appendix A- Why is Aggregation Necessary?

Why is Aggregation Necessary?

April 22, 2014

1. Farmers don't have the necessary carbon market knowledge
    a. History proves that farmers don't expand into tangential businesses.
        i. According to ARB data only 10 of the historic 19 diary digesters are currently in operation
    b. Protocols are very complicated and required experience to implement
        i. According to one verifier, dealing with forest owners takes significantly more time than dealing with a project developer
    c. Running DNDC is very technical and, even with the tools in development, will require someone who understands models to be able to run DNDC to create the baseline and project scenarios necessary for developing a project
    d. Negotiating a contract with a buyer is very complex and most farmers will not take the time to understand or have the capacity to negotiate them
        i. Contracts are long and complex. As an example PG&E's contract is 40 pages and SCE contract is 52 pages
        ii. Sellers are required to provide Letters of Credit, security interest in offset proceeds, and potentially other forms of collateral for their projects
    e. Due to purchase requirements farmers will not be able to contract with most buyers
        i. PG&E and SCE's Request for Offers have a minimum offer size of 25,000 tons
        ii. Farmers will need to sell to someone who will aggregate their projects for sale into the market. This will be aggregation, but will be extremely expensive due to the number of transactions required to enter the market

2. Project Developers (PD) have the capacity and incentive to aggregate projects
    a. If a PD's project fails, they risk going out of business
    b. PD's will be able to refund invalidated credits. This is something farmers will have a very hard time doing
    c. PD has the expertise to understand protocols and how to develop projects

d. PD can lower data acquisition costs through aggregation

e. PD will implement processes and procedures to ensure data collection and management for projects

f. PD can lower risks of the project. They become a filter for farmers without strong records or who can't meet the short or long term requirements inherent to offset protocols

Appendix B- Aggregation Concerns and Solutions

Aggregation Concerns Identified by ARB

April 22, 2014

ARB Concern	Proposed Solution
It is not possible to obtain farm or field-level data from individual farmers because the Offset Project Data Report (OPDR) would contain only summary (aggregate-level) data	Leverage the experience from the nitrogen tracking and reporting system developed by the California Department of Food and Agriculture (CDFA). Farmers report to their Regional Water Board through an aggregator. Field-level records are retained by the grower and the aggregator. Once sent to the aggregator, the data is compiled into a summary report before being reported to the relevant Regional Water Board. The field-level data is available for review by the Water Board upon request. ARB could require that Offset Project Operator (OPO) provide detailed records to the Authorized Project Designee (APD) and the verifier, but not require it in the OPDR due to confidentiality. Detailed information could be obtained by ARB through the verifier or the APD.
What if a farmer doesn't implement the practice, makes significant changes to their cropping cycle, or stops planting rice entirely once the project is underway?	1. This issue is addressed in the protocol, in that the OPDR must note whether information submitted at the time of project listing is still correct, and if not, how it has changed. OPOs are also required to report total project acreage to ARB each year. Fields ceasing to implement a project activity and/or grow rice should be removed from the aggregate and not permitted to reenter. Notably, additional consideration is needed for treatment of a fallow year that is part of the baseline cropping cycle. 2. Conduct a desk audit of critical criteria on ALL fields every year. Problems with data collection and inaccuracies can be very often be caught through review of the paperwork. 3. Utilize a local notary or agronomist to take notarized pictures of a field when practices take place. 4. Verify practices with remote sensing technologies or

	independent databases (see section below).
It is impossible to verify practices without site visits	Challenges exist with verifying all agricultural projects, partly because verification doesn't take place concurrent to the project activity. As such, site visits (for all rice projects) provide only minimal added value. Suitable alternatives are: 1. Wet seeding (CA) – Satellite technology is 93% accurate at separating wet versus dry seeding 2. Early Drainage (CA) – Utilize a local notary or agronomist to take notarized pictures of a field when practices take place. In the future farmers could use a tool in development by the University of California at Davis, similar to the DD50 used in the Midsouth, which could provide documentation indicating when a farmer should have drained his field. This combined with pictures and logbooks could demonstrate when a farmer would have versus when they did implement a practice. 3. Early Drainage (AR) – The output from the DD50 model demonstrates when Heading should occur. This data is entered into a database independently managed by the University of Arkansas. This information can be used to corroborate other records, such as log books, demonstrating when a farmer implements a practice. 4. Alternate Wetting and Drying (AR) – Farmers typically outsource the water management on their land. This is an independent source of data confirming when the farmer requested water deliveries. An additional option is to take soil moisture samples remotely.
In the case that invalidation of some credits from a project is necessary, it is not possible to distinguish which credits to invalidate (i.e. which credits come from the field requiring invalidation) within a single OPDR	The solution here depends on the reason for invalidation of credits: 1. Overstatement by more than 5% - the data in the project must be reviewed in order to determine where the overstatement occurred. Unless the original verifier failed to identify a systemic error at the APD level, the

	overstatement in an aggregate project will be specific to data collected from specific fields. Further, ARB could require that materiality is assessed and discussed at both the aggregate and field-levels in offset verification. 2. Project was not in accordance with all local, state, or national environmental and health and safety regulations – in order to know a violation, you need to know the entity and location where the violation occurred. The APD and the verifier will know the details for each landowner/field and will be able to determine how many credits were generated on that field (and need to be invalidated) if such a violation warrants invalidation. 3. Offset credits were issued in another voluntary or mandatory program – in this case the violation could be a result of action at the OPO or APD level. Either entity could have tried to seek credit in another program. In either case, the invalidation would be relative to the credits which were listed in another program.

Analysis of the Scale-up Potential for Carbon Credits from Changing Rice Cultivation Practices

From model simulations, we estimate that 3,067,637 tons of CO_2 equivalent is the maximum annual abatement potential from the implementation of rice cultivation practices[1] across all rice fields in the California Sacramento Valley and Midsouth rice growing regions.

July 2015 |NRCS Conservation Innovation Grant 69-3A75-11-133

I. Introduction

As a part of a grant from USDA, Environmental Defense Fund (EDF) has estimated the biophysical potential for greenhouse gas reductions for four rice management practices included in the American Carbon Registry's *Voluntary Emissions Reductions in Rice Management Systems Methodology* (here forward "ACR Rice Methodology"): dry seeding, early drainage, alternate wetting and drying, and baling.[2] In this protocol, specific practices and guidelines are presented but it is important to remember that such protocols are in a constant state of refinement. Additionally, there could be separate incentives and environmental benefits from adopting these practices that are not examined here. Furthermore, this estimation does not take into account the practices adopted by the California Air Resources Board (ARB) in their June 25, 2015 version of the *Rice Cultivation Projects Compliance Offset Protocol* (here forward "ARB Rice Protocol"); however, the practices between the two protocols are similar. Analysis of the maximum abatement potential is included for both California and Midsouth rice cultivation. This document provides those estimates along with the corresponding assumptions and calculations.

The DNDC Biogeochemical Model

To estimate the potential greenhouse gas (GHG) offset volume from rice management practices in California and the Midsouth, EDF contracted with DNDC Applied Research and Technology (DNDC-ART) to run the DeNitrification Decomposition (DNDC) biogeochemical model.[3] Analysis was performed by Applied GeoSolutions (AGS). Generally, the DNDC model predicts crop yield, carbon sequestration, nitrate leaching and carbon and nitrogen emissions by simulating the complex and multifaceted relationship between weather, soil type, crop, and geography. DNDC has been used to estimate (1) soil carbon sequestration in forested ecosystems, (2) GHG and ammonia emissions from livestock

[1] Practices included here are acknowledged under the American Carbon Registry Rice Methodology.
[2] ACR Rice Methodology, "Rice Management Systems," ACR, (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems)
[3] These simulations were run in 2013 for California and 2013-2014 for the Midsouth.

management systems, and (3) nitrous oxide (N_2O) and methane emissions from over 20 types of crops in a variety of agro-ecosystems. The DNDC model has been developed and continuously improved over the past 17 years to estimate GHG emissions from rice growing ecosystems in China, India, Japan, Thailand, Vietnam, Philippines, Brazil and Italy, as well as in the United States.

Input Requirements

As a part of developing this estimate, DNDC model version 9.5 was calibrated using field-measured data from peer reviewed articles as well as government databases. Previously, the model's calibration was primarily based on Asian rice production to provide estimates. AGS drew from University of California-Davis studies on actual CH_4 emissions in California rice production to calibrate the model for that region. For the Midsouth region which is consists rice grown in Arkansas, Missouri, Mississippi, Louisiana, and Texas, AGS drew from University of Arkansas, USDA Agricultural Research Service, UC Davis and peer reviewed published data to calibrate the model. Significant thought has been put into the analysis of uncertainty for both rice-growing regions and a journal article entitled "Margins of Safety for Agricultural Greenhouse Gas Emissions Offsets in the Presence of Model Bias and Structural Uncertainty" currently in preparation.[4] Uncertainty explanations are also included in each rice protocol (ACR Rice Methodology and ARB Rice Protocol).

To conduct a "run" of DNDC, three major data inputs are necessary: climate information, soil information and farming management information. Once a region or field location is specified, DNDC9.5 uses location-based temperature, precipitation and solar radiation information from the Daymet surface weather model (http://daymet.ornl.gov/). This data is then combined with detailed soil data from SSURGO. The farming management information required includes crop type and rotation, tillage practices, irrigation schedule or flood-up and drainage dates, and nutrient application dates and quantities. In California, AGS used the University of California Cooperative Extension (UCCE) Cost and Return studies to help determine the baseline management practices. In the Midsouth AGS used interviews with University of Arkansas researchers and extension publications (e.g. Mississippi Rice Grower's Guide, Louisiana Rice Production Handbook, Trends in Arkansas rice production, etc). Working with UCCE and industry experts, EDF used average dates and application rates as part of the rice management practices to calculate the below estimates.

The California run of DNDC simulates a 22-year time window, with the first 17 years serving to initialize the model for baseline conditions. Therefore, the volume of abatement potential for each of the practices (replacing wet seeding with dry seeding (drill seeding)), early drainage, and rice straw removal (baling)) represent the mean annual GHG fluxes for the last 5 years. Midsouth DNDC simulations were handled similarly to the California simulations: the model was initialized with a 10-year timeframe; abatement potential was calculated from a 2-year timeframe. In addition to the practices listed above for California, the Midsouth analysis included the alternate wetting and drying practice.

[4] Ducey, Mark and William Salas, et al, "Margins of Safety for Agricultural Greenhouse Gas Emissions Offsets in the Presence of Model Bias and Structural Uncertainty." *In Prep*.

Establishing Flooding Baseline with Remote Sensing

The DNDC9.5 model simulated GHG emissions from practice changes on more than 600,000 acres in California. This acreage data was drawn from the California Department of Water Resources information on where rice is grown and was specific down to the field level. For the Midsouth, the DNDC9.5 model simulated GHG emissions from practice changes on more than 5,700,000 acres – geographic modelling units were the combination of US General Soils Map (STATSGO2) polygons and county boundaries – rice area was based on USDA NASS Cropland Datalayer mapping of rice from 2008-2011. The baseline, against which the four ACR Rice Methodology practices are compared and evaluated, was designated in California from remote sensing imagery collected from 2008-2013 and in the Midsouth from a combination of soil map units in the SSURGO soils database and county-level political boundaries with rice production statistics from USDA. In this application of the DNDC model, AGS relied on multitemporal imagery from Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) available from USGS Earth Explorer. In addition, we evaluated Synthetic Aperture Radar (SAR) for mapping rice management practices in California and the Midsouth. Each sensor has particular strengths and the combination of multiple satellites can provide for comprehensive monitoring required to meet the needs of risk-based and randomized Monitoring, Reporting, and Verification necessary to make creation of offsets cost effective.

Using remote sensing, the past 5 years of historical winter flooding patterns were denoted for each field.[5] The baseline flooding pattern was designated according to the most prevalent pattern during this 5 year period. By using Landsat observations after the harvest, AGS then delineated which fields were flooded and which were not at time of overpass. By using multitemporal imagery we are able to track the flood patterns of an individual field with very high overall accuracy (>95%) in a cost efficient manner. The remote sensing science and algorithms have been peer-reviewed and published in a transparent and open manner. For the simulations, flood and drain dates were based on typical plant-harvest dates drawn from various sources of management data.

The baseline practice in California is continuous flooding on wet seeded fields with normal drainage and residue incorporation on a continuous rice field. The most prevalent baseline practice in the Midsouth is continuous flooding on dry seeded fields with normal drainage, residue incorporation on a rice-soy rotation. Therefore, the results below assume that baseline flooding patterns would remain the same, and that only other management practices are at play.

Uncertainty Deductions

A structural uncertainty deduction must be incorporated to account for the inherent uncertainty associated with the calculations in a process-based model such as DNDC. Across all practices, a deduction of 0.0268 t/ha (0.0108 t/ac) was applied to modeled reductions in emissions.[6,7]

[5] Given the success of remote sensing efforts and the potential remote sensing holds for future rice management monitoring and verification, the authors refer readers to CIG semi-annual report results for more analysis.
[6] This assumes an aggregated project area of greater than 10,000 hectares.

Input uncertainty was not accounted for in these estimates, as these estimates are site-dependent. In general, it has been estimated that this deduction will amount to 10% or less of the final abatement potential. More information on these uncertainties and deductions can be found in section 10.1 of the *Voluntary Emissions Reductions in Rice Management Systems Methodology*, or in additional documentation on the ACR website.[8,9]

Additional Project Emissions from Rice Straw Removal (Baling) and Practice Uncertainty

Additional emissions were assigned to baling practices according to ACR's Rice Methodology specification. The calculations were based on an assumed average of 7.5 t/ha of rice straw produced. The model assumes that baling removes 80% of this rice straw, or around 6 t/ha.

When rice straw is removed from a field, a large amount of nutrients is also removed. According to the ACR Rice Methodology, additional GHG emissions are generated from increases in N_2O emissions resulting from additional fertilization in the season after baling.[10] In the below calculation, EDF included the additional emissions from fertilizer application, which amount to 0.0447 tCO_2e/t x 6 t/ha or 0.2682 tCO_2e/ha. The impact of bailing is primarily a reduction of winter emissions for those systems that use winter flooding. This analysis incorporated a limited number of disparate data points in the model and, as a result, has higher uncertainty for baling than for the other three practices. This is the same for both CA and Midsouth.

Since rice straw will be removed from fields during baling for alternative end-uses, the ACR Rice Methodology requires that emissions from the end-use be included in the abatement calculation. EDF referenced the off-field emissions from rice straw description in the Methodology to determine that additional GHG emissions from off-field end uses averaged 0.02875 tCO_2e/t x 6 t/ha = 0.1725 tCO_2e/ha. All end-uses of straw are considered and averaged in this estimate.[11]

Adding both the increases in fertilization due to baling and the off-field emissions from rice straw, EDF determined the total value of additional project emissions to be 0.4407 tCO_2e/ha, or 0.1783tCO_2e/acre.

[7] This deduction is different from the uncertainty deduction approved for the ARB protocol, which is 0.128 $MTCO_2e$ according to equation 5.4 of the ARB Rice Protocol June 2015 (http://www.arb.ca.gov/regact/2014/capandtradeprf14/3CTAttach2RiceProtocol051115FINAL.pdf)

[8] ACR Rice Methodology, Structural Uncertainty Deduction Factors, ACR, February 2014 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/structural-uncertainty-deduction-factors-v2-0-feb2014-final.pdf), Errata and Clarifications, February 2014 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/errata-and-clarification-v1-0-feb2014-final.pdf), Errata and Clarifications, May 2015 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/acr-rice-errata-and-clarifications-v1-2-may-2015.pdf)

[9] ACR Rice Parent Methodology, ACR, July 2013 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/rice-meth-acr-v1-0_july-2013_final.pdf)

[10] ACR Rice Methodology, IFEF section 8.3.3, ACR, July 2013 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/rice-meth-acr-v1-0_july-2013_final.pdf)

[11] ACR Rice Methodology, OFEF section 8.3.2, ACR, July 2013 (http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/rice-meth-acr-v1-0_july-2013_final.pdf)

Because of limited data and measurements for certain emissions scenarios that include baling, the DNDC model struggles modeling emissions for baling, demonstrated by the estimation of potentials included below.

Baling was eliminated from the compliance offset protocol developed by the California Air Resources Board due to an impact on waterbird populations. A report developed by Point Blue Conservation Science for the California practices found much found much reduced populations of waterbirds in fields that were baled, even if the fields were subsequently flooded after baling. Similar concerns were raised by stakeholders in the Midsouth. Additional research is necessary to determine opportunities to implement baling in a manner than does not impact waterbird populations.

II. Greenhouse Gas Abatement Potential in California Rice

After being calibrated and validated for the Sacramento Valley region using peer-reviewed datasets, AGS calculated the potential GHG abatement (in tCO_2e) for each of the three practices included in the ACR Rice Methodology for California. EDF's analysis uses model simulations of rice management practices on each field, and then indicates which practice combination would yield the most GHG abatement for that particular field. For instance, because of certain soil characteristics (drawn from SSURGO), a rice field could potentially abate more by practicing both dry seeding and baling, but not practicing early drainage. In this case, the tCO_2e abatement from dry seeding and baling on that field would be included in the calculation. Similarly, a different field may abate the most by only practicing early drainage. The estimates below depict maximum abatement levels, achievable by pursuing the best possible practice combinations across all fields.

GHG Abatement Potential of ACR Rice Methodology Practices (California)

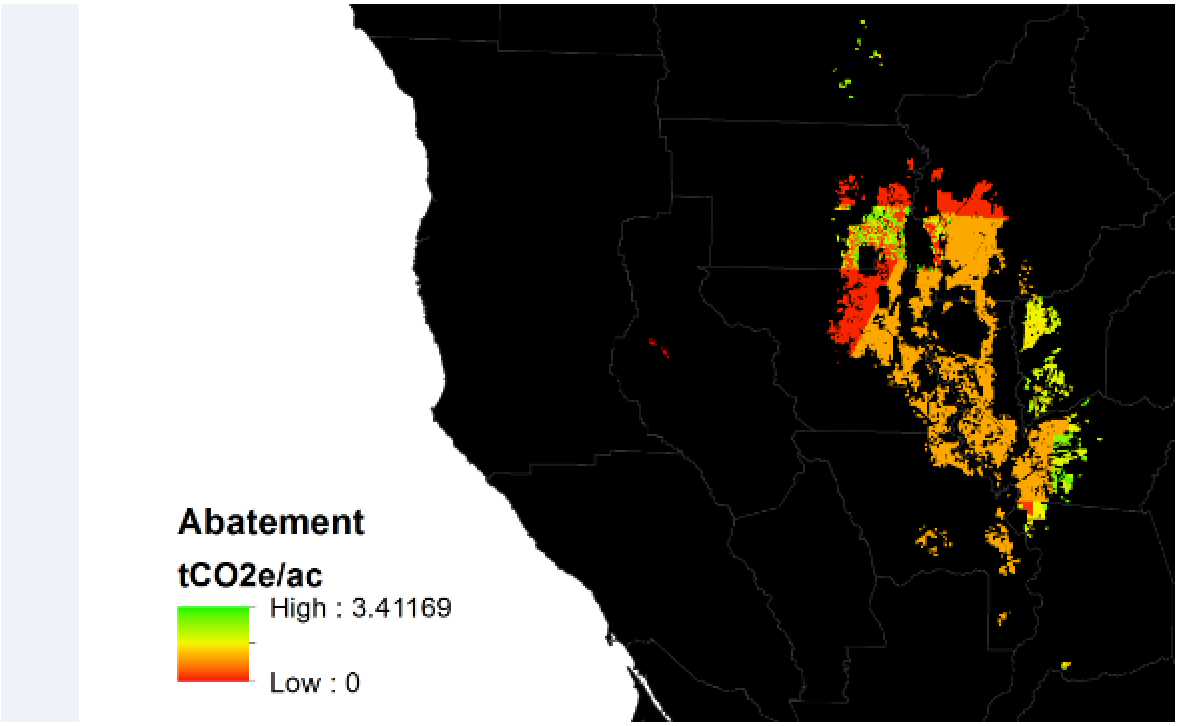
Figure 1: Baseline: 2008-2013 remote sensing imagery

Rice Management Practice	Maximum Potential Abatement (tCO_2e/yr)	% of Total Abatement Potential
Replacing wet seeding with dry seeding (drill seeding)	260,824	44%
Early drainage	151,459	25%
Rice straw removal (baling)*	187,134	31%
Total	***599,417***	*100%*

* This estimate of the maximum potential abatement of baling assumes a straight average of the end-use emissions of all eight possible end uses of baled rice straw (outlined in the ACR Rice Methodology). Baling is not an acceptable practice under the newly adopted ARB Rice Protocol.

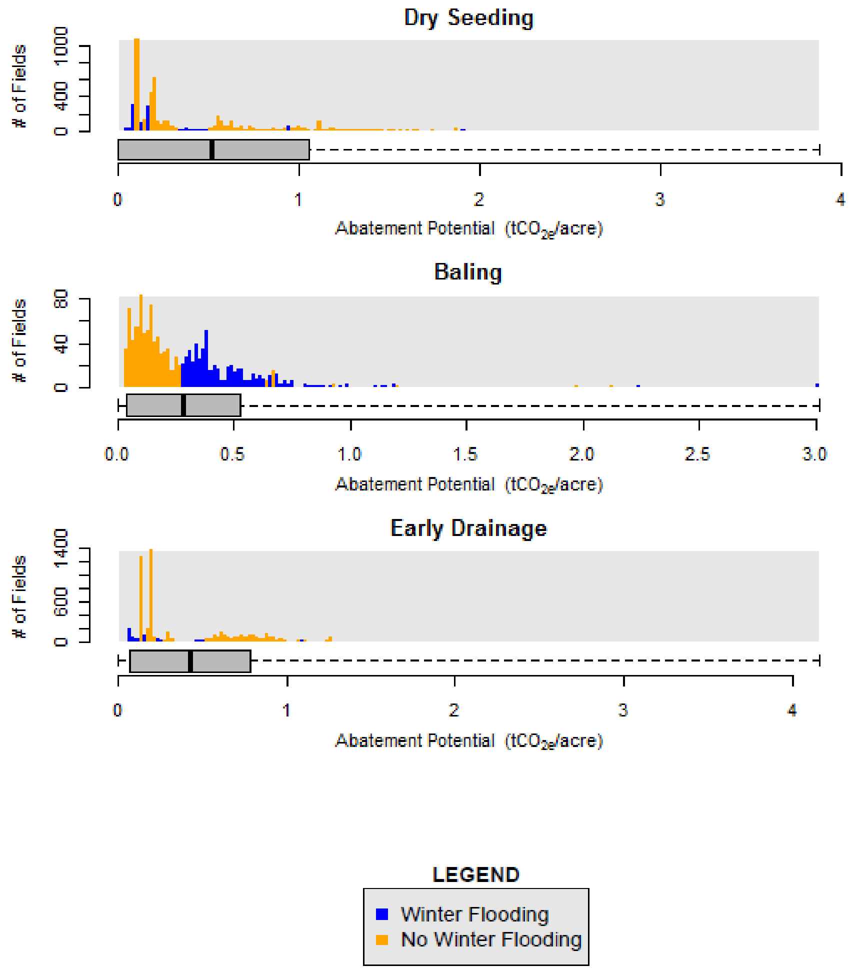
The maximum potential annual GHG abatement of 599,417 tCO_2e could hypothetically be achieved if all rice fields were farmed under the most optimal combination of the three practices listed above. Again, this optimal combination of practices was determined by specific soil characteristics of an individual field and the compared to the baseline information collected.

Figure 2: Maximum Abatement Potential through the Sacramento Valley of California



Distribution of Abatement Potential

The boxplots below depict the abatement potential by practice and by field. The dark black line represents means; boxes denote interquartile ranges, while whiskers illustrate the minima and maxima. These charts underline the fact that there is a large inherent variability in abatement potential for these fields, largely driven by changes in soil composition as one moves across the Sacramento Valley. Note that this analysis includes the potential for combining the three main practices (dry seeding, baling, and early drainage) with an additional practice of flooding or not flooding during winter. Because of the value of winter-flooded rice fields to migratory birds in California, the “no winter flooding” practice cannot generate credits under the ACR Rice Methodology or the ARB Rice Protocol.



III. Greenhouse Gas Abatement Potential in Midsouth Rice

After being calibrated and validated for the Midsouth region using peer-reviewed datasets, AGS calculated the potential GHG abatement (in tCO_2e) for each of the three practices included in the ACR Rice Methodology for the Midsouth. The Midsouth region includes the states of Arkansas, Louisiana, Missouri, Mississippi, and Texas. As was done for the California analysis, the DNDC model simulated different combinations of rice management practices on each field and then indicated which practice combination would yield the most GHG abatement for that particular field.

The analysis begins by delving into broad statistics on the levels of abatement potential by practice and their spatial distribution. Unlike the preceding California module analysis, the Midsouth data spans an extremely large region stretching across five states. This key difference leads to an inherently greater variability in climatic conditions across the study area. As such, this analysis relies on assumptions and extrapolations that produce a “generalized” assessment for the entire region. This must be kept in mind when interpreting results; additional efforts are required to downscale the analysis to localized, specific cases.

As with the California simulations above, because of certain soil characteristics (drawn from SSURGO), a rice field could potentially abate more by practicing different combinations of practices. For instance, it might be most optimal for a rice producer to practice both alternating wetting and drying (AWD) and baling, but not practice early drainage. Also, under AWD, some of the benefit of reduced methane emissions was offset by increased N_2O. In practice this increase in N_2O can be averted by reducing fertilizer application rates and adjusting the timing of fertilizer application. This was not done for our regional modeling simulations, so the AWD reduction estimates are significantly conservative. The maximum abatement potential is the sum of the GHG reductions by practice, determined by simulating the most optimal practice combinations for each location. This simulation was run for all of the rice acreage in Midsouth. Below are the summarized results.

GHG Abatement Potential of ACR Rice Methodology Practices (Midsouth)

Figure 3: Baseline: 2008-2013 remote sensing imagery

Rice Management Practice	Maximum Abatement Potential (tCO_2e/yr)	% of Total Abatement Potential
Alternate wetting and drying	325,805	13.2%
Early drainage	4,936	<1%
Rice straw removal (baling)*	2,137,279	86.6%
Total	*2,468,220*	*100%*

* This estimate of the maximum potential abatement of baling assumes a straight average of the end-use emissions of all eight possible end uses of baled rice straw (outlined in the ACR Rice Methodology). Baling is not an acceptable practice under the newly adopted ARB Rice Protocol.

The maximum potential annual GHG abatement of 2,468,220 tCO_2e would hypothetically be achieved if all rice acreage in Arkansas, Louisiana, Missouri, Mississippi, and Texas were farmed under the most optimal combination of the three practices listed above. Again, this optimal combination of practices was determined by specific soil characteristics of an individual field and the compared to the baseline information collected.

Additional Analysis - Midsouth Abatement Potential

Maximum potential abatement exhibits a great deal of variability across location and practice, particularly in the Midsouth. On average, it appears the greatest reductions are achievable through baling, followed by alternate wetting and drying. Adopted individually, practices aside from baling show low levels of abatement but the aggregate reductions from combinations of all practices can add up to substantial amounts.

Due to the fact that limited data was used to calculate the emission reductions and that the most significant reductions come from baling alone, further research is warranted in both the accuracy of biogeochemical modeling as well as negative environmental consequences of this practice. Also, under AWD, some of the benefit of reduced methane emissions was offset by increased N2O. This increase in N2O can be averted by reducing N application rates and adjusting the timing of N application. This was not done for our regional modeling simulations, so the AWD reduction estimates are significantly conservative. Higher emission reductions are definitely possible.

In terms of spatial distribution, all five states included in this study area indicate good potential for abatement. Clustering is highly prevalent, likely on the basis of soil type, suggesting that regionally targeted piloting and implementation would be advantageous.

Below are some additional statistics by state and practice.

Figure 4: Average Abatement per Acre per Year by Midsouth State

State	Average Abatement ($tCO_2e/ac/yr$)	USDA Rice Acreage 2013[12]	Maximum Abatement Potential (tCO_2e/yr)
Arkansas	1.31	1,055,000	1,381,192
Mississippi	1.27	159,000	202,497
Missouri	1.38	161,000	222,277
Louisiana	1.23	395,000	487,197
Texas[13]	1.36	129,000	175,057
Total	*1.31*	*1,899,000*	*2,468,220*

Figure 5: Abatement Potential Range Per Acre Per Year by Practice[14]

Rice Management Practice	Abatement Range (tCO_2e/yr)
Alternate wetting and drying	0-0.40
Early drainage	0-0.09

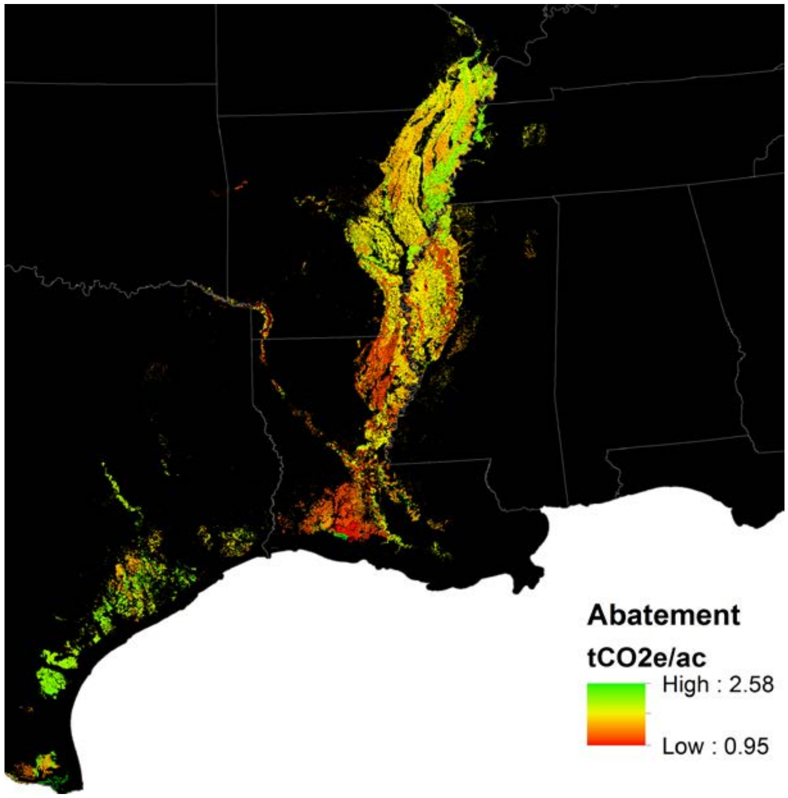
[12] U.S. Dept. of Agriculture, Statistical Reporting Service, Crop Reporting Board. Acreage. National Agricultural Statistics Service, 28 June 2013. ISSN: 1949-1522. Web. (http://usda.mannlib.cornell.edu/usda/nass/Acre//2010s/2013/Acre-06-28-2013.pdf)

[13] Under the ARB Rice Protocol, the state of Texas is not allowed to participate due to uncertainty around the data used to calibrate the DNDC model for that area.

[14] For a better understanding of the practices and abatement range, see separate sections on baling and on AWD above.

Rice straw removal (baling)*	0-1.85

Figure 6: Maximum Abatement Potential through the Midsouth



DNDC data depicted in the map above is constrained to all agricultural land area in these states. Rice area would be a subset of the above. Per-acre abatement estimates would apply to rice farmed within each area. A high resolution PDF with locations and labels is available here.

IV. Conclusion

From model simulations, we conclude that 3,067,637 tons of CO_2e is the maximum abatement potential each year from the implementation of the most optimal rice cultivation practices across all rice fields in California's Sacramento Valley and the Midsouth. The DNDC assessment model and satellite remote sensing tools advanced during this project, specifically for rice monitoring, showed a strong ability to accurately and precisely monitor and assess the management practices. These tools were constructed in a way to be scalable, transferable, robust, and serve as an informational platform in a cost efficient manner to support a carbon market including producers, brokers, verifiers, and investors.

We recognize, this does not take into account the social and economic feasibility of practice implementation, the risks for growers, implications for wildlife habitat, the concept of additionality, or the significant impact that weather has on greenhouse gas fluxes.[15] By removing certain practices from the suite of options for rice growers, the maximum abatement potential for each acre will change, since the implementation of one practice affects the emissions reduction potential of the other practices.

As of the writing of this report, baling is not an accepted practice under the ARB Rice Protocol due to potential waterbird impacts. These impacts are explained fully in the Point Blue Conservation Science report that summarizes the study of each of the recommended rice cultivation practices.

Continued analysis of the abatement potential in light of the recent policy changes is highly encouraged. In addition, additional research is warranted to determine opportunities to implement baling in a manner which preserves waterbird populations.

[15] For more information on the feasibility of rice cultivation projects to reduce emissions, see the Technical Feasibility Report submitted to NRCS for CIG project 69-3A75-11-133 (July 2015).

Rice and Waterfowl Habitat in the Mid-South

A Synthesis Report

American Carbon Registry, June 2015

While the original Rice CIG grant deliverables included a study on the impacts of pilot rice management activities on waterfowl habitat in the Mid-South, further research, discussion with project participants, and the scope of the Mid-South methodology module made it clear that a synthesis report on the waterfowl and rice habitat nexus would be more appropriate in informing this project. Both the Mid-South and the California rice growing regions are located along important international flyways – the Mississippi Americas Flyway and the Pacific Americas Flyway, respectively. For this reason, the American Carbon Registry (ACR) and its stakeholders want to be sure that the novel and innovative rice management techniques to decrease greenhouse gas (GHG) emissions and conserve water incentivized by approved carbon offset methodologies do not inadvertently adversely impact the waterfowl that use crucial migration corridors.

Activities that have the potential to jeopardize the habitat and/or food resources that sustain the waterfowl during their migration include winter flooding changes and rice straw baling. As the rice systems serve mainly as waterfowl habitat during winter months, activities that affect the growing season, like alternate wetting and drying, are not expected to have significant effects on the winter habitat. ACR's protocol specifies that yields - and therefore leftover rice grains - will not be sacrificed for GHG emission savings.

Winter flooding has traditionally been used as a way of breaking down leftover rice straw during the winter months, to clear the fields for the next season's crop. The anaerobic (absence of oxygen) decomposition of organic matter, however, releases methane, a potent greenhouse gas (34 times the global warming potential as compared to carbon dioxide)[1]. After rice burning was prohibited in California beginning in 1992[2], winter flooding became the main method of rice straw decomposition. In the Mid-South, however, rice straw burning is not prohibited (although occasional burning bans exist), and is still used as a method for decomposing leftover on-field biomass. More importantly, however, winter flooding provides habitat for waterfowl – and an

---

[1] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[2] Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991

important alternate income stream for rice growers in the winter season. As much of what is now rice habitat in the Mid-South was once seasonally inundated bottomland hardwood forest and wetland[34], returning water to the fields in the winter is a way to mimic historical land cover and allows agricultural working lands to fulfill a habitat niche for migrating waterfowl.

Due to the waterfowl habitat concerns, ACR stipulates in section 3.3.3 of the *Voluntary Emission Reductions in Rice Management Systems*[5] GHG quantification protocol, "Winter-flooded Rice Fields represent critical habitat for waterbirds… any reduction in winter flooding cannot be credited under this methodology." For this reason, winter flooding habitat changes in the Mid-South due to altered management practices under ACR's protocol are not permissible.

Rice straw baling, or rice straw removal, is an eligible project activity in the Mid-South. Baling removes biomass from the field before flooding, putting it to use in another resource stream, and preventing it from decomposing anaerobically and releasing methane. While rice straw removal has the potential to impact habitat structure and food sources[6], it is rarely practiced in the Mid-South. The equipment and time required, as well as the lack of a market for the baled rice straw, on top of the potential impact to waste rice that the waterfowl rely on, make the adoption of this practice increasingly unlikely.

Potential for baling could arise if a consistent market was available for rice straw. Erosion control, manufactured fiberboard, and cattle feed are all potential alternate uses for rice straw. Anecdotal evidence of rice straw being removed and sold as cattle feed during droughts in Texas is one example of how changing climatic and market conditions could, in the future, make baling more economical in the Mid-South.

The practice of baling rice straw may not negatively impact waterfowl if habitat structure, food sources and winder flooding levels are actively managed for bird habitat. In many areas, this is likely, given the high income potential from duck blinds in the Mid-South. Multiple studies have highlighted the kind of habitat most attractive to migrating waterfowl and other waterbirds – specifically, an interspersion of stubble and open water[7]. This can be achieved through burning or other mechanical means like rolling, chopping, incorporating, or baling[8]. In fact, Elphick and Oring (2003) report that in California, "fields are flooded deeper than necessary to maximize bird densities". Removing some or all biomass could allow for water savings by more accurately tailoring

---

3 Havens, J.H. et al. 2009. Winter Abundance of Waterfowl and Waste Rice in Managed Arkansas Rice Fields. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 63:41–46

4 Kross, J. K., R. M. Kaminski, K. J. Reinecke, and A. T. Pearse. 2008. Conserving waste rice for wintering waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 72:1383-1387.

5 ACR's methodology can be found at: http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems

6 C.S. Elphick & L.W. Oring. 2003. Conservation implications of flooding rice fields on winter waterbird communities. Agriculture, Ecosystems, and the Environment 94:17-29.

7 Havens et al, 2009.

8 Elphick, C.S & L.W. Oring, 2003.

the flooding levels to specific species' needs. "Even very shallow flooding", Elphick and Oring report, "could have considerable benefits for some waterbird species"[9].

Recently, a main driver impacting waterfowl in the Mid-South is not baling, but instead the trend towards early planting and harvest. With new hybrid cultivars allowing for shorter duration cultivation cycles, leftover 'waste rice' has more time during the autumn months to be lost to germination, decomposition, and granivory[10]. Additionally, increasingly efficient harvesting practices and equipment have the potential to further decrease the amount of waste rice left over for the waterfowl[11][12]. Recent trends towards a ratoon crop – an autumn crop after the main harvest – can substantially supplement the waste rice left over for migrating waterfowl[13]. Sorghum and other grains, some of which may not be economical to harvest commercially, but can exist on marginal land adjacent to rice crops, may be useful for increasing the calories available to migrating waterfowl[14].

ACR's *Voluntary Emission Reductions in Rice Management Systems* GHG quantification protocol is not envisioned to have negative effects on waterfowl habitat or food security. Rather, more intensive water management during the growing season and into the winter season could actually benefit waterbirds by providing habitat structures and water depths that support a diversity of bird species. It is likely that growers seeking revenue from the duck hunting industry have already, and will continue to, consider some of the management options to promote waterfowl populations on their properties. As the waterfowl industry continues to grow, and groundwater becomes more and more scarce, water conservation measures that go hand in hand with the GHG reduction activities promoted through the voluntary carbon market can help to keep Mid-South rice farmers thriving, while providing quality habitat for migrating waterfowl.

Current ongoing research across the Mid-South can continue to refine our understanding of how rice and water management practices interact with waterfowl habitat and food sources. Recent management experiments on the Five Oaks property near Stuttgart, Arkansas, focus on rotating winter flooded fields to encourage waterfowl populations to different areas on the property. Ongoing work by Ducks Unlimited calls

---

[9] Elphick, C.S & L.W. Oring, 2003.
[10] Stafford, J. D., R. M. Kaminski, K. J. Reinecke, M. E. Kurtz, and S. W. Manley. 2005. Post-harvest field manipulations to conserve waste rice for waterfowl. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 59:155–163.
[11] Kross et al., 2008.
[12] Havens et al, 2009.
[13] Stafford, J. D., R. M. Kaminski, K. J. Reinecke, and S. W. Manley. 2006. Waste rice for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:61-69.
[14] Wiseman, A.J, R.M. Kaminski, S.K. Riffell, K.J. Reinecke, and E.J. Larson. 2010. Ratoon Grain Sorghum and Other Seeds for Waterfowl in Sorghum Croplands. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 64:106-111.

for continuing research and extension activity to promote ratoon rice crops, increasing forage for migrating waterfowl[15].

With an increasing reliance on rice as habitat for waterfowl, groundwater becoming scarcer in many parts of the Mid-South, and climate change and emissions becoming an essential part of the equation for responsible agriculture, the rice-waterfowl nexus is a fitting example of the land use challenges of our time. Using specific management techniques, there are ways to reduce water use year round, better manage flooded bird habitat and food sources, and reduce emissions while doing it. Voluntary and compliance carbon markets can play an important role in promoting and incentivizing these cascading benefits.

---

[15] Brasher, M, D. James, and M. Petrie. Estimating the Biological and Economic Contributions that Rice Habitats Make in Support of North American Waterfowl Populations. A Report to the Rice Foundation from Ducks Unlimited, Inc. Project #19-09.

Point Blue Report

Waterbird response to practices aimed at reducing greenhouse gas emissions from rice fields in the Sacramento Valley

Report to the Environmental Defense Fund

August 29, 2014

Kristin A. Sesser, Matthew E. Reiter, Daniel A. Skalos, Khara M. Strum, and Catherine M. Hickey

Conservation science for a healthy planet

3820 Cypress Drive, #11 Petaluma, CA 94954
T 707.781.2555 | F 707.765.1685
pointblue.org

Point Blue Conservation Science – Point Blue's 140 staff and seasonal scientists conserve birds, other wildlife and their ecosystems through scientific research and outreach. At the core of our work is ecosystem science, studying birds and other indicators of nature's health. Visit Point Blue on the web www.pointblue.org.

Cover photo by D. Skalos

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

INTRODUCTION 3

METHODS 5

Study Area 5

I. Post-harvest Management Practices 5

II. Seeding Practices 12

RESULTS 13

I. Post-harvest Management Practices 13

II. Seeding Practices 16

DISCUSSION 17

I. Post-harvest Management Practices 17

II. Seeding Practices 18

CONCLUSIONS 19

ACKNOWLEDGMENTS 20

LITERATURE CITED 21

LIST OF TABLES 25

LIST OF FIGURES 26

LIST OF APPENDICES 27

EXECUTIVE SUMMARY

The benefits of agricultural landscapes for wildlife, particularly birds, are many. In California's Sacramento Valley, management practices of rice fields can benefit both farmers and wildlife. Flooding, in particular, increases the decomposition of rice stubble post-harvest while providing habitat for over 50 species of waterbirds. Post-harvest flooding of over 143,000 hectares of rice fields is estimated to provide 85% of flooded habitat in the Sacramento Valley during winter. This flooding, however, contributes to greenhouse gas (GHG) emissions, specifically methane. Greenhouse gas emissions contribute significantly to global climate change and finding ways to reduce overall GHG emissions is a goal for mitigating the effects of climate change in California. Recent efforts to develop practices that reduce GHG emissions within the context of rice production have identified several approaches that may be effective including reduced winter flooding, removal of rice straw via baling, and drill seeding. The potential impacts to waterbirds of these proposed alternative strategies, particularly baling and drill seeding, were not well-understood prior to this study.

During December and January of 2011-2012 and 2012-2013, we examined the effects of reduced winter flooding and baling on waterbird use and food availability by comparing waterbird and food densities in four combinations of practices: baled/flooded, baled/non-flooded, non-baled/flooded, and non-baled/non-flooded. We also evaluated factors that may be causing the observed differences in waterbird densities among practices.

- We found significantly higher dabbling duck and shorebird densities in the non-baled/flooded practice compared to the other three practices. Goose densities were not significantly different among the four practices.
- Dabbling duck and shorebird densities were strongly associated with presence and depth of water which explained differences in use between flooded and non-flooded practices.
- Shorebird densities were positively associated with whether the leftover straw and stubble was incorporated, or mixed into the soil (via stomping, chiseling, or disking), and both ducks and shorebirds were negatively associated with the amount of standing stubble. After accounting for the possible influence of incorporation, shorebird densities were still significantly higher in non-baled versus baled fields.

- We found flooded fields had significantly higher densities of nematodes and crustaceans than non-flooded fields with no significant difference between baled and non-baled. We found similar densities of oligochaetes in all four practices and no discernible patterns in densities of insects or moist soil seeds among practices.
- We found significantly lower mass-densities of waste rice in fields after they were baled.

During April and May of 2012 and 2013, we examined the response of waterbirds to drill seeding versus the traditional wet fly-on seeding.

- We found no significant differences in mean density between the two seeding practices for dabbling ducks or shorebirds. Geese were only observed twice, and in low abundance, during these surveys.

INTRODUCTION

The mosaic of natural wetlands and agricultural fields in the Central Valley of California make it an internationally important area for migratory waterbirds in the Pacific Flyway (Gilmer et al. 1982, WHSRN 2003). Although the Central Valley has lost 90% of its original natural wetlands, largely to agriculture and urbanization (Frayer et al. 1989), nearly three million ducks, one million geese, and 350,000 shorebirds continue to overwinter in this region (Shuford et al. 1998, Collins et al. 2011). A large proportion of these birds rely on flooded rice fields, which provide habitat for over 50 species of waterbirds during the winter (Day and Colwell 1998, Elphick and Oring 1998). As a result, the future of migratory waterbirds in the Central Valley depends upon how both wetlands and agriculture are managed.

The post-harvest management of rice fields has changed over time and depends on a number of environmental considerations. State regulations enacted in the 1990s restricted the amount of allowable straw burning (Rice Straw Burning Reduction Act, AB 1378 1991) resulting in an increase in the amount of rice that is winter-flooded post-harvest for the purpose of stubble decomposition (Miller et al. 2010). This reduction in burning for straw management post-harvest decreased air pollution but increased annual greenhouse gas (GHG) emissions (Bossio et al. 1999, Fitzgerald et al. 2000, Lindberg 2003). Greenhouse gas emissions increased because the by-product of straw fermentation via flooding is methane (CH_4), which is a more potent GHG than carbon dioxide (CO_2), the by-product of rice burning.

Recent work has identified several post-harvest management practices that may reduce methane GHG emissions from rice fields (Lauren et al. 1994, Bossio et al. 1999, Fitzgerald et al. 2000, EDF 2010, Suddick et al. 2010). These practices include reduced winter flooding, removal of rice straw after harvest via baling, and drill seeding during spring planting, an alternative to the traditional fly-on seeding method. Currently only 3% of rice fields are baled post-harvest while approximately 50% of all rice fields are flooded (Garr 2014). Although waterbird use of winter-flooded rice has been studied (Taft and Elphick 2007, Strum et al. 2013), little information is available regarding the effect of straw removal via baling on waterbird use or on waterbird food resources (i.e. invertebrates and seeds).

Greenhouse gas emissions contribute significantly to global climate change (IPCC 2007) and finding ways to reduce overall GHG emissions is a goal for mitigating the effects of climate change in California (AB-32). The potential impacts of climate change on agriculture include decreased yields, increased variation in water availability, an increase or change in pressures from pests and weeds, and changes in abundance and diversity of pollinators (Hayhoe et al. 2004, Lee et al. 2011, Lobell and Field 2011, Hatfield et al. 2014). When weighing the costs and benefits of implementing GHG-reducing management practices in rice, it is important to understand the impacts of these practices on wildlife, particularly waterbirds, some of which are reliant on rice agriculture.

Our overall goal was to study the effects of GHG emissions-reducing rice management practices on waterbirds and their food resources. Specifically, we (1) compared waterbird density, food resources, and other indicators of habitat quality for shorebirds and waterfowl across four combinations of post-harvest management practices in rice fields including flooding and baling; and (2) compared waterbird density between drill seeding and the traditional wet fly-on seeding.

METHODS

Study Area

The Sacramento Valley is located north of the Sacramento-San Joaquin River Delta in the Central Valley of California (Fig. 1). Average annual rainfall is 51 cm and most falls between the months of October and February. The region historically flooded in late winter creating seasonal wetlands across the valley floor, probably on the order of 1.5 million ha (CVJV 2006). Over the last century, the majority of these historical wetlands have been converted to agricultural fields. Currently, there are approximately 199,000 ha of rice grown in the Sacramento Valley. On average, flooded habitat is provided by over 143,000 ha of rice and 28,300 ha of managed wetlands irrigated by a series of highly managed, interconnected canals and ditches (CVJV 2006).

I. Post-harvest Management Practices

Practice descriptions. We surveyed wintering waterbirds on four combinations of baling and winter flooding practices: baled/flooded (BF), baled/non-flooded (BNF), non-baled/flooded (NBF), and non-baled/non-flooded (NBNF).

After harvest, there is usually 0.3–1 meter (height) of standing stubble left in a rice field. Baling removes most of this bulk as straw, but still leaves 7–15 cm of standing stubble which is the base of the rice stalk. These baled fields are left either "as-is" until spring, burned, or the remaining stubble is incorporated (mixed) into the soil. Since most of the straw has been removed from baled fields, neither flooding nor incorporation is required for straw decomposition. However, some rice farmers flood baled fields to provide waterfowl habitat and hunting opportunities, and some growers prefer to incorporate all the remaining standing stubble. Non-baled fields still have the 0.3–1 meter of standing stubble that is often chopped or mowed to break the standing stubble into shorter pieces, creating loose straw that lies horizontally, often on top of the standing stubble. Many growers then incorporate (or mix) that straw and the remaining standing stubble into the soil through various methods such as disking, chiseling, or stomping, the latter of which is performed after they flood using special equipment which smashes the straw into the mud. Depending on the incorporation method and the grower's individual preference, there can be varying amounts of remaining standing stubble left by the path of the tractor, sometimes even up to 30-40% cover of the field. In addition to the incorporation methods, flooding also enhances straw decomposition and can occur immediately after, to a month or more after, harvest.

Within the four practice combinations studied herein, the amount, timing, and method of incorporation, if used, varied across fields. For example a BF field may be baled then flooded without any incorporation, or baled, disked, then flooded. Similarly, a NBF field may be chopped, disked, and then flooded, or flooded, then stomped, or chopped and flooded with no incorporation. Given the complexity and constraints of working with many different private landowners and their different preferences and capabilities, it was not practical to design a study where all the practice combinations were implemented with the exact same set of methods, timing, and equipment.

Study design. We used a study design that captured the variation in waterbird density and habitat characteristics across existing post-harvest practices. In the first year, we contacted rice growers and identified 11 farms where one or more of the four study practice combinations, hereafter "practices", were implemented. Across these farms, we made an effort to achieve a spatially balanced distribution of practices and survey locations. Within farms, rice fields are divided into subunits called paddies that are separated by internal earthen levees. We considered the individual paddy to be the sample unit. Thus, paddies were spatially nested within fields, and fields were further nested within farms. We selected paddies from participating farms using Generalized Random Tessellation Stratified (GRTS) sampling methodology, which enabled the selection of spatially balanced random locations with respect to practice (Stevens and Olsen 2004). The number of paddies in each practice varied among farms. In the second year, we worked on five of the same farms as in the previous year and added nine more farms. We used the same sampling methodology as the first year. Some of the same paddies, fields, and farms were visited in both years of the study. Overall, we worked on a total of 20 rice-growing farms spread across the Sacramento Valley (Fig. 1).

Because this study was conducted in coordination with private landowners, relying on their cooperation, and occurred during standard operations on each farm we were not able to select a completely random set of farms from across the Sacramento Valley. However, our sample of farms and practices is spatially representative of the rice growing region and thus we feel we can make reasonable inference to the broader landscape with our findings.

Waterbird surveys. From 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013, we surveyed waterbirds (ducks, geese, and shorebirds) approximately every 10 days in the four post-harvest rice management practices defined above: BF, BNF, NBF, and NBNF. We conducted 2,270 surveys across 479 paddies representing the four post-harvest practices (Table 1). We conducted surveys from a randomly selected, pre-determined point on the edge of an individual rice paddy and used a 200-m fixed-radius and the paddy boundary (whichever was closer) to define the survey area. Where possible, we varied the order in which we surveyed points to avoid bias in counts due to the effects of time of day. We identified all waterbirds to species and counted all individuals. All survey areas were scanned for at least two minutes. There was no maximum time limit for completing a count, though they ranged from 2–15 minutes, with a median of 3 minutes. We only counted waterbirds using the survey area, and did not count birds that flew over. Surveys were not conducted in inclement weather, i.e. winds ≥ 40 kph, heavy fog, or rain.

For our analysis, we focused on three guilds – dabbling ducks, geese and swans, and shorebirds. We selected these guilds because they represent the largest use of rice by waterbirds in the Sacramento Valley (Sterling and Buttner 2011). Furthermore, quantitative objectives are established for these guilds in conservation planning by the Central Valley Joint Venture (CVJV 2006), thus understanding their response to different rice agriculture practices is important for their conservation and management. Sample sizes for individual species were often not large enough to analyze separately.

Paddy characteristics. During each survey, we collected data on water depth using two wooden stakes placed at 50-m and 200-m in the center of the paddy marked with 5-cm depth increments. We confirmed whether incorporation or mixing of the straw and/or standing stubble into the soil had occurred within the survey area. We also recorded several metrics to characterize cover and soil moisture in the survey area on each visit, including the

- proportion of the survey area with standing rice stubble,
- proportion flooded (completely covered in water),
- proportion saturated (no standing water but soil appearing with a sheen),
- proportion moist (wet areas visible in soil but no sheen), and
- proportion dry (no moisture content visible in soil).

Food resource availability. Rice seed remaining in both flooded and non-flooded rice fields after harvest (waste rice) is a critical food resource for wintering waterfowl including dabbling ducks, geese, and swans (Miller et al. 1989, CVJV 2006). We sampled waste rice seed immediately after harvest using the line-intercept method recommended by Halstead et al. (2011). We compared waste rice mass-density between baled and non-baled fields. In 2011, we sampled from three randomly placed plots in fields that were either baled or non-baled. We discovered a large amount of variation in waste rice mass-density among fields, likely due to harvester speed, efficiency, and model. Many growers have multiple harvesters and drivers, so while this variation exists among farms and among fields, often only one harvester will work on any one particular field. In order to account for some of this variation, in fall of 2012, we again sampled from three randomly placed plots in each field being sampled, however we used a paired design and sampled all fields, both before and after baling occurred. For both years, each sample plot consisted of one line intercept sample. The line intercept method involved placing a 6-m line with alternating red and white sections, each 10-cm in length, along the ground, perpendicular to and spanning the width of the path of the rice harvester. We recorded the number of seeds that intercepted the red sections (each is 0.001175 m^2) and calculated the waste rice seed mass density (kg/ha) using an equation provided by Halstead et al. (2011). A non-negligible amount of rice seed is contained within the straw itself (still attached to the stem, not loose on the ground) and is available as forage for waterbirds (Miller et al. 1989). The practice of baling removes this straw and its associated waste rice. Waste rice in the straw, although not measured directly, was estimated for fields where the straw was not removed (non- or pre-baled) using our line transect estimates of rice seed mass-density and the regression equation provided by Halstead et al. (2011).

Invertebrates are important food items in wetlands and rice fields for many groups of waterbirds including ducks (Euliss and Harris 1987, Miller 1987, Safran et al. 1997) and shorebirds (Safran et al. 1997, Davis and Smith 1998, Smith et al. 2012). Important groups of invertebrates include insects and their larvae (Orders: Diptera, Coleoptera, Hemiptera), crustaceans and their aquatic larvae, nematodes, oligochaetes, and gastropods. Moist-soil seeds (aka weed seeds) are also important food resources for waterfowl (Euliss and Harris 1987, Miller 1987). We sampled invertebrates and moist-soil seeds within the benthos (hereafter sediment) and the water column (for flooded practices only) from 20 – 28 December 2011 and 10 – 17 December 2012 in all four post-harvest management practices (BF, BNF, NBF, NBNF). We randomly selected fields and two sampling plots per field. At each sampling plot, we used a 0.5-m^2 frame to contain mobile invertebrates and collected two samples, each at opposite corners of the frame, using a 125-mm diameter steel corer. We placed sediment cores in a plastic bag and stored them in a cool place. In flooded fields, we sampled the water column using a stovepipe affixed to the top of our benthic corer. We poured the water sample into a 0.5-mm sieve in the field then stored the sample in 90% ethanol with rose bengal dye in a cool place until laboratory processing (Mitchell and Grubaugh 2005). We washed all benthic samples within three weeks of collection using a 0.5-mm sieve. All invertebrates in the samples were sorted and counted by broad taxonomic classifications (e.g. phylum, class, subclass, order) by the USGS Western Ecological Research Center, San Francisco Bay Field Station. To increase efficiency of core processing, for samples with large numbers of invertebrates (e.g., Nematoda) or moist-soil seeds, a random 25% of the sample was used to estimate density.

Data analysis. We calculated the area (ha) surveyed for waterbirds at each sample point using ArcMap Version 9.3.1 (© 1999-2009 ESRI Inc.). We compared waterbird densities, calculated for dabbling duck, shorebird, and goose guilds, among practices and years using the average of the pooled mean density (birds/ha) from each survey location and 95% confidence intervals (95% CI). Due to the large number of zeroes and non-normal distribution of bird counts and subsequently bird density estimates, we used bootstrapping and the percentile method to estimate the 95% CI for the mean density estimates of each guild (Manly 2007). We chose to use this non-parametric bootstrap approach as it was better able to characterize the mean values by practice than a parametric regression model which assumes a specific distribution. To calculate the confidence intervals, we generated 1000 bootstrap iterations (random resample with replacement) from the original data set, and then calculated the mean for each bootstrap replicate. To account for correlation from repeated measurements on the same paddy, we sampled with replacement from each paddy, averaged those values within paddy and then averaged across paddies in each bootstrap iteration. We considered density estimates from different practices to be significantly different if their 95% CI did not overlap. We recognize that this is a strict measure of significance and represents $\sim P = 0.01$ (Gardner and Altman 1986) but wanted to set a high burden of proof. We calculated these statistics for both years combined and independently for the first and second year of the study to assess year to year variation.

Our approach treated each paddy as the independent sample unit but by averaging repeated measurements (surveys) on the same paddy we limited temporal autocorrelation (as source of pseudoreplication; Hurlbert 1984). If there was additional spatial autocorrelation, our assumption of independence is violated, potentially raising the risk of Type I error when interpreting parameter estimates (Legendre et al. 2004); 95% CI would be too small. To investigate possible correlation among the paddies within farms and regions we used zero-inflated negative binomial regression models (Zuur et al. 2009) to assess residual effects of farm or region after accounting for practice effects. We found no significant effects and thus feel confident in considering paddies as independent samples in our bootstrap analyses. However we did evaluate years separately as there was evidence of differences in duck and shorebird abundance between years.

Paddy Characteristics as Driving Mechanisms. We examined paddy characteristics that could be considered mechanisms driving the observed differences in waterbird density among practices. To better assess continuous covariates (not possible with bootstrapping) we used zero-inflated negative binomial regression models (Zuur et al. 2009) to quantify the effect of the following possible mechanisms on waterbird density. We examined the effect of whether a survey area was incorporated or not, and combined all the different methods of incorporation (disking, chiseling, stomping). We expected some waterbird groups such as ducks and geese to have higher use of non-incorporated paddies since the waste grain should be on the surface and more accessible (Miller et al. 1989) though Elphick and Oring (1998) showed no effect of straw management practices on ducks. However shorebirds have been shown to be positively associated with incorporation (Elphick and Oring 1998) and would be expected to use paddies with little to no standing stubble which would be more likely in an incorporated paddy (Strum et al. 2013). We examined the effect of the proportion of the survey area that was flooded (having standing water) and the effect of water depth in both linear and quadratic forms, as both shorebirds and ducks have been shown to have optimal depth range preferences (Strum et al. 2013). We also examined the effect of the proportion of the survey area with standing stubble since previous studies have found some groups, such as shorebirds, may avoid paddies with tall stubble which can obstruct their view and make them more susceptible to predation. We considered the effect of these paddy characteristics to be significant if the 95% CI of the model coefficient estimate did not overlap zero. To assess the relative influence of our selected paddy characteristics as mechanisms influencing densities of waterbird guilds, we ranked models using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). Generally models within 2 AIC units of the model with the lowest AIC are considered in the top model set.

Habitat Quality. One measure of habitat quality is whether water of the appropriate depth is being provided by each of the practices. We examined the probability that a practice provided suitable water depths for shorebirds and dabbling ducks following methods outlined in Strum et al. (2013). They defined suitable water depth for shorebirds to be between mudflat and 16 cm and suitable water depth for dabbling ducks to be greater than 16 cm. Geese use a wide range of water depths from 0 to greater than 16 cm, so were not assigned a suitable depth range. We also compared the probability of incorporation (all methods combined) among practices. We used mixed-effects logistic regression models to estimate the mean and 95% CI of the probability of suitable water depth or incorporation by practice (Zuur et al. 2009). We again considered coefficient estimates for practices significantly different if their 95% CI did not overlap.

Food Resource Availability. For waste rice data collected in 2011, we compared mean rice seed mass-density from baled and non-baled fields using a two-tailed t-test on log-transformed data. For the data collected in 2012, we used paired t-tests on non-transformed mean rice seed mass-densities (after testing for normality) to compare densities pre- and post- baling. Significance was set at $P \leq 0.05$.

For sediment and water column samples in all four practices, we compared densities of broad taxonomic groups (invertebrates and seeds) among practices using the average of the pooled mean density (individuals/m^2) from each field and 95% CI. Due to the large number of zeroes and non-normal distribution of these counts and subsequently density, we used bootstrapping and the percentile method to estimate the 95% CI for the density estimates of each group (Manly 2007 and see description on page 9). We considered density estimates from different practices within groups to be significantly different if their 95% CI did not overlap.

We used R v.3.0.2 (©2013 The R Foundation for Statistical Computing) for all statistical analyses.

II. Seeding Practices

Practice descriptions. We compared waterbird use of the traditional wet fly-on seeding practice with an alternative drill seeding practice. Fly-on seeding involved rolling a rice field to create furrows then flooding the field 10–13 cm deep and distributing pre-germinated rice seed over the field by airplane. The rice seed then sinks into the furrows and begins to grow. These fields are continuously flooded for the growing season. Drill-seeded fields in our study were not flooded prior to seeding. A seed drill is pulled over the field and sows seeds below the surface of dry ground. Fields are then flooded in pulses 2–3 times to germinate the rice seed before flooding is constant. Eventually, both seeding methods are kept flooded at 8–10 cm for the remainder of the growing season.

Study design. Similar to our study on post-harvest practices, rice fields are divided into subunits called paddies that are separated by internal earthen levees. We considered the individual paddy to be the sample unit. Thus, paddies were spatially nested within fields, and fields were further nested within farms. On the two larger farms where we had relationships with the growers, we selected survey points using GRTS sampling methodology. In order to bolster our sample size, we also selected rice fields that were close to our known farms, accessible from public roads, and starting the seeding process at about the same time. On these fields, we used simple random sampling to select paddies to survey. This study was conducted primarily in Sutter County (Fig. 1).

Waterbird surveys. From 3 – 26 May 2012 and 18 April – 24 May 2013, we conducted two waterbird surveys per week in the two rice seeding practices, drill and fly-on seeding. We conducted 1,911 surveys across 281 paddies, including 149 drill-seeded and 132 fly-on seeded paddies. The early start to seeding in 2013 prompted our study to start earlier in Year 2 than in Year 1. Survey methods were the same as those described above for post-harvest practices (page 6).

Paddy Characteristics. For the seeding practices, we recorded the same cover and soil moisture measurements that we recorded with the post-harvest practices (proportion of survey area flooded, saturated, moist, dry, and with stubble).

Data analysis. We compared densities, calculated for dabbling duck and shorebird guilds, between seeding practices and years using the same methods described above for post-harvest practices (page 9). For shorebirds, we summarized mean densities per seeding practice both including and excluding the April surveys to account for any potential effects bird migration, as spring shorebird migration peaks in April in the Sacramento Valley. We assumed that populations of dabbling ducks and geese were relatively stable during this time period as migration is generally complete for those guilds (at least in the Sacramento Valley).

We used individual zero-inflated negative binomial regression models (Zuur et al. 2009) to evaluate paddy characteristics that could be considered mechanisms driving the observed differences in waterbird densities between seeding practices. We considered the proportion of the survey area that was flooded, saturated, moist, and dry as model covariates. We assessed these gradients in soil moisture, as generally, water characteristics are more variable and dynamic in fields during planting than during post-harvest winter flooding. We again considered coefficient estimates to be significant if the 95% CI did not overlap zero and we compared among models using AIC.

RESULTS

I. Post-harvest Management Practices

Waterbirds. We observed 36 species of waterbirds, representing six foraging guilds (Table 2, Appendix A). The most numerous species were American coot (*Fulica americana*), mixed goose flocks (*Chen/Anser* spp.), northern pintail (*Anas acuta*), and dunlin (*Calidris alpina*). The two flooded practices, BF and NBF, had almost twice the waterbird species richness compared to non-flooded practices.

When both years were combined, we found dabbling duck mean density to be significantly higher in the NBF practice than the BF practice (Fig. 2). However the 95% CI were very close to overlapping between these two flooded practices. The difference between non-baled and baled was not significant in the first year but was significant in the second year of the study. We found no dabbling ducks in the two non-flooded practices (BNF, NBNF). Shorebird mean density was significantly higher in the NBF practice than in the other three practices (Fig. 2) although we found more variation around the mean density for NBF in the second year; this led to a small amount of overlap of the 95% CIs with the other practices. We detected some very large flocks of geese in the first year which resulted in the large 95% CIs (Fig. 2). Our data suggested no significant differences among the practices for geese.

Mechanism models used to evaluate the effects of paddy characteristics on waterbird density suggested significant effects of water depth, proportion flooded, and proportion standing stubble on dabbling duck and shorebird density, as 95% CIs of the parameter estimates did not overlap zero; however none of the covariates had a significant effect on goose density (Table 3). Additionally, whether a paddy was incorporated or not also had a significant effect on shorebird density. The proportion of the survey area that had standing stubble had a significant negative effect on both shorebird and dabbling duck densities. Overall, for shorebirds, the quadratic water depth model had the lowest AIC and was >2 AIC units less than the next best supported mechanism model which included the variable indicating whether straw incorporation had occurred. Similarly, the quadratic depth model was best supported by AIC for dabbling ducks; however the model including the proportion flooded was within 2 AIC units of the top dabbling duck model, further emphasizing that water is essential for dabbling duck use. All models for shorebirds and all models except the incorporation model for ducks were a significant improvement, based on AIC, over the intercept-only model. However, for geese, the intercept-only model was best supported, further substantiating the finding that none of the covariates considered had a significant effect on goose density.

Habitat quality. Differences in field characteristics were often associated with the four practices (Fig. 3) and consequently may help explain the observed variation in waterbird use. Predictably, water was more prevalent and deeper in flooded practices than in the non-flooded practices. Water depth was not significantly different from a bird's perspective between the two flooded practices, BF and NBF. The probability of water being at shorebird depth was significantly higher in both BF (0.21; 0.15 – 0.29 95% CI) and NBF (0.29; 0.19 – 0.49 95% CI) than in BNF (0.08; 0.05 – 0.14 95% CI). However there was considerable uncertainty in our estimate of the effect of NBNF on water depth resulting in a large 95% CI (0.13; 0.08 – 0.61 95% CI) despite a low probability for shorebird depth. There also was not a significant difference in the probability of water of suitable depth for dabbling ducks between the two flooded practices, BF (0.78; 0.68 – 0.87 95% CI) and NBF (0.65; 0.48 – 0.79 95% CI) but both non-flooded practices had zero probability of providing water depth suitable for dabbling ducks. Standing stubble was strongly associated with non-flooded practices which may be related to water depth obscuring the substrate of the field when flooded. Where visible in dry practices, BNF had a higher average proportion standing stubble than NBNF which, in part, may be explained by the higher frequency of incorporation in our sample of non-baled practices resulting in lower amounts of standing stubble in that practice (Fig. 3). In baled practices in our study, BF (0.52; 0.46 – 0.58 95% CI) and BNF (0.35; 0.28 – 0.42 95% CI), there was a significantly lower probability of incorporation than in non-baled practices, NBF (0.90; 0.86 – 0.93 95% CI) and NBNF (0.83; 0.78 – 0.98 95% CI).

Post-hoc. Our results suggested that shorebirds were significantly associated with incorporation and that the probability of incorporation was associated with whether a field was baled or not-baled. We further examined whether differences in incorporation was the mechanism driving the difference in use between baled and non-baled fields by filtering the dataset to control for flooding and incorporation. We performed bootstrapping according to the methods described above, separately for baled and non-baled fields that were incorporated and non-incorporated. For shorebirds, non-baled and incorporated paddies still had significantly higher densities (mean=5.3; 2.97–8.05 95% CI) than any other combination of practices (Table 4). Our mechanism models did not indicate straw incorporation was important for ducks, or geese and swans, which is supported to some extent by other research (Elphick and Oring 1998) thus we feel our initial comparison of means by practice is robust to differences in incorporation rates between baled and non-baled practices.

Food resource availability. When assessing waste rice, we sampled a total of 30 plots in 10 fields (6 baled, 4 non-baled) in 2011 and 60 plots in 10 fields (3 plots per field both pre- and post-baling) in 2012. In 2011, we found no significant difference in rice mass-density (t = 0.22, df = 4, P = 0.83) between baled and non-baled fields, although we found large variation in rice seed mass-density from field to field (Table 5). In 2012 our sample size was larger and we found no significant difference in rice mass-density on the ground pre- and post-baling (t = 1.13, df = 9, P = 0.29). However, when we took into account the estimated amount of rice seed in the straw layer (above the ground), we found that overall, fields had significantly higher waste rice mass-density before the field was baled than after (t = 3.11, df = 9, P = 0.013; Table 6).

We sampled invertebrates and moist soil seeds in 15 fields during December 2011 and 31 fields during December 2012 (Table 7). Eleven broad invertebrate taxa and moist soil seeds were found in our samples (Table 8). Moist soil seeds and nematodes were the most numerous potential food items found in flooded and non-flooded fields. Other abundant invertebrates included oligochaete worms and several orders of crustaceans (Cladocera, Copepoda, Ostracoda). We found flooded fields had significantly higher densities of nematodes and crustaceans than non-flooded fields, with no significant difference between baled and non-baled. We found similar densities of oligochaetes in all practices and generally no discernible patterns in densities of insects or moist soil seeds among practices, although insects were very low in NBF and moist soil seeds very high in BF (Fig. 4).

II. Seeding Practices

Waterbirds. We observed 28 species of waterbirds representing six foraging guilds (Table 9, Appendix A). The most numerous species were mallards (*Anas platyrhyncos*), western sandpiper (*Calidris mauri*), white-faced ibis (*Plegadis chihi*), and American coot (*Fulica americana*). Over 99% of the ducks observed in seeding surveys were mallards. We found no significant difference in mean dabbling duck density between the two seeding practices (Fig. 5). There was also no significant difference in mean shorebird density between the two practices, whether we included the April observations or not. Mean shorebird density was actually higher when we excluded April, likely because the cut-off did not include the high number of shorebirds observed on 2 May 2013. Geese (all greater white-fronted geese) were only detected twice during this study, and both times in small groups. Many of the shorebirds and dabbling ducks encountered in May were likely breeding locally; potentially even in the rice fields.

Mechanism models used to evaluate the effects of paddy characteristics on waterbird density suggested that both shorebirds and dabbling ducks had significant negative associations with the proportion of the survey area that was dry (Table 10) and, inversely, a significant positive association with the proportion of the survey area that was flooded. The proportion of dry area was the best supported model based on AIC for both guilds. Shorebirds were also positively associated with proportion of the survey area that was saturated with water.

Habitat quality. Overall the average proportion of the survey area that was flooded was higher and less variable in the fly-on practice (0.86) than in drill seeding (0.33; Fig. 6), while the opposite was true for the proportion of the survey area that was dry. However, the proportion of the survey area that was saturated and moist was, on average, higher in the drill seeding practice.

DISCUSSION

I. Post-harvest Management Practices

Our study documented significant differences in densities of shorebirds and dabbling ducks in rice fields in the winter depending on the post-harvest practices. Overall, the flooded practices had significantly higher waterbird densities than non-flooded practices, as has been found in other studies (Elphick and Oring 1998, Taft and Elphick 2007, Strum et al. 2013). Non-flooded practices received some use by geese with the highest density of geese occurring in baled, non-flooded fields. Other studies have also found geese to use both flooded and non-flooded fields (Elphick and Oring 1998). Overall, our flooded practices had comparable but lower density estimates for dabbling ducks than another recent study in winter-flooded rice using the same survey protocol, but slightly higher density estimates for shorebirds (Strum et al. 2013).

Of the two flooding practices, we found significantly higher densities of shorebirds and dabbling ducks in the NBF than BF. Even though mean duck densities were three times larger in NBF than BF, the difference between 95% CIs for ducks was small. These differences in use may result from the additional post-harvest practices applied to non-baled fields; though, ducks and geese and swans were not significantly associated with incorporation while shorebirds were. However, after controlling for incorporation (about half of our BF fields were not incorporated, leaving more standing stubble on the surface compared to NBF fields of which about 90% were incorporated, resulting in more exposed soil on the surface and less standing stubble) shorebird density was still significantly higher in non-baled compared to baled paddies. This additional result further supports the higher value of non-baled fields compared to baled fields for shorebirds.

Our study estimated day-time use of rice by waterbirds and it is possible that day-time use underestimates dabbling duck densities, as it has been documented that there is greater use of flooded agricultural fields by waterfowl at night during December and January, especially when farms are close to wetland refuges (Fleskes et al. 2005). As well, it is possible that our density estimates were low, as some dabbling duck species flush easily and may use habitat outside the 200-m range of our survey area though our densities, albeit slightly lower, were similar to those from Elphick and Oring (2003) which were based on surveys of the entire rice field. We have no evidence, however, to suggest that there would be an interaction between time of day and field management practice thus our findings would likely not change if there were higher night-time densities.

Food resource availability. Prior to this study, the effect of baling on the availability of waste rice seed was unknown and our study provides some data to answer this question, although our sample sizes were modest. The baling process shakes some unknown portion of remaining rice seeds from the straw onto the ground as the straw is pushed into rows and bales are created, thus increasing ground density of rice seed. However, the baling equipment and multiple passes through the field also likely push a portion of rice down into the soil where it is no longer available to waterbirds and removal of straw along with its associated waste rice should decrease the availability of waste rice from the field overall. Our results suggest that while baling may increase the ground density of waste rice in some fields, when rice seed in the straw layer is accounted for before baling, fields have significantly less waste rice available after baling. Overall, our rice densities were greater than those found in similar studies in the Sacramento Valley (Fleskes et al. 2012: 364 kg/ha, Miller et al. 1989: 386 kg/ha). Our results support food availability from rice seed as a plausible mechanism resulting in the differences in dabbling duck use between baled and non-baled fields.

Our data indicate baling does not have a large impact on invertebrate or moist soil seed density, but flooding does. Both nematodes and crustaceans had significantly higher densities in the flooded practices, both of which are known food resources for shorebirds and the latter for waterfowl. We did not find any other discernible patterns in invertebrate and seed abundance though overall we had low samples sizes given the spatial variability in invertebrate abundance. The invertebrate densities in our four post-harvest practices may have been influenced by other factors which we were unable to control for, such as grower preference for herbicides and pesticides as well as the water source, if flooded.

II. Seeding Practices

Our results suggest that drill seeding, and the resulting pulses of flooding, provide comparable habitat for shorebirds and dabbling ducks to fly-on seeding. Fly-on seeding had a greater proportion flooded, but drill seeding provided more saturated and moist habitat. Shorebirds were significantly associated with saturated soils.

During seeding, there are two major lifecycle stages to consider for migratory birds when assessing results and making decisions about seeding practices: spring migration for shorebirds and the beginning of the breeding season for Central Valley nesting species (e.g. mallard, black-necked stilt). The timing of rice planting varies annually (2012 was a late year for planting) and waterbird use of rice fields in spring likely varies annually as well, in response to variation in timing of flooding and with regard to migration timing. Migration was apparent in our data as western sandpipers were the second most abundant shorebird species in this study, yet they were only present through 18 May in 2012 and 3 May in 2013. Dunlin, semipalmated plover (*Charadrius semipalmatus*), whimbrel (*Numenius phaeopus*), and dowitchers (*Limnodromus* spp.) were all present during the study with numbers decreasing during the course of our surveys, making it more difficult to assess differences between the seeding practices. Another variable not accounted for in this analysis is the behavioral shift for some waterfowl and shorebirds from maintenance (loafing and foraging) to breeding (incubation) which could potentially decrease the number of individuals detected in either of the practices. For dabbling ducks, females would be sitting quietly on a nest on the edge of rice or in surrounding uplands. For shorebirds, while some species that nest in the middle of rice fields would be easy to detect (e.g. black-necked stilts), others would be quietly incubating on the rice checks (e.g. American avocet, killdeer) and thus more difficult to detect. However, we have no reason to suspect that these behavioral shifts would differ between practices, so this should not dramatically influence our results, only decrease our overall densities. Further evaluation of the effects of these two seeding practices on breeding species (i.e. nest success, productivity) is needed.

Overall, our study suggests that some post-harvest practices (reduced winter flooding, baling) to reduce greenhouse gas emissions from rice may reduce use by waterbirds. The relative GHG reductions of different practices (EDF 2010) must be evaluated against the trade-off of reduced habitat for waterbirds.

CONCLUSIONS

- Rice paddies that were baled prior to flooding had lower densities of dabbling ducks and shorebirds than paddies that were not baled. Baled fields also had less waste rice seed than non-baled fields.

- Ducks and shorebirds were significantly associated with flooded fields, with ducks not even being observed in non-flooded practices.
- Shorebirds were positively associated with fields in which the straw and stubble had been incorporated, or mixed, into the soil. Though after accounting for differences in incorporation among practices, shorebird density was still higher in non-baled compared to baled fields.
- Shorebirds and ducks were negatively associated with the amount of the survey area with standing stubble which may suggest why there were higher densities of both guilds in non-baled fields compared to baled fields.
- Seeding practices were nearly equivalent in the potential to support shorebirds and dabbling ducks. Further evaluation of the effects of these two seeding practices on breeding species (i.e. nest success, productivity) is needed.

ACKNOWLEDGMENTS

This study would not have been possible without the participation and support of many Sacramento Valley rice growers. We are also grateful for the support of our partners at Environment Defense Fund, the California Rice Commission, and the Migratory Bird Conservation Partnership (with Audubon California and The Nature Conservancy). We thank Monica Iglecia and Paul Buttner for outreach support. We thank Jeff Stoddard and the Yolo Bypass Wildlife Area for providing a location to wash benthic core samples and Ryan Gilpin, Michelle Gilbert, and Brent Campos for help washing benthic core samples in the cold and rain. We thank the USGS Western Ecological Research Center and San Francisco Bay Estuary Field Station personnel John Takekawa, Isa Woo, and Ashley Smith for their support with our invertebrate sampling and processing efforts. Nat Seavy and Lynne Stenzel of Point Blue offered helpful discussions on study design for the food resources component. Nat Seavy, Tom Gardali, Robert Parkhurst, and Sara Snider provided valuable comments on earlier versions of this report. Funding was provided by a contract through EDF from their USDA Natural Resources Conservation Service National Conservation Innovation Grant and the S. D. Bechtel, Jr. Foundation. This is contribution No. 1999 of Point Blue Conservation Science.

LITERATURE CITED

AB-32. Global Warming Solutions Act of 2006. California Assembly Bill 32. <www.arb.ca.gov/cc/ab32/ab32.htm>

Bossio, D. A., W. R. Horwath, R. G. Mutters, and C. van Kessel. 1999. Methane pool and flux dynamics in a rice field following straw incorporation. Soil Biology and Biochemistry 31: 1313–1322.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer, New York, NY.

Collins, D. P., C. A. Palmer, and R. E. Trost. 2011. Pacific Flyway Data Book 2011: Waterfowl harvests and status, hunter participation and success in the Pacific Flyway and United States. U. S. Fish and Wildlife Service Division of Migratory Bird Management, Portland, Oregon.

CVJV. 2006. Central Valley Joint Venture Implementation Plan—conserving bird habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Davis, C. A., and L. M. Smith. 1998. Ecology and management of migrant shorebirds in the Playa Lakes region of Texas. Wildlife Monographs 140: 3–45.

Day, J. H., and M. A. Colwell. 1998. Waterbird communities in rice fields subjected to different post-harvest treatments. Colonial Waterbirds 21: 185–197.

EDF. 2010. Creating and quantifying carbon credits from voluntary practices on rice farms in the Sacramento Valley: accounting for multiple benefits for producers and the environment. Final report to NRCS from Environmental Defense Fund, Inc., Sacramento, CA.

Elphick, C. S., and L. W. Oring. 1998. Winter management of Californian rice fields for waterbirds. Journal of Applied Ecology 35: 95–108.

Elphick, C. S., and L. W. Oring. 2003. Conservation implications of flooding rice fields on winter waterbird communities. Agriculture, Ecosystems & Environment 94: 17–29.

Euliss, Jr., N. H., and S. W. Harris. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. The Journal of Wildlife Management 51: 724–732.

Fitzgerald, G. J., K. M. Scow, and J. E. Hill. 2000. Fallow season straw and water management effects on methane emissions in California rice. Global Biogeochemical Cycles 14: 767–776.

Fleskes, J. P., J. L. Yee, M. L. Casazza, M. R. Miller, J. Y. Takekawa, and D. L. Orthmeyer. 2005. Waterfowl distribution, movements, and habitat use relative to recent habitat changes in the Central Valley of California: A cooperative project to investigate impacts of the Central Valley Joint Venture and changing agricultural practices on the ecology of wintering waterfowl. Final Report. U.S. Geological Survey-Western Ecological Research Center, Dixon Field Station, Dixon, California.

Fleskes J. P., B. J. Halstead, M. L. Casazza, P. S. Coates, J. D. Kohl, and D. A. Skalos. 2012. Waste rice seed in conventional and stripper-head harvested fields in California: Implications for wintering waterfowl. Journal of Fish and Wildlife Management 3: 266–275.

Frayer, W. E., D. D. Peters, and H. R. Pywell. 1989. Wetlands of the California Central Valley: Status and Trends - 1939 to mid-1980s. U.S. Fish and Wildlife Service, Region 1, Portland, Oregon, 28 pp.

Gardner, M. J., and D. G. Altman. 1986. Confidence intervals rather than p values: estimation rather than hypothesis testing. British Medical Journal 292: 746–750.

Garr, J. D. 2014. The status of rice fields during mid-winter in the Sacramento Valley, California: 2013 – 2014 Data Summary. Final Report to The Central Valley Joint Venture, The California Rice Commission, and Ducks Unlimited. Wildlife Friendly Farming, Colusa, CA.

Gilmer, D. S., M. R. Miller, R. D. Bauer, and J. R. LeDonne. 1982. California's Central Valley wintering waterfowl: concerns and challenges. Transactions of the North American Wildlife and Natural Resources Conference 47: 441–452.

Hatfield, J., G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall, and D. Liverman. 2014. Chapter 6: Agriculture. Climate Change Impacts in the United States: The Third National Climate Assessment *in* J. M. Melillo, T. C. Richmond, and G. W. Yohe, Eds., U. S. Global Change Research Program. pp. 150–174. <http://nca2014.globalchange.gov/report/sectors/agriculture>.

Halstead, B. J., M. R. Miller, M. L. Casazza, P. S. Coates, M. A. Farinha, K. B. Gustafson, J. L. Yee, and J. P. Fleskes. 2011. Rapid assessment of rice seed availability for wildlife in harvested fields. Wildlife Society Bulletin 35: 377–393.

Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff, E. P. Maurer, N. L. Miller, S. C. Moser, S. H. Schneider, K. N. Cahill, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, C. K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences, USA. 101: 12422–12427.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54: 187–211.

IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Lauren, J. G., G. S. Pettgrove, and J. M. Duxbury. 1994. Methane emissions associated with a green manure amendment to flooded rice in California. Biogeochemistry 24: 53–65.

Lee, J., S. DeGryze, and J. Six. 2011. Effect of climate change on field crop production in California's Central Valley. Climatic Change 109: S335–S353.

Legendre, P., M. R. T. Dale, M. J. Fortin, P. Casgrain, and J. Gurevitch. 2004. Effects of spatial structures on the results of field experiments. Ecology 85: 3202–3214.

Lindberg, Jeff. 2003. Progress report on the phase-down of rice straw burning in the Sacramento Valley Air Basin. California Air Resources Board, California Department of Food and Agriculture December. Accessed on 25 July 2014. <http://www.arb.ca.gov/research/apr/reports/l2075.pdf>

Lobell, D. B., and C. B. Field. 2011. California perennial crops in a changing climate. Climatic Change. 109: 317–333.

Manly, B. F. 2007. Randomization, bootstrap, and Monte Carlo methods in biology. Chapman and Hall, Boca Raton, Florida, USA.

Miller, M. R. 1987. Fall and winter foods of northern pintails in the Sacramento Valley, California. The Journal of Wildlife Management 51: 405–414.

Miller, M. R., D. E. Sharp, D. S. Gilmer, and W. R. Mulvaney. 1989. Rice available to waterfowl in harvested fields in the Sacramento Valley, California. California Fish and Game 75: 113–123.

Miller, M. R., J. D. Garr, and P. S. Coates. 2010. Changes in the status of harvested rice fields in the Sacramento Valley, California: Implications for wintering waterfowl. Wetlands 30: 939–947.

Mitchell, D. W., and J. W. Grubaugh. 2005. Impacts of shorebirds on macroinvertebrates in the Lower Mississippi Alluvial Valley. The American Midland Naturalist 154: 188–200.

R Core Development Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed in December 2013. <http://www.R-project.org/>.

Safran, R. J., C. R. Isola, M. A. Colwell, and O. E. Williams. 1997. Benthic invertebrates at foraging locations of nine waterbird species in managed wetlands of the northern San Joaquin Valley, California. Wetlands 17: 407–415.

Shuford, W. D., G. W. Page, and J. E. Kjelmyr. 1998. Patterns and dynamics of shorebird use of California's Central Valley. Condor. 100: 227–244.

Shuford, W. D., M. E. Reiter, K. M. Strum, C. J. Gregory, M. M. Gilbert, and C. M. Hickey. 2013. The effects of crop treatments on migrating and wintering waterbirds at Staten Island, 2010-2012. Final Report to The Nature Conservancy. Point Blue Conservation Science, Petaluma, CA.

Smith, R. V., J. D. Stafford, A. P. Yetter, M. M. Horath, C. S. Hine, and J. P. Hoover. 2012. Foraging ecology of fall-migrating shorebirds in the Illinois River Valley. PLOS One 7: e45121.

Sterling, J. and P. Buttner. 2011. Wildlife known to use California ricelands. California Rice Commission, Sacramento, CA.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association. 99: 262–278.

Strum, K. M., M. E. Reiter, C. A. Hartman, M. N. Iglecia, T. R. Kelsey, and C. M. Hickey. 2013. Winter management of California's rice fields to maximize waterbird habitat and minimize water use. Agriculture, Ecosystems and Environment 179: 116-124.

Suddick, E. C., K. M. Scow, W. R. Horwath, L. E. Jackson, D. R. Smart, J. Mitchell, and J. Six. 2010. The potential for California agricultural crop soils to reduce greenhouse gas emissions: a holistic evaluation. In D. L. Sparks, ed. Advances in Agronomy, Vol. 107, Academic Press, Burlington, VT, pp. 123–126.

Taft, O. W. and C. S. Elphick. 2007. Waterbirds on working lands: literature review and bibliography development. Technical Report. National Audubon Society, New York, New York. http://www.audubon.org/bird/waterbirds/downloads.html, accessed January 10, 2009.

Western Hemisphere Shorebird Reserve Network (WHSRN). 2003. Sacramento Valley as site of international importance to shorebirds. <http://www.whsrn.org/site-profile/sacramento-valley>

Zuur, A. F., E. N. Ieno, N. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York, NY.

LIST OF TABLES

Table 1. Total number of rice field paddies in each post-harvest practice for waterbird surveys conducted from 2 December 2011 – 27 January 2012 (Year 1) and 3 December 2012 – 25 January 2013 (Year 2) in the Sacramento Valley, CA. 28

Table 2. Waterbird occurrence (# surveys detected; Occ.), abundance (total count; Abun.), and species richness grouped by guild in four post-harvest rice field practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. 29

Table 3. Summary of models evaluating mechanisms influencing waterbird use of four post-harvest rice field practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. In addition to covariates listed, all models included an intercept, an overdispersion parameter, and a zero-inflation parameter. 31

Table 4. Mean shorebird densities and 95% CIs in the two flooded post-harvest rice field practices, BF and NBF, with incorporation (or non-incorporation) of straw and/or standing stubble separated for each practice. Paddies surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. *n* is the number of surveyed paddies in each group. 32

Table 5. Estimated ground and overall (ground + straw) post-harvest waste rice mass-density (kg/ha) in 6 non-baled and 4 baled fields, sampled in fall of 2011 (Year 1) in the Sacramento Valley, CA. 33

Table 6. Estimated ground and overall (ground + straw) post-harvest waste rice mass-density (kg/ha) in 10 fields, sampled pre- and post-baled, in fall of 2012 (Year 2) in the Sacramento Valley, CA.. 34

Table 7. Total number of rice fields (field) sampled for invertebrates and seeds, including the number of core samples (sample) processed and identified, collected during December 2011 and 2012 in the Sacramento Valley, CA. 35

Table 8. Food resources in four post-harvest rice field practices BF (baled/flooded), BNF (baled/non-flooded), NBF (non-baled/flooded), and NBNF (non-baled/non-flooded). Occurrence (proportion of fields in which detected; Occ.) and abundance (total count: Abun.) of invertebrates and seeds, ranked by total abundance, sampled in December 2011 and 2012 in the Sacramento Valley, CA. 36

Table 9. Waterbird occurrence (# surveys detected; Occ.), abundance (total count; Abun.), and species richness in fields of two seeding practices (Drill and Fly-on) surveyed from 5 – 26 May 2012 and 18 April – 24 May 2013 in the Sacramento Valley, CA. 37

Table 10. Summary of models evaluating mechanisms influencing waterbird use of rice fields during seeding (April – May) in the Sacramento Valley, CA. In addition to covariates listed, all models included an intercept, an overdispersion parameter, and a zero-inflation parameter. 38

LIST OF FIGURES

Figure 1. Participating rice farms in the Sacramento Valley, CA. All farms were included in waterbird surveys and a subset of farms was sampled for waste rice and winter invertebrates and seeds. 39

Figure 2. Mean waterbird density (birds/ha) and 95% confidence intervals in four post-harvest rice field practices, BF (baled/flooded), BNF (baled/non-flooded), NBF (non-baled/flooded), and NBNF (non-baled /non-flooded) surveyed from 2 December 2011 – 27 January 2012 (Year 1) and 3 December 2012 – 25 January 2013 (Year 2) in the Sacramento Valley, CA. 40

Figure 3. Distribution of observed paddy characteristics in four post-harvest rice practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. 41

Figure 4. Mean invertebrate density (count/m^2) and 95% confidence intervals in four post-harvest rice field practices, BF (baled/flooded), BNF (baled/non-flood), NBF (non-baled/flooded), and NBNF (non-baled /non-flooded) sampled in December 2011 and 2012 in the Sacramento Valley, CA. 42

Figure 5. Mean waterbird density (birds/ha) and 95% confidence intervals in two seeding practices, drill and fly-on seeding from surveys conducted from 5 – 26 May 2012 (Year 1) and 18 April – 24 May 2013 (Year 2) in the Sacramento Valley, CA. 43

Figure 6. Distribution of observed soil moisture characteristics in rice paddies in two seeding practices, drill and fly-on seeding from surveys conducted from 5 – 26 May 2012 and 18 April – 24 May 2013 in the Sacramento Valley, CA. 44

LIST OF APPENDICES

Appendix A. List of all species detected during surveys of rice fields during the post-harvest and seeding studies in the Sacramento Valley, CA.. 45

Table 1. Total number of rice field paddies in each post-harvest practice for waterbird surveys conducted from 2 December 2011 – 27 January 2012 (Year 1) and 3 December 2012 – 25 January 2013 (Year 2) in the Sacramento Valley, CA.

	Baled/ Flooded	Baled/ Non-flooded	Non-baled/ Flooded	Non-baled/ Non-flooded	Overall
Year 1	45	74	54	60	233
Year 2	65	39	72	70	246
Both years combined	110	113	126	130	479

Table 2. Waterbird occurrence (# surveys detected; Occ.), abundance (total count; Abun.), and species richness grouped by guild in four post-harvest rice field practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. "--" indicates 0.

Common Name	BF		BNF		NBF		NBNF		Total
	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	
Dabbling ducks									
Wood Duck	1	1	--	--	--	--	--	--	1
Gadwall	--	--	--	--	6	52	--	--	52
Eurasian Wigeon	--	--	--	--	1	2	--	--	2
American Wigeon	4	130	--	--	8	277	--	--	407
Mallard	2	23	--	--	15	242	--	--	265
Northern Shoveler	9	164	--	--	34	763	--	--	927
Northern Pintail	7	808	--	--	39	6,084	--	--	6,892
Green-winged Teal	4	12	--	--	12	1,174	--	--	1,186
Unknown Duck	--	--	--	--	1	600	--	--	600
Geese and Swans									
Gr. White-fronted Goose	6	372	6	407	12	563	7	2,583	3,925
White geese (Snow + Ross's)	4	409	2	582	6	523	3	1,156	2,670
Canada Goose	1	25	--	--	--	--	--	--	25
Mixed Goose	--	--	1	5,000	1	3,000	--	--	8,000
Tundra Swan	9	693	1	150	7	423	--	--	1,266
Shorebirds									
Black-bellied Plover	1	6	2	37	3	5	--	--	48
Killdeer	25	128	36	249	67	380	72	427	1,184
Black-necked Stilt	6	18	--	--	--	--	--	--	18
Greater Yellowlegs	8	40	2	2	54	176	1	2	220
Lesser Yellowlegs	--	--	--	--	1	1	--	--	1
Long-billed Curlew	3	3	13	174	28	156	18	156	489
Western Sandpiper	--	--	--	--	1	3	--	--	3
Least Sandpiper	4	61	--	--	29	1,864	9	111	2,036
Unknown Peep	--	--	--	--	1	18	--	--	18
Dunlin	3	221	4	90	30	4,879	12	203	5,393
Dowitcher spp.	2	5	--	--	15	1,102	--	--	1,107
Wilson's Snipe	9	17	10	18	28	81	20	62	178
Species richness - waterfowl & shorebirds	**19**		**9**		**20**		**9**		**24**

Table 2, continued. Waterbird occurrence (# surveys detected; Occ.), abundance (total count; Abun.), and species richness grouped by guild in four post-harvest rice field practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. "--" indicates 0.

Common Name	BF		BNF		NBF		NBNF		Total
	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	
Long-legged waders									
Great Blue Heron	29	29	17	17	31	32	20	22	100
Great Egret	20	21	35	37	30	36	28	35	129
Snowy Egret	3	6	1	5	6	8	2	2	21
Green Heron		--		--		--	1	1	1
White-faced Ibis	10	2,785	2	3	5	205		--	2,993
Sandhill Crane	2	25	16	605	8	157	11	264	1,051
Gulls and marsh birds									
Ring-billed Gull	8	34	15	295	57	281	11	83	693
California Gull	1	19		--	4	53	1	2	74
Herring Gull	3	9	2	2	2	2	1	1	14
Pied-billed Grebe	1	1		--		--		--	1
American Bittern		--		--	1	1		--	1
American Coot	71	7,636	2	370	49	3,569		--	11,575
Species richness - all waterbirds	**29**		**17**		**30**		**17**		**36**

Table 3. Summary of models evaluating mechanisms influencing waterbird use of four post-harvest rice field practices surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. In addition to covariates listed, all models included an intercept, an overdispersion parameter, and a zero-inflation parameter.

Guild	Model Covariate	AIC[1]	DeltaAIC[2]	LL[3]	K[4]	Estimate[5]	95%Low[6]	95%Up[7]	EstQ[8]	95%Low	95% Up
Dabbling	Depth[9] + Depth^2[10]	948.52	0.00	-469.26	5	0.96	0.56	1.36	-0.02	-0.04	-0.01
Ducks	Flood[11]	950.20	1.68	-471.10	4	6.19	4.24	8.15			
	Depth	963.77	15.25	-477.89	4	0.19	0.08	0.30			
	Stubble[12]	965.83	17.31	-478.92	4	-7.45	-10.79	-4.12			
	Intercept[13]	976.07	27.56	-485.04	3						
	Incorporation[14]	977.12	28.60	-484.56	4	0.83	-0.52	2.19			
Geese	Intercept	817.72	0.00	-405.86	3						
	Stubble	818.70	0.98	-405.35	4	0.96	-1.01	2.93			
	Flood	818.75	1.04	-405.38	4	-1.20	-3.41	1.00			
	Depth	819.48	1.76	-405.74	4	-0.02	-0.11	0.06			
	Depth + Depth^2	821.46	3.75	-405.73	5	-0.04	-0.29	0.21	0.00	-0.01	0.01
	Incorporation	822.26	4.54	-407.13	4	-0.38	-2.12	1.35			
Shorebirds	Depth + Depth^2	2065.84	0.00	-1027.92	5	0.41	0.30	0.53	-0.02	-0.02	-0.01
	Incorporation	2083.58	17.74	-1037.79	4	2.13	1.49	2.77			
	Flood	2099.84	33.99	-1045.92	4	1.89	0.86	2.91			
	Stubble	2104.30	38.46	-1048.15	4	-2.00	-3.16	-0.84			
	Intercept	2111.21	45.37	-1052.61	3						
	Depth	2112.10	46.26	-1052.05	4	0.03	-0.03	0.09			

[1]Akaike's Information Criterion; [2]difference from model with lowest AIC; [3]log likelihood; [4]number of parameters in model; [5]parameter estimate for model covariate; [6]lower 95% confidence bound; [7]upper 95% confidence bound; [8]parameter estimate for quadratic term of water depth model (Depth^2); [9]average water depth (cm); [10]quadratic term for water depth; [11]proportion of the survey area that was flooded; [12]proportion of the survey area with standing stubble; [13] intercept-only model; [14]whether a field was stomped, chiseled or disked post-harvest.

Table 4. Mean shorebird densities and 95% CIs in the two flooded post-harvest rice field practices, BF and NBF, with incorporation (or non-incorporation) of straw and/or standing stubble separated for each practice. Paddies surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA. *n* is the number of surveyed paddies in each group.

Flooded practices only	*n*	mean	95% CI
Baled, incorporated	59	0.484	0.129 - 0.985
Baled, non-incorporated	51	0.124	0.078 - 0.173
Non-baled, incorporated	114	5.333	2.963 - 8.052
Non-baled, non-incorporated	14	1.047	0.300 - 2.069

Table 5. Estimated ground and overall (ground + straw) post-harvest waste rice mass-density (kg/ha) in 6 non-baled and 4 baled fields, sampled in fall of 2011 (Year 1) in the Sacramento Valley, CA.

	Ground		Overall	
	Non-baled	Baled	Non-baled	Baled
	499.1	296.6	499.1	342.9
	569.1	769.2	569.1	1000.5
	716.2	706.5	716.2	895.3
	547.4	207.4	547.4	240.8
	561.8		561.8	
	282.1		282.1	
Mean	529.3	494.9	529.3	619.9
SE	23.6	71.0	23.6	95.9

Table 6. Estimated ground and overall (ground + straw) post-harvest waste rice mass-density (kg/ha) in 10 fields, sampled pre- and post-baled, in fall of 2012 (Year 2) in the Sacramento Valley, CA.

	Ground		Overall	
	Pre-baled	Post-baled	Pre-baled	Post-baled
	243.5	267.7	281.7	267.7
	161.6	142.3	189.8	142.3
	995.9	856.0	1467.3	856.0
	716.2	501.6	911.0	501.6
	653.5	754.8	812.0	754.8
	631.8	419.6	779.3	419.6
	653.5	535.3	812.0	535.3
	844.0	704.1	1137.7	704.1
	658.3	827.1	819.4	827.1
	424.4	491.9	497.2	491.9
Mean	598.3	550.0	770.7	550.0
SE	25.6	23.7	38.0	23.7

Table 7. Total number of rice fields (field) sampled for invertebrates and seeds, including the number of core samples (sample) processed and identified, collected during December 2011 and 2012 in the Sacramento Valley, CA.

Year	BF		BNF		NBF		NBNF		Total fields	Total samples
	field	sample	field	sample	field	sample	field	sample		
2011	3	8	5	10	4	7	3	6	15	31
2012	7	14	7	14	8	16	9	18	31	62
Total	10	22	12	24	12	23	12	24	46	93

Table 8. Food resources in four post-harvest rice field practices BF (baled/flooded), BNF (baled/non-flooded), NBF (non-baled/flooded), and NBNF (non-baled/non-flooded). Occurrence (proportion of fields in which detected; Occ.) and abundance (total count: Abun.) of invertebrates and seeds, ranked by total abundance, sampled in December 2011 and 2012 in the Sacramento Valley, CA.

Taxonomic Group	BF		BNF		NBF		NBNF		Total Abun.
	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	Occ.	Abun.	
Invertebrates									
Nematoda	1	3,401	1	2,164	1	4,863	1	1,509	11,937
Oligochaeta	1	1,986	0.9	1,430	1	1,001	1	1,872	6,289
Crusteaceans (all)	0.9	2,265	0.2	20	1	2,613	0.2	9	4,907
Cladocera	0.7	728	0	0	0.6	1,279	0.1	8	2,015
Copepoda	0.9	811	0.2	20	0.9	727	0	0	1,558
Ostracoda	0.8	715	0	0	0.8	552	0	0	1,267
Insecta	0.7	189	0.8	229	0.4	34	1	211	663
Gastropoda	0.4	35	0.1	11	0.3	34	0.3	164	244
Collembola	0.4	12	0.4	22	0.1	4	0.3	21	59
Arachnida	0	0	0.1	4	0	0	0	0	4
Seeds									
Moist soil seeds	1	19,077	1	5,639	1	12,704	1	10,395	47,815

Table 9. Waterbird occurrence (# surveys detected; Occ.), abundance (total count; Abun.), and species richness in two rice field seeding practices (Drill and Fly-on) surveyed from 5 – 26 May 2012 and 18 April – 24 May 2013 in the Sacramento Valley, CA. "--" indicates 0.

Guild	Waterbird species	Drill		Fly-on		Total
		Occ.	Abun.	Occ.	Abun.	
Dabbling ducks	Wood Duck	--	--	1	2	2
	Gadwall	1	2	--	--	2
	Mallard	205	847	235	588	1,435
	Cinnamon Teal	--	--	3	4	4
	Northern Shoveler	--	--	2	2	2
Geese	Gr. White-fronted Goose	2	12	--	--	12
Shorebirds	Black-bellied Plover	6	22	1	2	24
	Semipalmated Plover	8	21	2	38	59
	Killdeer	105	177	86	108	285
	Black-necked Stilt	4	6	19	40	46
	American Avocet	--	--	7	21	21
	Spotted Sandpiper	3	3	1	1	4
	Greater Yellowlegs	3	13	5	34	47
	Whimbrel	13	78	2	2	80
	Western Sandpiper	22	739	5	421	1,160
	Least Sandpiper	4	45	--	--	45
	Sandpiper sp.	--	--	1	365	365
	Dunlin	8	39	3	13	52
	Dowitcher sp.	1	14	1	2	16
	Wilson's Snipe	--	--	1	1	1
	Wilson's Phalarope	2	5	3	5	10
	Red-necked Phalarope	2	2	1	1	3
Long-legged waders	Great Blue Heron	7	7	7	7	14
	Great Egret	12	12	28	45	57
	Snowy Egret	1	1	--	--	1
	White-faced Ibis	2	15	9	602	617
Misc. marsh birds	Black Tern	7	18	13	28	46
	American Bittern	--	--	1	1	1
	American Coot	10	98	34	505	603
Predators	Northern Harrier	1	1	--	--	1
	Peregrine Falcon	1	1	--	--	1
	Species Richness	24		24		30

Table 10. Summary of models evaluating mechanisms influencing waterbird use of two rice field seeding practices, surveyed from 5 – 26 May 2012 and 18 April – 24 May 2013 in the Sacramento Valley, CA. In addition to covariates listed, all models included an intercept, an overdispersion parameter, and a zero-inflation parameter.

Guild	Model /Covariate	AIC[1]	DeltaAIC[2]	LL[3]	K[4]	Estimate[5]	95%Low[6]	95%Up[7]
Dabbling ducks								
	Dry[8]	1744.18	0.00	-867.09	5	-1.60	-2.30	-0.90
	Flood[9]	1753.30	9.12	-871.65	5	0.79	0.30	1.27
	Intercept[10]	1761.69	17.51	-877.84	3			
	Saturated[11]	1762.68	18.50	-876.34	5	-0.41	-1.52	0.71
	Moist[12]	1763.17	18.99	-876.58	5	0.10	-1.34	1.54
Shorebirds								
	Dry[8]	1421.68	0.00	-705.84	5	-3.34	-4.64	-2.04
	Saturated[11]	1431.99	10.31	-711.00	5	4.53	1.41	7.65
	Flood[9]	1435.92	14.24	-712.96	5	1.39	0.25	2.53
	Moist[12]	1439.39	17.71	-714.69	5	-1.91	-4.51	0.68
	Intercept[10]	1460.87	39.19	-727.43	3			

[1]Akaike's Information Criterion; [2]difference from model with lowest AIC; [3]log likelihood; [4]number of parameters in model; [5]parameter estimate for model covariate; [6]lower 95% confidence bound; [7]upper 95% confidence bound; [8]proportion of survey area that was dry; [9]proportion of survey area that was flooded; [10]intercept-only model; [11]proportion of survey area that was saturated; [12]proportion of survey area that was moist.

Figure 1. Participating rice farms in the Sacramento Valley, CA. All farms were included in waterbird surveys and a subset of farms was sampled for waste rice and invertebrates and seeds.

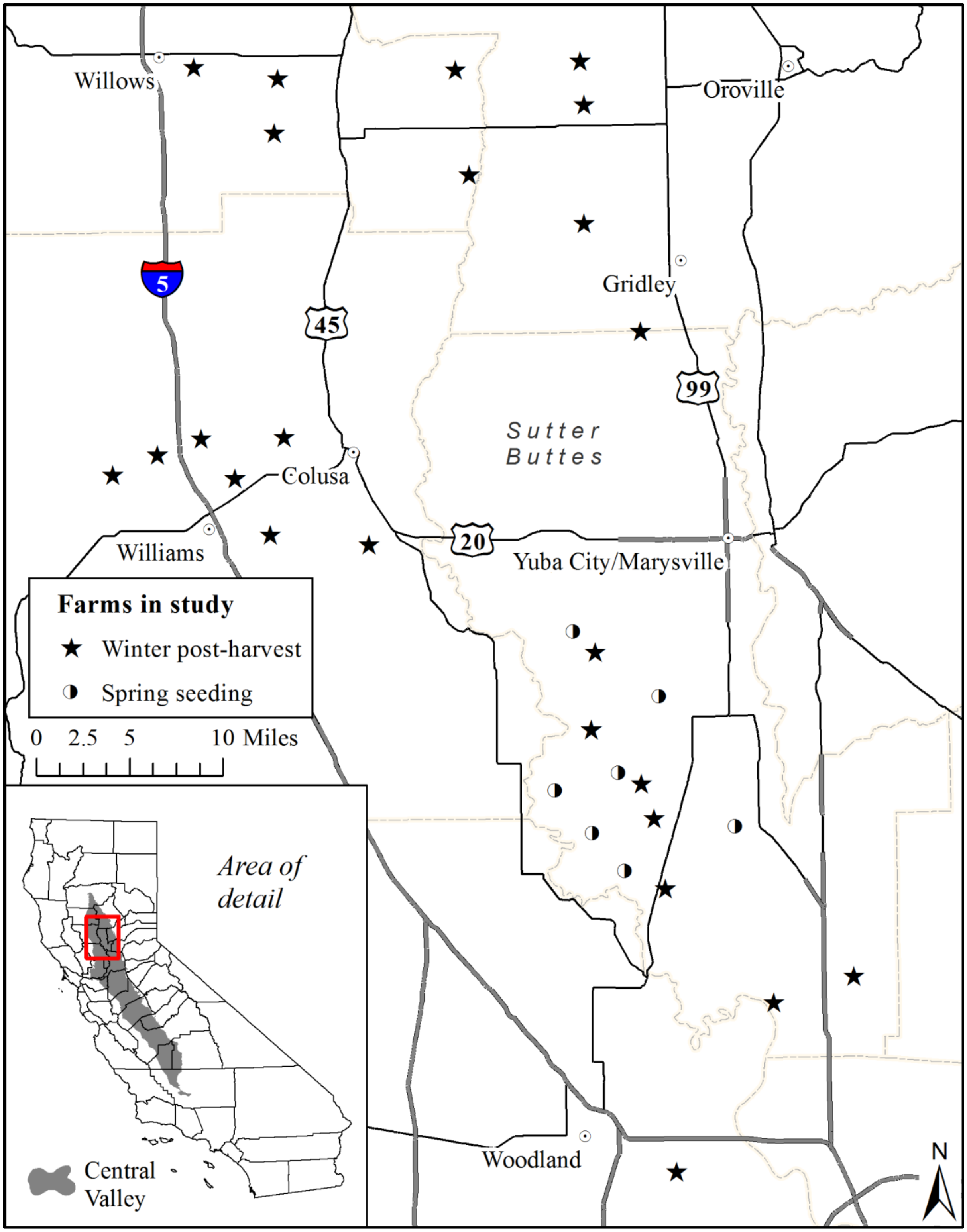


Figure 2. Mean waterbird density (birds/ha) and 95% confidence intervals in four post-harvest rice field practices, BF (baled/flooded), BNF (baled/non-flooded), NBF (non-baled/flooded), and NBNF (non-baled /non-flooded) surveyed from 2 December 2011 – 27 January 2012 (Year 1) and 3 December 2012 – 25 January 2013 (Year 2) in the Sacramento Valley, CA.

Dabbling ducks

Geese

Shorebirds

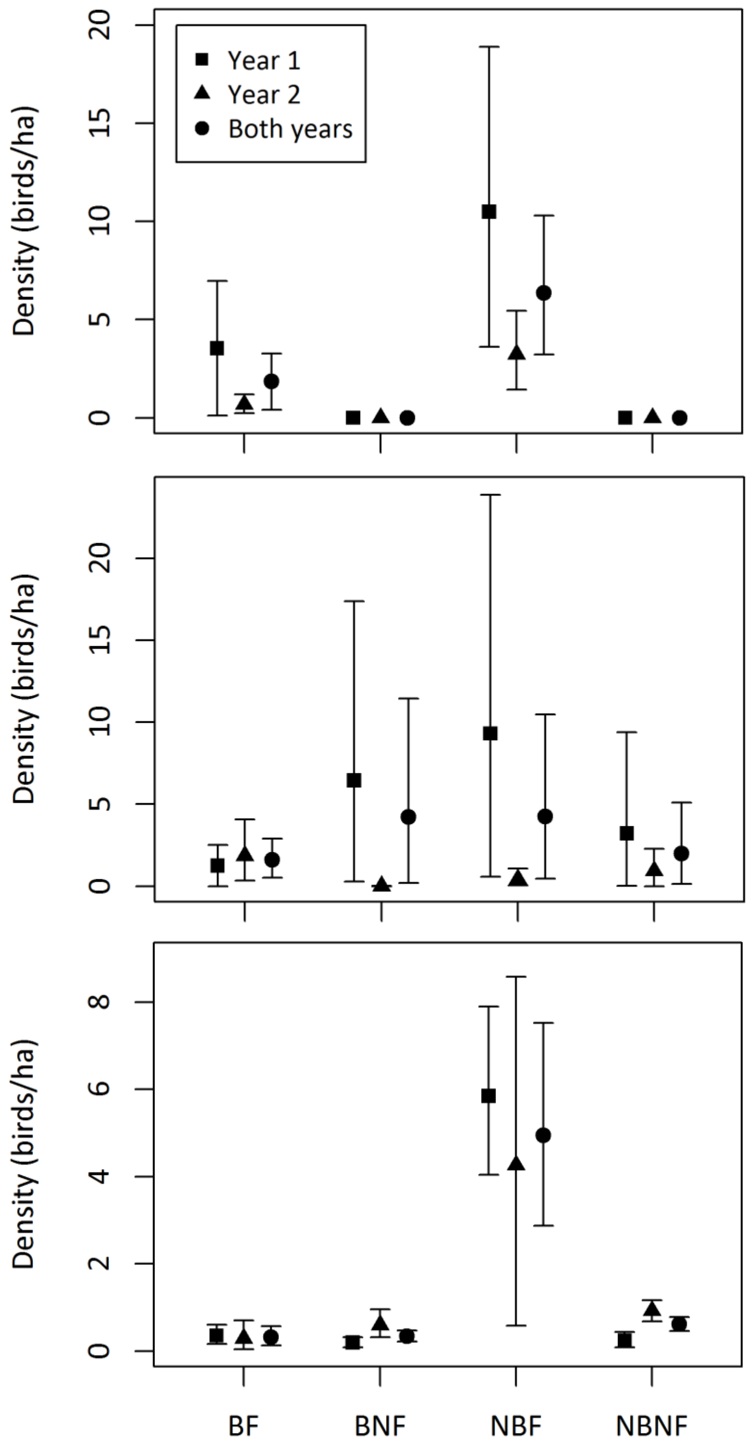


Figure 3. Distribution of observed paddy characteristics in four post-harvest rice practices, BF (baled/flooded), BNF (baled/non-flood), NBF (non-baled/flooded), and NBNF (non-baled /non-flooded), surveyed from 2 December 2011 – 27 January 2012 and 3 December 2012 – 25 January 2013 in the Sacramento Valley, CA.

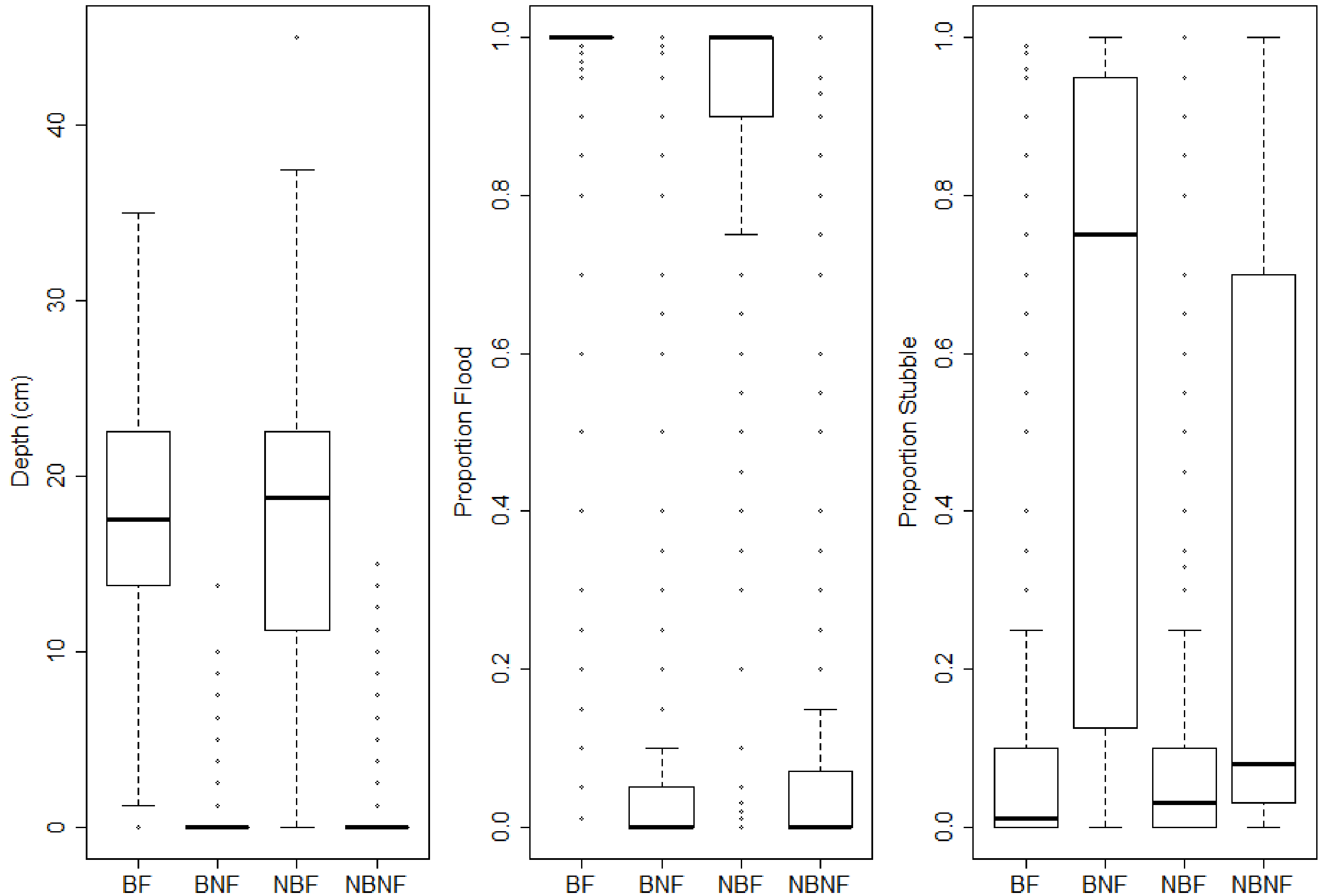


Figure 4. Mean invertebrate density (count/m²) and 95% confidence intervals in four post-harvest rice field practices, BF (baled/flooded), BNF (baled/non-flood), NBF (non-baled/flooded), and NBNF (non-baled /non-flooded) sampled in December 2011 and 2012 in the Sacramento Valley, CA.

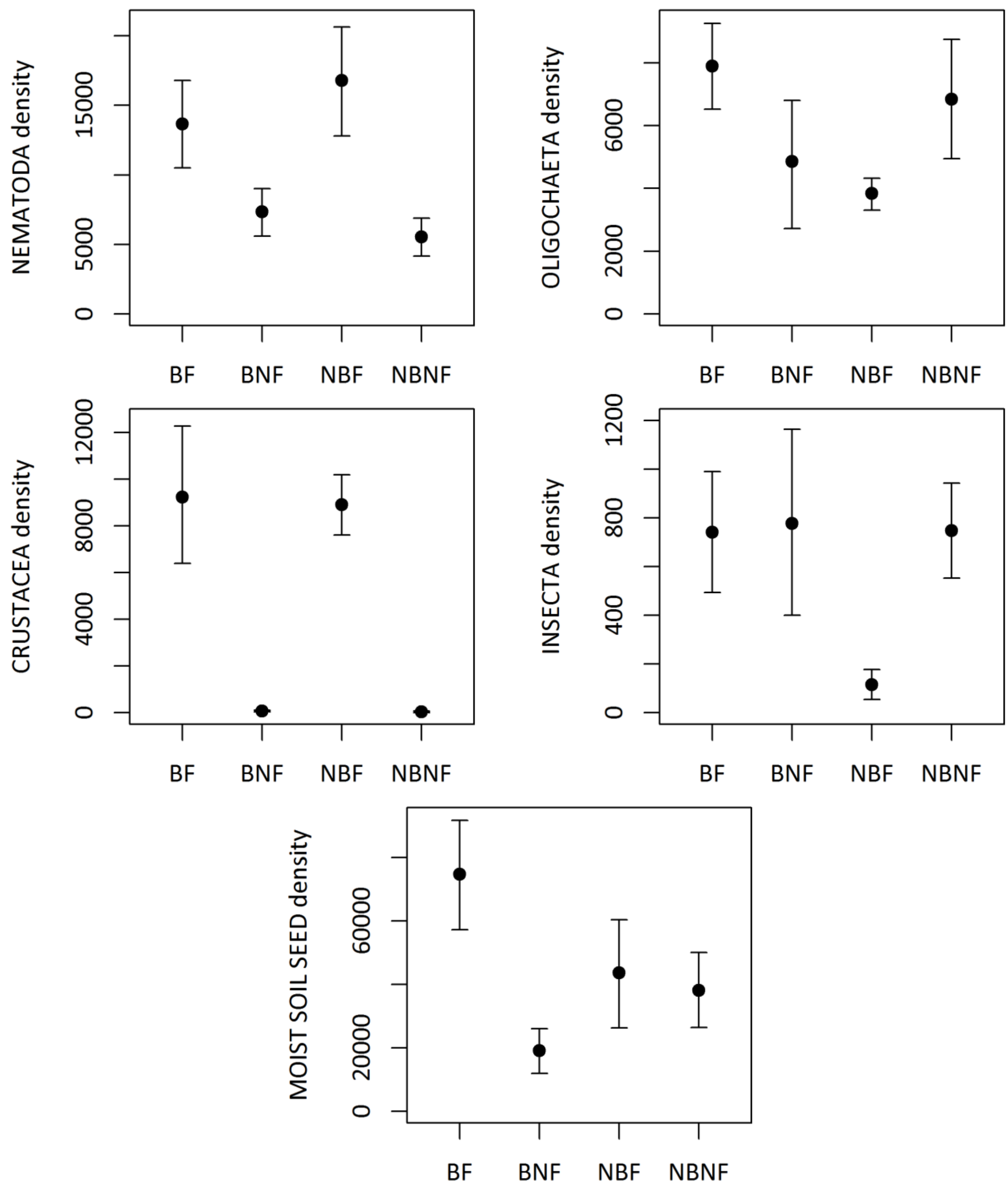


Figure 5. Mean waterbird density (birds/ha) and 95% confidence intervals in two seeding practices, drill and fly-on seeding from surveys conducted from 5 – 26 May 2012 (Year 1) and 18 April – 24 May 2013 (Year 2) in the Sacramento Valley, CA.

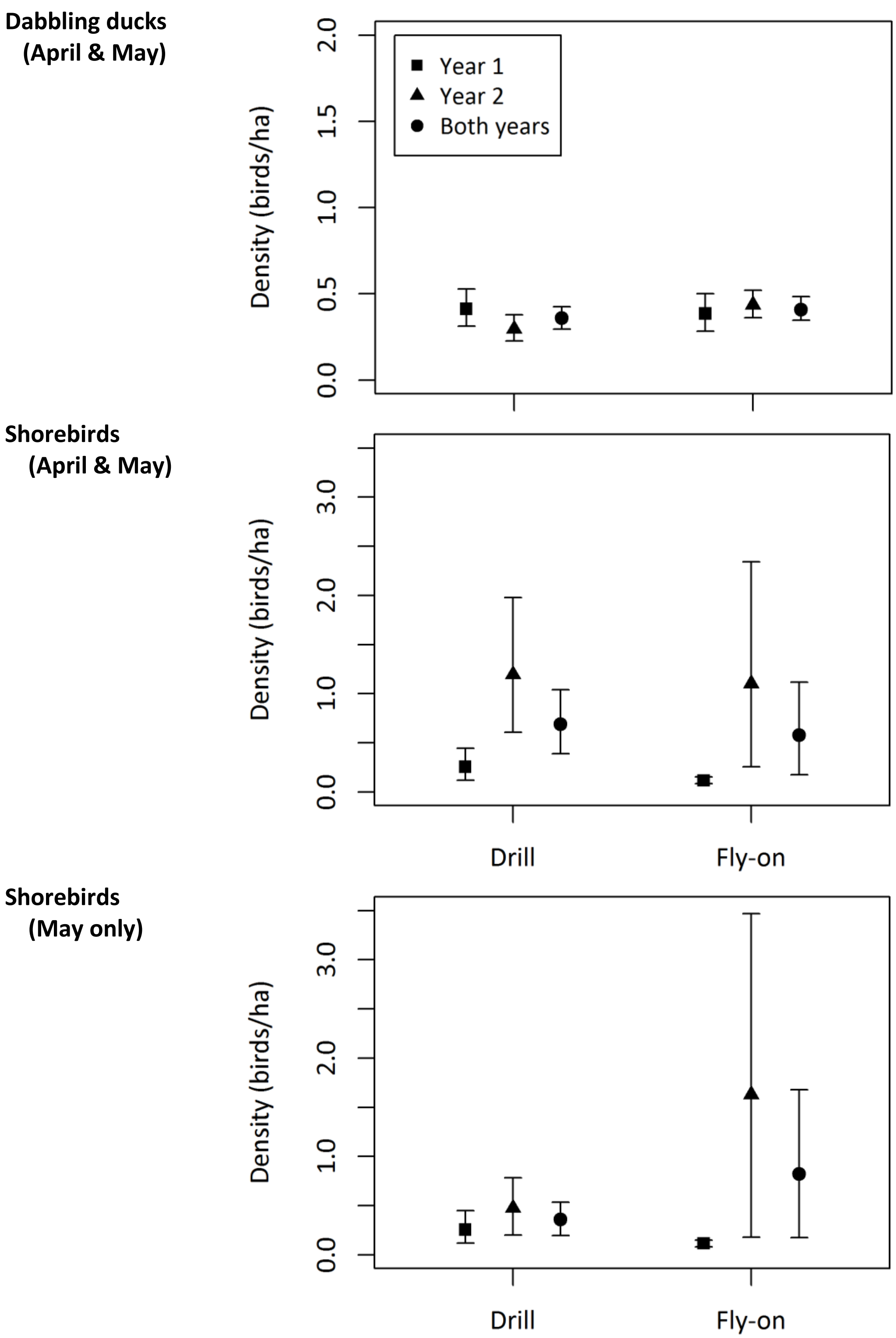
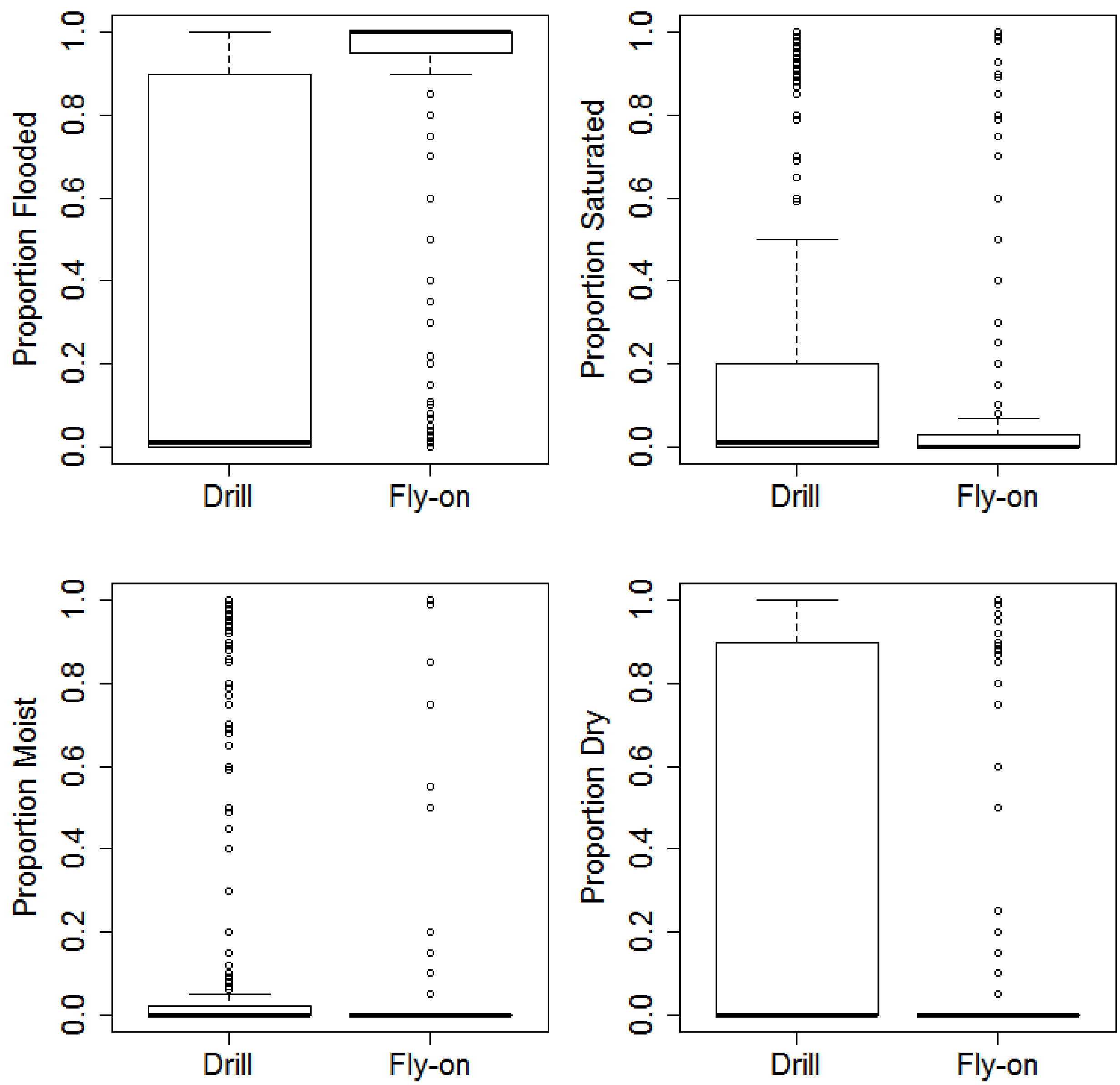


Figure 6. Distribution of observed soil moisture characteristics in rice paddies in two seeding practices, drill and wet fly-on seeding from surveys conducted from 5 – 26 May 2012 and 18 April – 24 May 2013 in the Sacramento Valley, CA.



Appendix A. List of all species detected during surveys in rice fields during the post-harvest and seeding studies in the Sacramento Valley, CA.

Common Name	Scientific Name
Gr. White-fronted Goose	*Anser albifrons*
Mixed Goose	*Anser/Chen/Branta*
Snow Goose	*Chen caerulescens*
Ross's Goose	*Chen rossii*
Canada Goose	*Branta canadensis*
Tundra Swan	*Cygnus columbianus*
Wood Duck	*Aix sponsa*
Gadwall	*Anas strepera*
Eurasian Wigeon	*Anas penelope*
American Wigeon	*Anas americana*
Mallard	*Anas platyrhynchos*
Cinnamon Teal	*Anas cyanoptera*
Northern Shoveler	*Anas clypeata*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Unknown Duck	Anatidae
Canvasback	*Aythya valisineria*
Ring-necked Pheasant	*Phasianus colchicus*
Pied-billed Grebe	*Podilymbus podiceps*
American Bittern	*Botaurus lentiginosus*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Snowy Egret	*Egretta thula*
Green Heron	*Butorides virescens*
White-faced Ibis	*Plegadis chihi*
Turkey Vulture	*Cathartes aura*
White-tailed Kite	*Elanus leucurus*
Bald Eagle	*Haliaeetus leucocephalus*
Northern Harrier	*Circus cyaneus*
Sharp-shinned Hawk	*Accipiter striatus*
Cooper's Hawk	*Accipiter cooperii*
Unknown Accipiter sp.	*Accipiter* sp.
Red-shouldered Hawk	*Buteo lineatus*
Red-tailed Hawk	*Buteo jamaicensis*
Rough-Legged Hawk	*Buteo lagopus*
American Kestrel	*Falco sparverius*
Merlin	*Falco columbarius*
Peregrine Falcon	*Falco peregrinus*
Prairie Falcon	*Falco mexicanus*
Unknown Hawk	Accipitridae
American Coot	*Fulica americana*

Common Name	Scientific Name
Sandhill Crane	*Grus canadensis*
Black-bellied Plover	*Pluvialis squatarola*
Semipalmated Plover	*Charadrius semipalmatus*
Killdeer	*Charadrius vociferus*
Black-necked Stilt	*Himantopus mexicanus*
American Avocet	*Recurvirostra americana*
Greater Yellowlegs	*Tringa melanoleuca*
Lesser Yellowlegs	*Tringa flavipes*
Whimbrel	*Numenius phaeopus*
Long-billed Curlew	*Numenius americanus*
Sanderling	*Calidris alba*
Western Sandpiper	*Calidris mauri*
Least Sandpiper	*Calidris minutilla*
Western/Least Sandpiper	*Calidris mauri/minutilla*
Dunlin	*Calidris alpina*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Unknown Dowitcher	*Limnodromus* sp.
Wilson's Snipe	*Gallinago delicata*
Wilson's Phalarope	*Phalaropus tricolor*
Red-necked Phalarope	*Phalaropus lobatus*
Ring-billed Gull	*Larus delawarensis*
California Gull	*Larus californicus*
Herring Gull	*Larus argentus*
Black Tern	*Chlidonias niger*
Mourning Dove	*Zenaida macroura*
Great Horned Owl	*Bubo virginianus*
Short-eared Owl	*Asio flammeus*
Black Phoebe	*Sayornis nigricans*
Western Kingbird	*Tyrannus verticalis*
Loggerhead Shrike	*Lanius ludovicianus*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax*
Horned Lark	*Eremophila alpestris*
Tree Swallow	*Tachycineta bicolor*
Violet-green Swallow	*Tachycineta thalassina*
Bank Swallow	*Riparia riparia*
Cliff Swallow	*Petrochelidon pyrrhonota*
Barn Swallow	*Hirundo rustica*
Marsh Wren	*Cistothorus palustris*
Red-winged Blackbird	*Agelaius phoeniceus*
Tricolored Blackbird	*Agelaius tricolor*

ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

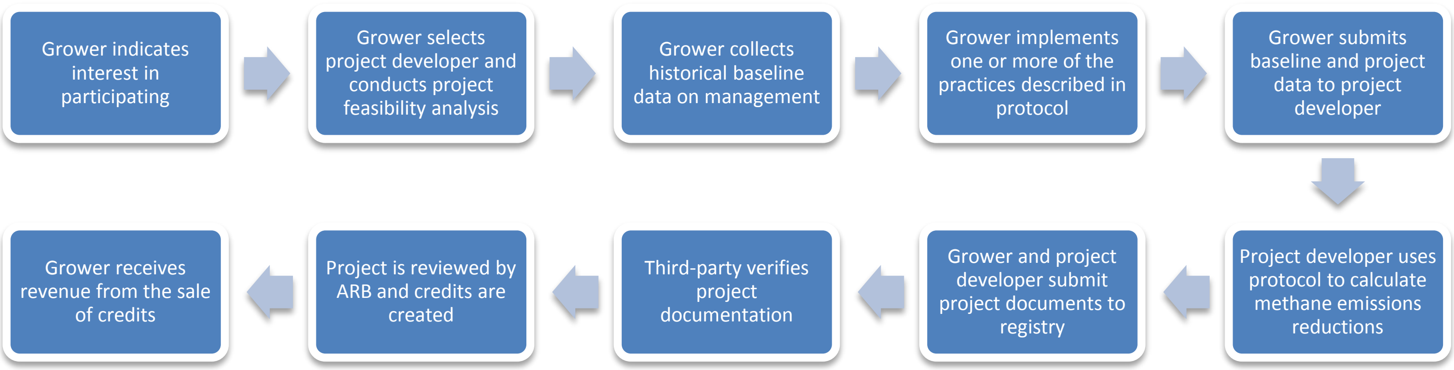
AGRICULTURE GHG MARKETS

Development of Protocols and Accounting Methods for Greenhouse Gas Emissions Reductions from Rice Cultivation Practices

Contact: Robert Parkhurst, rparkhurst@edf.org (415) 293-6097

The Rice Cultivation Project Compliance Offset Protocol[1], adopted by the California Air Resources Board (ARB) in June 2015, is the first crop-based protocol for use in a cap-and-trade program. In order to reduce emissions on their farms, rice growers who enroll in the program can implement one or more of the practices outlined in the protocol. By doing so, growers generate offsets and can sell them in California's carbon market to receive a new source of revenue.

Phases in a Rice Carbon Offset Project



GHG Emission Reductions in California and Midsouth Rice Production Conservation Innovation Grant

Developed by: Environmental Defense Fund – American Carbon Registry – California Rice Commission – White River Irrigation District – DNDC-ART – Terra Global Capital, LLC[2]

The cultivation of rice has multiple environmental benefits. Rice cultivation contributes approximately 8 MMT CO_2e, or 4%, of the total U.S. agricultural CH_4 emissions[3] and this voluntary protocol provides five different practices which allow growers to reduce those emissions. Three of those practices can also generate emission reductions as a part of California's cap-and-trade program. This protocol is the cornerstone in creating a market for the reduction of methane emissions from rice grown in the U.S. and paves the way for the development and adoption of other crop-based offset protocols.

To generate carbon offsets, growers interested in participating:

1. Implement one or more of the five practices listed below
2. Collect records of management practices and yields for both current and historic practices
3. Select a developer to assist in creating the necessary paperwork to generate a carbon offset
4. Participate in a randomized verification audit of the practices on the grower's land
5. Decide when to sell credits generated as a result of implementing one of the five practices

---

[1] Compliance Offset Protocol Rice Cultivation Projects. California Air Resources Board. http://www.arb.ca.gov/regact/2014/capandtradeprf14/ctriceprotocol.pdf
[2] For more information, contact: rparkhurst@edf.org, acr@winrock.org, or pbuttner@calrice.org
[3] U.S. Environmental Protection Agency. (2014). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013. Chapter 5, page 5-2. http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Chapter-5-Agriculture.pdf

Practices which are allowed under the American Carbon Registry's (ACR) *Voluntary Emission Reductions in Rice Management Systems*[4]:

- Dry-seeding– the practice of sowing dry seeds rather than aerially applying pre-germinated seeds
- Early Drainage – draining the field seven to 10 days earlier than usual
- Alternate Wetting and Drying[5] – the practice of periodically flooding and then drying down a field throughout the growing season
- Baling – the removal of rice straw residue at the end of the growing season
- Energy and/or Water Efficiency Practices – the adoption of any technology or measure that demonstrably increases water and/or energy use efficiency

The new rice protocol is important because:

- The program rewards rice famers for implementing a set of practical, science-based approaches that reduce emissions.
- Rice farmers can generate a new revenue stream through carbon credits without impacting their yield.
- Important wetland habitat will be maintained for wildlife and bird populations.

Why rice?

- Rice is one of California's largest crops and contributes over $5 billion a year and 25,000 jobs to the state's economy.
- The science on the carbon and nitrogen cycle of rice is well established allowing for the development an offset methodology.
- Rice cultivation emits methane, a potent greenhouse gas.
- Rice farmers have long been at the forefront of innovative farming practices that promote sustainability.

Interest in this protocol by growers has been substantial. Twenty-one growers on more than 22,000 acres (just under 1% of all rice grown in the U.S.) in California and the Midsouth are participating in offset projects that have been listed on ACR's public registry. The first credits are expected to be generated by a California project in the winter of 2015 and the first credits from a Midsouth project are expected to be generated by mid-2016.

---

[4] Voluntary Emission Reductions in Rice Management Systems – Parent Module. (May 2013). American Carbon Registry. http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/rice-meth-acr-v1-0_july-2013_final.pdf
Voluntary Emission Reductions in Rice Management Systems – California Module. (May 2013). American Carbon Registry. http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/california-module_v1-0_errata-corrected.pdf
Voluntary Emission Reductions in Rice Management Systems – Midsouth Module. (February 2014). American Carbon Registry. http://americancarbonregistry.org/carbon-accounting/standards-methodologies/emission-reductions-in-rice-management-systems/midsouth-module-acr-v1-0-feb2014-final.pdf
[5] Dry-seeding, Early Drainage and Alternate Wetting and Drying are all practices accepted under the California Air Resources Board's Compliance Offset Protocol Rice Cultivation Projects. http://www.arb.ca.gov/regact/2014/capandtradeprf14/3CTAttach2RiceProtocol051115FINAL.pdf

AGRICULTURE GHG MARKETS

California Air Resources Board

Rice Cultivation Projects Compliance Offsets Protocol

Contact: Robert Parkhurst, rparkhurst@edf.org (415) 293-6097

California is poised to approve the first crop-based protocol for the state's pioneering emissions trading system. This protocol will allow U.S. rice farmers to generate offsets to sell in California's carbon market, providing a new source of revenue for growers while contributing to the state's clean air goals.

The new protocol is important because:

- The program rewards rice famers for implementing a set of practical approaches that reduce emissions.
- Rice farmers can generate a new revenue stream through carbon credits without impacting their yield.
- Important wetland habitat will be maintained for wildlife and bird populations.

Why rice?

- Rice is one of California's largest crops and contributes more than $5 billion a year and 25,000 jobs to the state's economy.
- The science on the carbon and nitrogen cycle of rice is well established.
- Rice cultivation emits methane, a potent greenhouse gas.
- Rice farmers have long been at the forefront of innovative farming practices that promote sustainability.

How does it work?

- Farmers can volunteer to implement one of three methods included in the protocol: dry seeding, early drainage, or alternate wetting and drying.
- Dry seeding is the practice of sowing dry seeds rather than aerially applying pre-germinated seeds.

One of the eligible practices - dry seeding

- Early drainage refers to draining the field seven to 10 days earlier than usual.
- Alternate wetting and drying is the practice of periodically flooding and then drying down a field throughout the growing season.

What are the rules?

- Interested rice producers will provide historical information to create a baseline. Then producers will submit records collected throughout a growing season to quantify the amount of methane emissions reduced by undertaking one or more of the three management practices on their land.

How is this protocol unique?

- This is the first protocol to measure GHG reductions from crop-based agriculture.
- The emissions reductions are quantified yearly, based on weather and a producer's management decisions.
- The emissions reductions are permanent and never have a chance of being re-released into the atmosphere.

How does the protocol consider and protect wildlife?

- Notes that "implementation of these activities would be within the natural variability of rice farming, and would not cause a significant effect on bird populations." (Staff Report, pp. 40, 41, 59)
- Excludes the Butte Sink Wildlife Management Area which has the highest concentration of waterfowl per acre in the world. (Staff Report, pp. 10, 40)
- Only allows project activities during the rice growing season to avoid any potential impacts to wintering habitat for migratory waterbirds. (Staff Report, p. 39)
- States that "Dry Seeding Activities would have a minimal effect on avian species, because the timing of seeding already fluctuates a great deal with existing seasonal and meteorological variations." (Staff Report, p. 39)
- Demonstrates that giant garter snake populations could improve as a result of the Early Drainage practice. (Staff Report p. 45)
- Has not included No Winter Flooding or Baling practices until further research on the impacts to birds can be completed. (Staff Report, p. 11)

How does the protocol set the stage for other land-based protocols?

- Allows growers to work together to decrease the administrative costs and increase the economic efficiency. (Staff Report p.20)
- Simplifies verification requirements by highlighting multiple options, including "remote sensing, video conferences, digital photographs (dated and geotagged), or digital escrow services." (Staff Report p.18)
- Eases the burden to report data from the DNDC model by streamlining its use.
- Has the framework to enable the creation of a Nutrient Management Compliance Offsets Protocol which EDF conservatively estimates could generate 2.5 MMT by 2020 and 25 MMT by 2030.

How does the protocol incorporate feedback collected from a thorough stakeholder engagement process?

- Conducted four Technical Working Group meetings, two Workshops, and independent consultations and presentations.
- Included diverse stakeholders, including rice growers in California and the Midsouth, agricultural trade groups (e.g. California Rice Commission, California Farm Bureau), conservation groups (Ducks Unlimited, Point Blue, TNC, Audubon), project developers, project registries (ACR, CAR), verifying bodies, and compliance entities.

How is the protocol different from a forestry protocol?

- Creates offsets annually. These emissions will never be released into the atmosphere. The potent methane reductions from a project occur annually and do not depend on sequestering carbon.
- Uses a rigorous, yet conservative, quantification method (DNDC biogeochemical model) that calculates the emission reductions farmers generate by their changes in cultivation practices.