RICE FARMING HANDBOOK

for the San Joaquin-Sacramento Delta Region

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Compiled and prepared by Restore the Delta's Sustainable Agriculture and Land Program
for the San Joaquin-Sacramento Delta farmers.
February 2024

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Marbled godwits in a flooded post-harvest rice field.
WETLAND PRESERVATION FOUNDATION

Dear farmer,

Embarking on a **rice offset** project may seem like a daunting journey, filled with various steps and processes. However, it's crucial to remember that throughout every stage, there will be knowledgeable individuals and support networks available to guide you. Whether it's understanding the intricacies of project design, navigating the validation process, or delving into the complexities of commercialization, assistance is readily accessible.

From agricultural experts and sustainability consultants to professionals specializing in offset project development, you won't be alone on this path. Take advantage of the resources provided by offset programs, engage with local communities and stakeholders, and leverage the expertise of those who have successfully navigated similar initiatives.

The primary purpose of the *Rice Farming Handbook: San Joaquin-Sacramento Delta Region* is to provide local Delta farmers with comprehensive and accessible information that empowers them to make informed decisions about pursuing rice farming. This handbook aims to serve as a vital educational tool and practical guide, highlighting the importance of rice farming, the science behind conversion, available resources, potential monetary benefits, and the significant role rice farming plays in subsidence reduction, carbon sequestration, and waterfowl habitat enhancement within their estuarine ecosystem.

Your commitment to sustainable rice farming is commendable, and with the right support, every step can lead toward Delta environmental stewardship and economic benefit for your farm. Don't hesitate to reach out, ask questions, and collaborate with the experienced individuals dedicated to making your rice offset project a success. Together, we can create a positive impact on both agricultural practices and our shared environment.

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RESTORE THE DELTA

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INTRODUCTION:

This *Rice Farming Handbook: San Joaquin-Sacramento Delta Region* aims to help farmers better navigate opportunities for rice growing in the San Joaquin-Sacramento Delta region, with a focus on the following key topics:

This Rice Farming Handbook: San Joaquin-Sacramento Delta aims to help farmers better navigate opportunities for rice growing in the San Joaquin-Sacramento Delta region, with a focus on the following key topics:

Subsidence Reduction: To emphasize the role of rice farming in reducing subsidence, thereby preserving the integrity of levees and the long-term protection of Delta lands from sea-level rise and flooding.

Understanding the Science: To explain how converting fields into rice paddies can positively impact habitat enhancement, and crop cultivation.

Educational Resource: To educate local Delta farmers about the fundamentals of rice farming.

Monetary Benefits: To illustrate the value of rice farming at a world market in comparison to other crops in the Delta. This can help farmers make an informed decision and confidently explore the world of rice agriculture.

Waterfowl Habitat Enhancement: To inform farmers about the ecological benefits of rice farming, including the creation of waterfowl habitats, fostering biodiversity, and contributing to the health of the local estuarine ecosystem.

The Rice Farming Handbook: San Joaquin-Sacramento Delta Region aims to be a valuable and comprehensive resource that gives local Delta farmers knowledge and tools to consider rice farming as a viable sustainable option, with major potential benefits for the local economy and community.

Farm fields and tributaries in the Delta.
RESTORE THE DELTA

RESTORE THE DELTA'S MISSION

Restore the Delta's mission is to ensure the health of the San Francisco Bay-Delta estuary and Delta communities.

Restore the Delta works in the areas of public education and outreach so that all Californians recognize the Sacramento-San Joaquin Bay Delta as part of California's natural heritage, deserving of restoration.

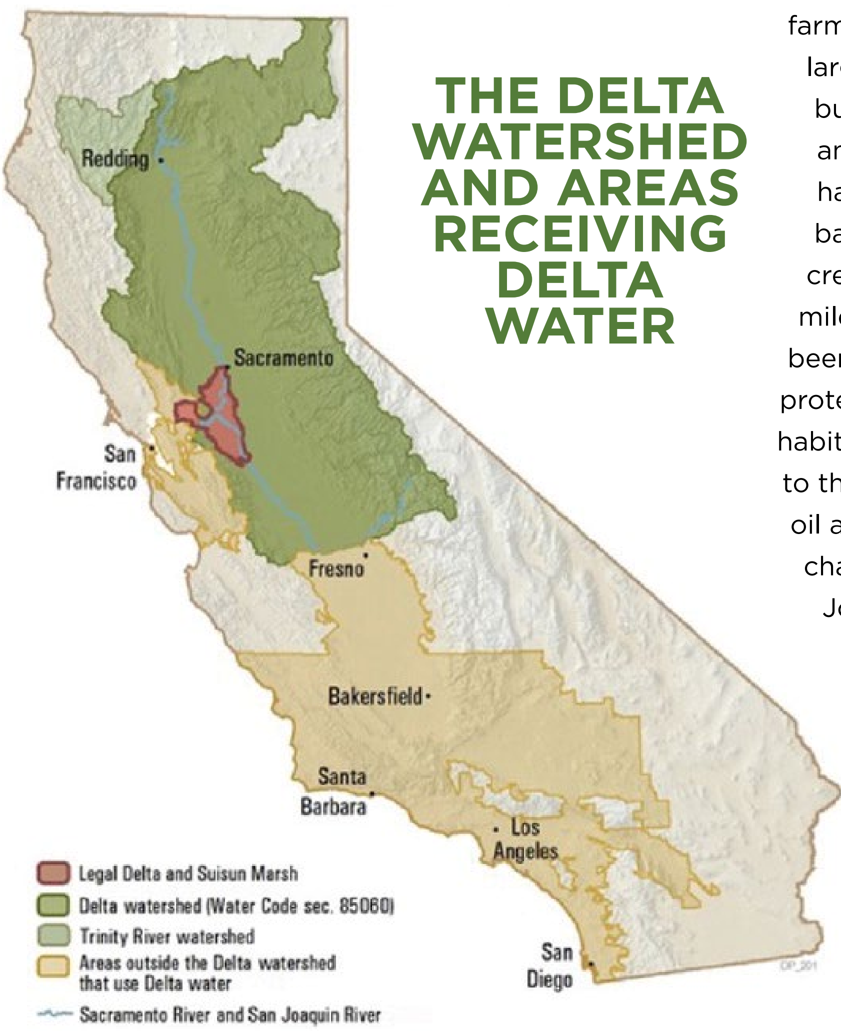
Restore the Delta envisions the Sacramento-San Joaquin Delta as a place where a vibrant local economy, tourism, recreation, farming, wildlife, and fisheries thrive because of resident efforts to protect our waterway commons.

Restore the Delta advocates for local Delta stakeholders to ensure that they have a direct impact on water management decisions affecting the well-being of their communities, and water sustainability policies for all Californians.

SACRAMENTO-SAN JOAQUIN DELTA GEOGRAPHY

The Sacramento-San Joaquin Delta is a land of stunning open spaces fed by five major rivers. A maze of creeks and sloughs spreads finger-like through some of California's most important habitats, especially for Chinook salmon and Greater Sandhill Cranes. It also contains over 500,000 acres of prime farmland devoted to diversified agriculture. The Delta is home to a $5.2 billion agricultural economy and to a fishing, boating, and recreation economy worth hundreds of millions of dollars annually. The Delta's cultural diversity and rich historical legacy add vibrancy to regional tourism.

THE DELTA WATERSHED AND AREAS RECEIVING DELTA WATER



The Delta Watershed and Areas Receiving Delta Water, DELTA PLAN, 2013.
DELTA COUNCIL.

Fisheries, agriculture, and people within the region and throughout the state are dependent on the Delta's freshwater supply. Although other factors affect Delta water quality, water management policies that help to maintain flows of fresh water into and through the Delta are of great environmental and economic importance to all Californians.

Until the middle of the 19th century, runoff from the Sacramento and San Joaquin rivers frequently flooded open Delta wetlands. Beginning with reclamation for farming in the late 1800s, the Sacramento-San Joaquin Delta was divided into tracts (islands), as farmers began building levees that protected the larger islands from flooding. The levees that were built over time gave the Delta its present shape and transformed the region. This is why future habitat restoration efforts must be carefully balanced to protect people and communities while creating space for species. Today, just under 1000 miles of Delta levees, the majority of which have been re-designed to modern engineering standards, protect agricultural and urban communities, natural habitat, and infrastructure worth billions of dollars to the state's economy: power lines, highways, oil and gas pipelines, and deep-water shipping channels. Thus, revitalizing the Sacramento-San Joaquin Delta is essential to California's overall environmental and economic health.

A levee breach along the San Joaquin River. Historical California Flood in Photos.
NBC LOS ANGELES.

SUBSIDENCE

"Subsidence is a gradual settling or sudden sinking of the Earth's surface." —USGS, 2019

"Exposure of previously water-logged wetland **peat soils** to air caused them to decompose and subside below sea level by 9 to 26 feet or more. The subsided Delta islands are perpetually at risk of flooding in the event of levee breaks or overtopping and many have flooded in the past, causing millions of dollars in damage." —USGS, 2018

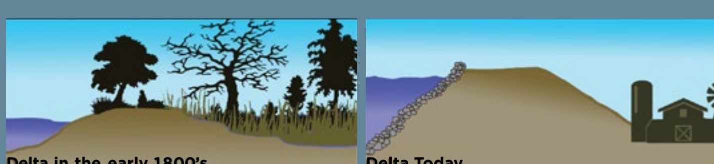


Figure #1. The Delta today, compared to how it was before farming.
FISHBIO

EFFECTS OF SUBSIDENCE

In the moonlit hours of June 21, 1972, a historic event unfolded in the Delta, forever altering its landscape. A levee succumbed to the water pressure, flooding about 150,000 acre-feet on the Brannan-Andrus Island. The repair costs amounted to a staggering $21 million in 1972, equivalent to about $150 million in today's dollars.

As Brannan-Andrus Island experienced subsidence, the dynamics of levee stability were fundamentally altered. Subsidence, diminishing the thickness of the marsh deposit, exponentially increased seepage forces, posing a threat to levee foundations, endangering the surrounding communities by flooding homes and fields, and increasing salinity levels in the soils of the island.

As the Delta deals with the enduring effects of subsidence, rice cultivation has emerged as a beacon of hope.

SUBSIDENCE OF THE SACRAMENTO–SAN JOAQUIN DELTA

This map displays varying subsidence levels across the Sacramento-San Joaquin Delta. The interior Delta exhibits the highest subsidence rates, with the Brannan-Andrus section experiencing subsidence ranging from -23 ft to -26 ft. Map provided by HydroFocus.

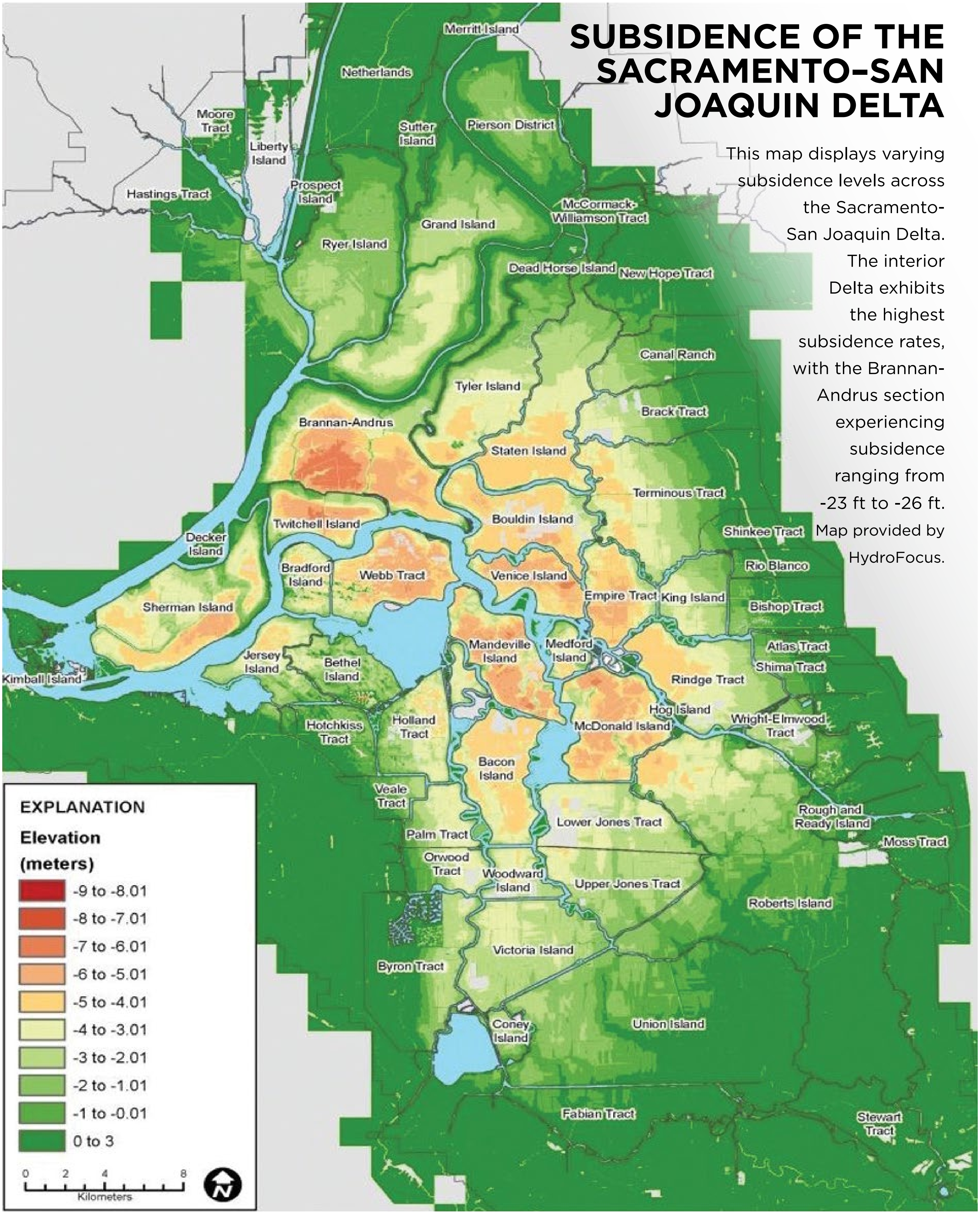
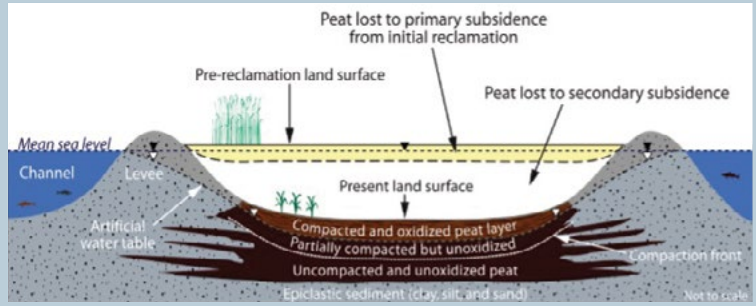


Figure #2 Delta subsidence map.
DEVERAL ET AL. 2016

WHY DOES IT HAPPEN?

The primary factor contributing to land subsidence in the Sacramento-San Joaquin Delta is the breakdown of organic carbon within peat soils. In its natural **waterlogged** state, the soil was anaerobic, allowing organic carbon to accumulate faster than it could decompose. However, agricultural drainage altered these conditions to become **aerobic,** leading to rapid **oxidation** of carbon by microbial activity. This process primarily results in carbon loss, mainly in the form of carbon dioxide gas released into the atmosphere (USGS, 2014).



(Levee infrastructure breakdown in the SJ SF-Bay Delta
USGS, 2014)

Over the years, the Delta region has grappled with significant subsidence challenges arising from the drainage of peat soils and long-standing conventional farming practices, such as land drainage and intensive tillage. This has exposed peat soil to open air, exacerbating subsidence issues. Understanding the root causes of subsidence, including **microbial oxidation** of organic material and agricultural compaction, is crucial for addressing the adverse impacts on the Delta's landscape and environment, notably the heightened risks of flooding, soil degradation, and various other environmental problems.

PRESERVING DELTA STABILITY:

Understanding and Mitigating Microbial Oxidation of Organic Material and Agriculture Compaction.

Microbial oxidation, (a process where organic carbon in peat soils breaks down in aerobic conditions due to drainage, which is a critical factor contributing to land subsidence), plays a pivotal role in the subsidence challenges faced by the Sacramento-San Joaquin Delta. The historical evolution of the Delta reveals that before agricultural conversion, sedimentation and accommodation space were in balance, maintaining tidal marsh conditions. However, the late 1800s saw significant changes, marked by the impact of hydraulic mining sediment, subsequent widespread reclamation, and the construction of levees. Farming practices, including extensive drainage, initiated a sustained period of land subsidence driven by microbial oxidation of organic-rich soils (Mount, 2005).

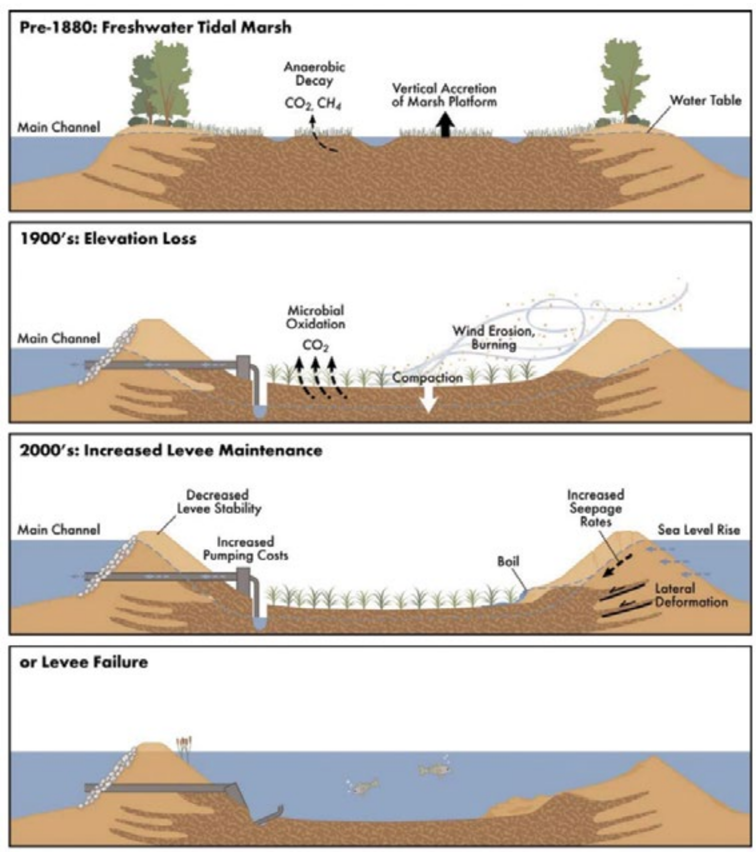


Figure #3 Illustration of the evolutionary process of Delta islands resulting from the construction of levees and the subsidence of islands.
MOUNT ET AL. 2005

Studies by Deverel et al. (1998) and Deverel and Rojstaczer (1996) reveal that this process releases gaseous CO_2, accounting for about 75% of current elevation losses. The remaining 25% is linked to **consolidation** from dewatering and compaction of saturated soils. Poor land practices pre-1950, like burning and wind erosion, worsened soil losses due to microbial oxidation.

Today, the Delta is comprised of a mosaic of levee-encased subsided islands, with elevations locally reaching more than 8 meters below **mean sea level.** This subsidence has created **anthropogenic accommodation space,** which is the space lying below sea level and filled neither with sediment nor water. As subsidence progresses, reducing marsh deposits (peat, silt, organic matter), seepage forces increase, as shown in Figure 4 from Deverel et al.'s 2016 study. This model quantifies the stress on Delta levees.

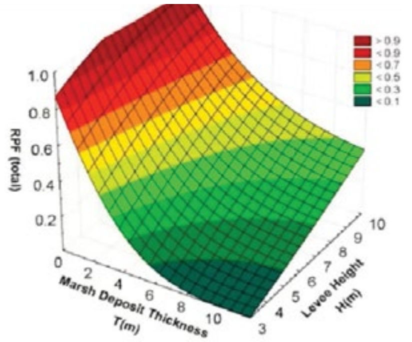


Figure #6 (RPF)
Relative Probability of Failure correlated to marsh deposit (T) and levee height(H)

To counter this, farmers often need to raise and widen levees, sometimes facing under-seepage issues, as seen in Figure 5. Over time, larger levees and increased hydraulic gradients result in higher under-seepage gradients, becoming a primary seepage concern.

Example of under-seepage in a drainage ditch.
DEVERAL, 2023.

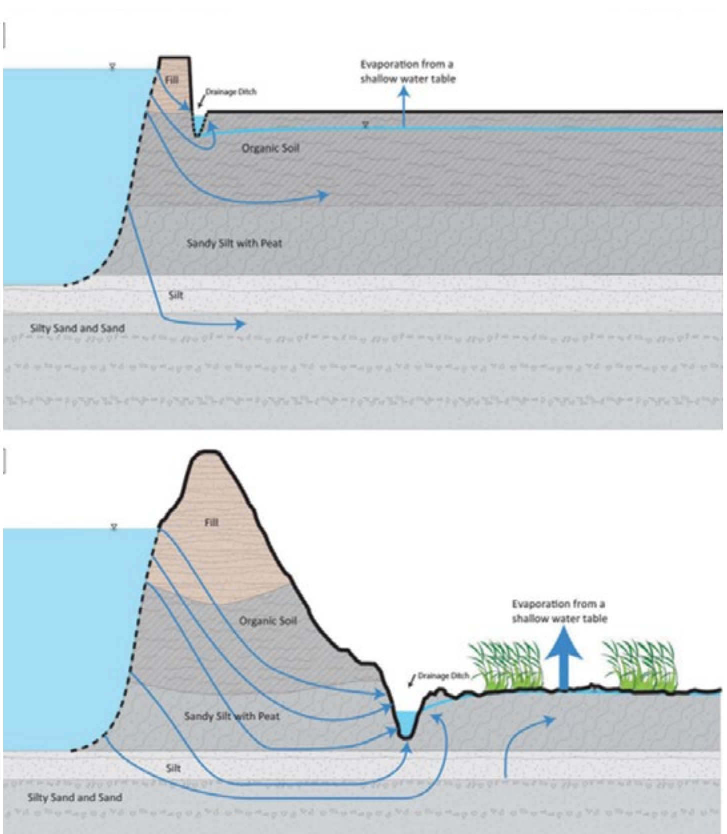


Figure # 5 Cross-sectional representation and conceptual model depicting (A) levee conditions in the early 1900s and (B) current wet conditions.
DEVERAL EL AL. 2015

Addressing this challenge, rice farming in the Sacramento-San Joaquin Delta emerges as a practical solution. Rice paddies, with their flooded conditions, create anaerobic environments, countering microbial oxidation. By fostering anaerobic conditions, rice farming helps prevent the breakdown of organic carbon, a crucial element in subsidence. This sustainable farming approach not only promotes Delta landscape stability but also reduces the risks of levee failure, offering a **resilient** financially smart solution for farmers.

Two Sandhill Cranes (Antigone Canadesis) in a rice field.
WETLAND PRESERVATION FOUNDATION

RICE CULTIVATION IN THE DELTA:
A STRATEGIC DEFENSE AGAINST SUBSIDENCE

Flooded rice field.
WETLAND PRESERVATION FOUNDATION

Subsidence Reduction Through Flooding:
Rice farming involves the controlled flooding of fields, creating anaerobic conditions that limit the microbial oxidation of organic material. This process inhibits subsidence, providing a sustainable solution to land degradation. (Mount, 2005)

Increased Organic Matter Accumulation
The flooded conditions in rice paddies promote the accumulation of organic matter, fostering a nutrient-rich environment. This organic matter contributes to soil structure and acts as a carbon sink, mitigating subsidence effects that put pressure on levees and having to extend the levee toe. (Deverel, 2015)

Long-Term Accretion
Studies on rice fields, such as those conducted on Twitchell Island, have demonstrated that the continuous flooding of wetlands can lead to long-term accretion, effectively reversing the downward trajectory of subsidence. Due to their natural composition, Delta soils are peat-based. It is a type of hydric soil, and they are designed to be periodically submerged or waterlogged.

Implementation Strategies
To maximize the benefits of rice farming for subsidence management, consider the following strategies:

a. Water Level Management: Maintain consistent and appropriate water levels to ensure optimal conditions for limiting subsidence.

b. Crop Rotation and Diversity: Incorporate crop rotation and diverse agricultural practices to enhance soil health and organic matter content.

COMPARATIVE SUBSIDENCE ARITHMETIC PER ACRE

Accretion/<Subsidence>	Rice	Corn	Subsidence/Accretion Net Difference
Centimeters Per year (a)	Plus 0.4	Minus (1.2)	(1.6)
	0.16	(.5)	(0.66)
Annual Inches Per year (b)	+1/8th inch	-1/2 inch	-5/8th inch
Times ten years	x 10	x 10	x 10
Inches Accreted/Subsided (c)	+1.6	(5.0)	(6.6)

(a) Dr. Steven Deverel, et al (DWR Twitchell Island 9-year Study) scientifically measured/compared Delta Rice and Delta Corn subsidence rates which demonstrates that Delta Rice raised field elevation (accretion) by .4 centimeters per year while Delta Corn reduced field elevation (subsidence) by 1.2 centimeters. Hence, Rice is 1.6 centimeters/year better than Corn as to annual subsidence!

(b) Centimeters converted to inches (2.5 centimeters = 1 inch).

(c) Ten-year difference of Rice versus Corn subsidence saves 6.6 inches of field elevation!

Figure #6. Comparative Subsidence Arithmetic per acre.
WETLAND PRESERVATION FOUNDATION

SUCCESS STORIES IN RICE FARMING FOR DELTA STABILITY

Numerous farmers have embraced rice farming, and its positive impact is evident in the data. The figures reveal that rice cultivation contributes to a yearly increase in field mass by 0.4 centimeters, proving its effectiveness in reducing subsidence. In contrast, corn cultivation is associated with a decrease in field elevation by 1.2 centimeters annually, as illustrated in Figure 6. Examining successful cases, like the documented 9-year study on Twitchell Island presented in Figure 6 by the Wetland Preservation Foundation, provides valuable insights for farmers aiming to improve their agricultural practices.

This map, provided by HydroFocus, depicts the current locations of rice cultivation in the San Joaquin-San Francisco Bay Delta in 2023, and the metric tons of **CO_2 emissions.** Additional expansions in rice cultivation are expected in the future.

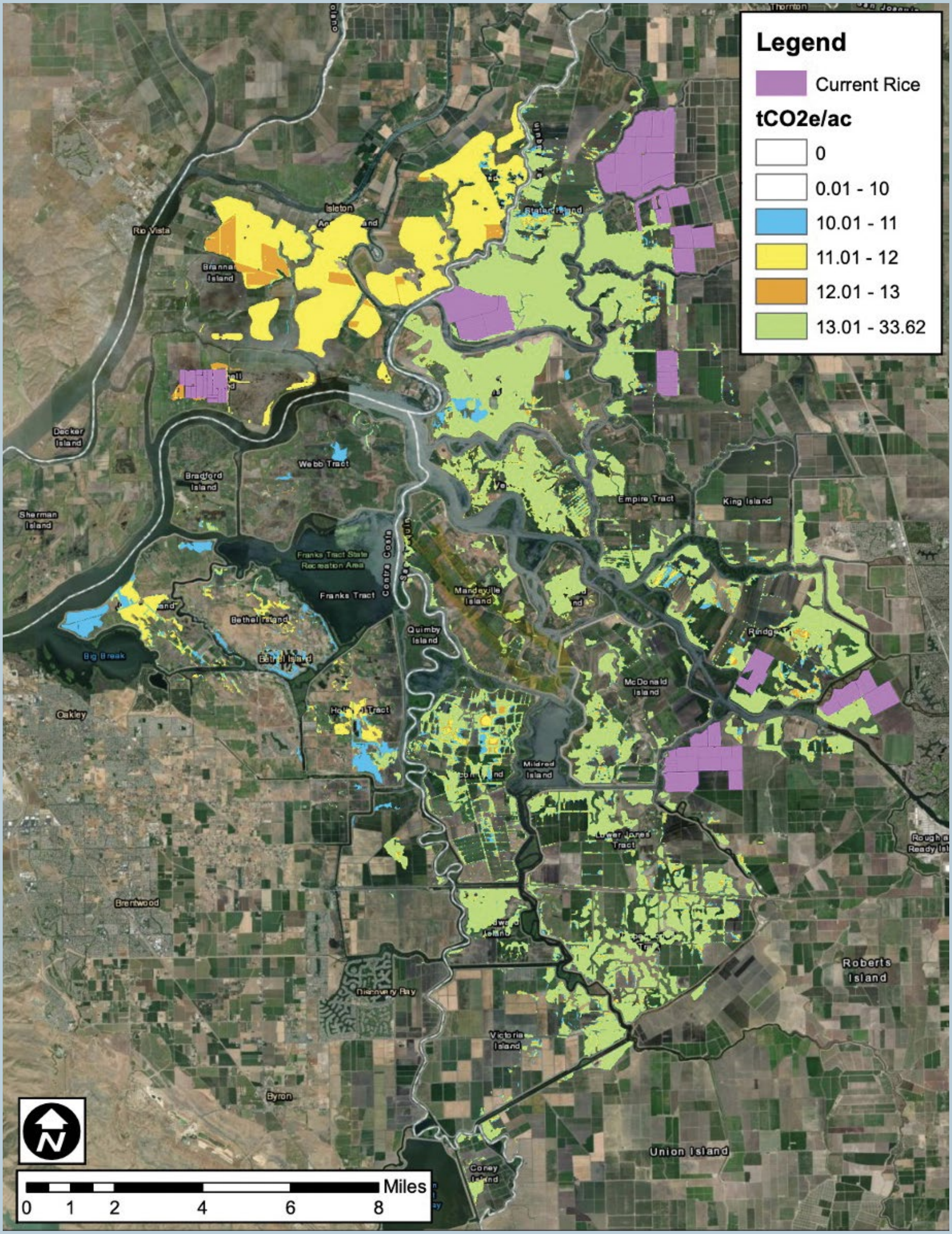


Figure #7. Location of rice in the Delta and CO_2 emissions.
DEVERAL, 2023

Black Phoebe sitting on straw from post harvest rice field.
WETLAND PRESERVATION FOUNDATION

Tractor flatting field, while Sandhill Cranes eat rice.
WETLAND PRESERVATION FOUNDATION

THE DYNAMIC LANDSCAPE OF THE RICE MARKET

The following is a cost-benefit analysis of rice farming in the Delta, starting with UC Cooperative's "Cost and Return Study." Additionally, this section delves into a cost comparison between rice and corn, offering valuable insights to enhance understanding of the economic aspects of Delta Rice cultivation.

The most important question that every farmer and investor must ask themselves is what it costs to get started growing rice. Naturally there have been many different studies and projects conducted to answer this question. The folks at University of California Cooperative Extension and University of California, Davis, have crunched the numbers and created a Cost and Return Study. The Wetland Preservation Foundation's arithmetic behind rice farming is also available for anyone who needs another farmer's perspective. Apprehension about investing in this process is entirely normal, and addressing such concerns is a crucial aspect of any successful business venture.

RICE COST AND RETURN STUDY

The following is a concise summary of the 2022 Sample Cost Study. For additional details, please scan the QR code provided at the end of the overview.

Introduction:
UNIVERSITY OF CALIFORNIA AGRICULTURAL AND NATURAL RESOURCES COOPERATIVE EXTENSION UC DAVIS DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS 2022 SAMPLE COSTS TO PRODUCE RICE DELTA REGION OF SAN JOAQUIN & SACRAMENTO COUNTIES SAN JOAQUIN VALLEY - North Continuous Rice Production, provides insights into the costs associated with producing medium grain rice in the Sacramento-San Joaquin Delta region, specifically San Joaquin and Sacramento counties. This type of grain was selected because it has proven to have the best yield for the type of climate the Delta undergoes. The study serves as a reference for farmers to make informed production decisions, budget, and evaluate production loans.

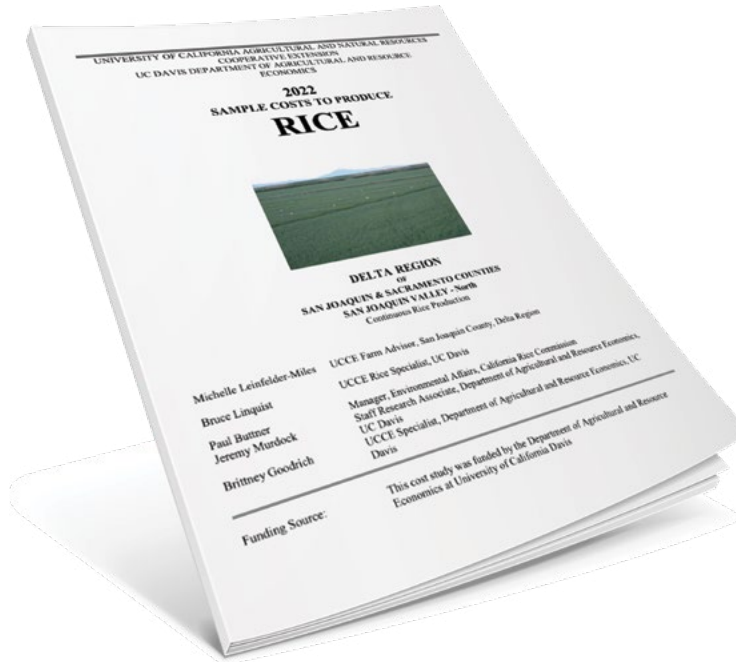


Figure #8. Title page of the 2022, Sample Cost to produce Rice in the Delta SJ & Sac Valley North.

STUDY SUMMARY

Farm Characteristics: The study is based on a hypothetical 1,100-acre farm, with 1,000 acres continuously planted with rice. The farm is situated in the Delta region of San Joaquin and Sacramento Counties and is primarily focused on organic peat soils. The land is leased by the grower.

CULTURAL PRACTICES AND INPUTS:

Field Establishment: Includes various operations like tillage, leveling, irrigation installation, and more for long-term continuous rice production.

Field Preparation: Disking, rolling, mowing, and box repair in the spring.

Planting: Certified seed of M-206 rice is drilled in April or May at a rate of 150 pounds per acre.

Nutrition: Starter fertilizer at planting, a dry fertilizer application in June, and a top-dress fertilizer if needed.

Soil/Tissue Sampling: Soil and tissue samples are collected for nutrient analysis.

Irrigation: Fields are flooded and drained as per rice growth stages.

Pest Management: Pesticides are used as needed for pest and weed control.

Harvest: Rice is harvested starting at 22% kernel moisture using a combine.

Yields and Returns: The study assumes an

UC COOPERATIVE EXTENSION-AGRICULTURAL AND RESOURCE ECONOMICS, UC DAVIS

Table 1. SAMPLE COSTS TO ESTABLISH A RICE FIELD

DELTA REGION (San Joaquin & Sacramento Counties) 2022

	Operation	Cash and Labor Costs per Acre						
Operation	Time (Hrs/A)	Labor Cost	Fuel	Lube &Repairs	Material Cost	Custom/ Rent	Total Cost	Your Cost
Pre-Plant:								
Disk 2X - Stubble Disc & Roll	0.47	13	50	17	0	0	81	
Landplane	0.00	0	0	0	0	30	30	
Apply Roundup	0.25	7	3	1	34	0	45	
GPS Level & Build Levees	0.50	14	54	13	0	250	332	
Install Boxes, Risers, & Pipe	0.04	12	0	0	0	250	263	
Chisel Plow - 16 inches	0.50	14	54	15	0	0	84	
Winter Flooding	0.00	4	0	0	0	0	4	
TOTAL PRE-PLANT COSTS	1.76	66	162	46	34	530	838	
Interest on Operating Capital at 7.00%							5	
TOTAL OPERATING COSTS/ACRE	2	66	162	46	34	530	843	
CASH OVERHEAD:								
Liability (3 Months)							0	
Office (3 Months)							13	
Land Rent							400	
Property Taxes							2	
Property Insurance							0	
Investment Repairs							4	
TOTAL CASH OVERHEAD COSTS/ACRE							419	
TOTAL CASH COSTS/ACRE							1,263	

Figure #9. Sample Costs to Establish a Rice Field, Delta Region-2022

average yield of 85 hundredweight per acre at 14% moisture.

The rice is sold for $21.50 per hundredweight.

Operating and Overhead Costs: Various costs are considered, including labor, equipment operating costs, interest on operating capital, property taxes, insurance, cash rents, regulatory compliance, administrative costs, and more.

Non-Cash Overhead: This category includes capital recovery costs for equipment, buildings, fuel tanks, shop/tools, and field establishment.

Key Points:

- Costs and practices are based on typical operations in the region and may vary among farms.
- The study serves as a reference for growers and is not a one-size-fits-all model.
- Actual results may differ from those presented in the study due to financial, agronomic, and market risks.
- Additional information and specific costs can be obtained from the UC Cooperative Extension or local county agricultural commissions' offices.

This summary provides an overview of the cost and return factors involved in rice production in the Sacramento-San Joaquin Delta region for 2022.

UC COOPERATIVE EXTENSION-AGRICULTURAL AND RESOURCE ECONOMICS, UC DAVIS

Table 5. RANGING ANALYSIS

DELTA REGION (San Joaquin & Sacramento Counties) 2022

COSTS PER ACRE AT VARYING YIELDS TO PRODUCE RICE

	YIELD (cwt/acre)						
	55.00	65.00	75.00	85.00	95.00	105.00	115.00
OPERATING COSTS/ACRE:							
Cultural	702	702	702	702	702	702	702
Harvest	297	319	341	363	384	406	428
Post-Harvest	36	36	36	36	36	36	36
Interest on Operating Capital @ 7.00%	21	21	21	21	21	22	22
TOTAL OPERATING COSTS/ACRE	1,057	1,079	1,101	1,122	1,144	1,166	1,188
TOTAL OPERATING COSTS/CWT	19.22	16.60	14.67	13.20	12.04	11.10	10.33
CASH OVERHEAD COSTS/ACRE	500	500	500	500	500	500	500
TOTAL CASH COSTS/ACRE	1,557	1,579	1,601	1,623	1,645	1,666	1,688
TOTAL CASH COSTS/CWT	28.32	24.29	21.35	19.09	17.31	15.87	14.68
NON-CASH OVERHEAD COSTS/ACRE	289	289	289	289	289	289	289
TOTAL COSTS/ACRE	1,847	1,868	1,890	1,912	1,934	1,956	1,977
TOTAL COSTS/CWT	34.00	29.00	25.00	22.00	20.00	19.00	17.00

Net Return per Acre Above Operating Costs for Rice

PRICE ($/cwt)	YIELD (cwt/acre)						
Rice	55.00	65.00	75.00	85.00	95.00	105.00	115.00
15.50	-204	-71	62	195	328	462	595
17.50	-94	59	212	365	518	672	825
19.50	16	189	362	535	708	882	1,055
21.50	126	319	512	705	898	1,092	1,285
23.50	236	449	662	875	1,088	1,302	1,515
25.50	346	579	812	1,045	1,278	1,512	1,745
27.50	456	709	962	1,215	1,468	1,722	1,975

Net Return per Acre Above Cash Costs for Rice

PRICE ($/cwt)	YIELD (cwt/acre)						
Rice	55.00	65.00	75.00	85.00	95.00	105.00	115.00
15.50	-705	-572	-438	-305	-172	-39	94
17.50	-595	-442	-288	-135	18	171	324
19.50	-485	-312	-138	35	208	381	554
21.50	-375	-182	12	205	398	591	784
23.50	-265	-52	162	375	588	801	1,014
25.50	-155	78	312	545	778	1,011	1,244
27.50	-45	208	462	715	968	1,221	1,474

Net Return per Acre Above Total Costs for Rice

PRICE ($/cwt)	YIELD (cwt/acre)						
Rice	55.00	65.00	75.00	85.00	95.00	105.00	115.00
15.50	-994	-861	-728	-595	-461	-328	-195
17.50	-884	-731	-578	-425	-271	-118	35
19.50	-774	-601	-428	-255	-81	92	265
21.50	-664	-471	-278	-85	109	302	495
23.50	-554	-341	-128	85	299	512	725
25.50	-444	-211	22	255	489	722	955
27.50	-334	-81	172	425	679	932	1,185

Figure #10, Ranging Analysis, Delta Region- 2022

On Figure 10, based on the Cost and Return Analysis from UC Cooperative Extension and UC Davis, breaks down the rate per yield for rice farming. Operating costs per acre, including $702 for cultural practices, $297 for harvest, and $36 for post-harvest activities, remained consistent. Despite fixed costs, total operating costs per acre ranged from $1,057 to $1,188. This translated to a per-hundredweight cost that decreased from $19.22 to $10.33 as yields increased from 55 to 115 cwt/acre.

Cash overhead costs remained steady at $500 per acre, resulting in total cash costs per acre ranging from $1,557 to $1,688, with corresponding per-hundredweight costs decreasing from $28.32 to $14.68. Non-cash overhead costs of $289 per acre contributed to total costs per acre ranging from $1,847 to $1,977, with per-hundredweight costs decreasing from $34.00 to $17.00 as yields increased.

Net returns per acre above operating costs show positive outcomes across all price-yield scenarios, emphasizing the economic potential and resilience of rice farming in the region. In a more optimistic perspective, net returns per acre above cash costs reflected a positive outlook, ranging from $94 to $456 per acre, showcasing profitability across varying price-yield combinations.

Incorporating information from Figure 9, outlining the Sample Costs to Establish a Rice Field in the Delta region (San Joaquin & Sacramento Counties) in 2022, involves various operations such as disk 2X, landplane, apply Roundup, GPS level and build levees, install boxes, risers, & pipe, chisel plow - 16 inches, and winter flooding. The total pre-plant costs amount to $838 per acre. The total operating costs per acre, inclusive of these pre-plant costs, are $843. Cash overhead costs, covering liability, office, land rent, property taxes, property insurance, and investment repairs, sum up to $419 per acre, resulting in total cash costs per acre of $1,263.

Finally, net returns per acre above total costs demonstrate the overall financial health of rice farming in the Delta region, ***with positive returns ranging from $35 to $456 per acre.*** This optimistic analysis highlights the potential for sustainable and economically viable rice production, providing farmers with encouraging insights into the financial rewards associated with higher yields and favorable market conditions.

"The study serves as a reference for growers and is not a one-size-fits-all model."

—RICE COST AND RETURN STUDY

For the full report
SCAN ME!

Sandhill Cranes (Antigone Canadensis) in a post harvest rice field.
WETLAND PRESERVATION FOUNDATION

RICE VS. CORN

The following pages unfold a thorough comparison between rice and corn, as outlined by the Wetland Preservation Foundation. Delve into crucial factors such as revenue, cost efficiency, and net cash flow, providing valuable insights into the financial dynamics of these crops in the Delta region.

Higher Revenue: Rice generates significantly higher gross revenue per acre.

Cost Efficiency: Despite higher direct and indirect expenses for rice, the overall cash flow for both tenants and landlords is substantially better for rice.

Share Crop Rent Impact: The higher share crop rent for rice contributes to increased income for both tenants and landlords.

Strategic Crop Selection: Depending on market conditions and cost structures, farmers and landlords may consider adjusting their crop selection to enhance financial returns.

Risk Consideration: Dependency on Prices: The financial superiority of rice over corn is subject to market prices. Any significant price fluctuations could impact the comparative results.

Management Implications: Optimizing Expenses: Efficient management of direct and indirect expenses is crucial for maximizing profits.

In conclusion, the comparative analysis suggests that, under the given conditions, rice cultivation appears to be more financially rewarding than corn. However, it's important for stakeholders to stay informed about market dynamics and adapt their strategies accordingly.

COMPARATIVE ARITHMETIC OF RICE/CORN

		Rice 86 CWT	Corn 41/2 Tons	Rice Better Than Corn
TENANT	Price	$19.41	$179	N/A
	Gross Revenue (a)	$1,670	$805	$865
	Share Crop Rent (b)	(420)	(200)	(220)
	Direct Crop Expense (c)	(450)	(300)	(150)
	Indirect Expense (d)	(300)	(200)	(100)
	Tenant Cash Flow	$500	$105	$395
		Rice 86 CWT	**Corn 41/2 Tons**	**Rice Better Than Corn**
LANDLORD	Share Crop Rent (b)	$420	$200	$220
	County Property Tax	(35)	(35)	0
	Reclamation Fee	(50)	(50)	0
	Indirect Expense	NA	NA	NA
	Landlord Cash Flow	$335	$115	220
TENANT/LANDLORD	Combined Cash Flows	$835	$220	$615

Arithmetic is not an opinion!

(a) Yield x's Price ='s Gross Revenue per acre
(b) Share Crop Rent is based on 25% of Gross Revenue per acre
(c) Seed/Fertilizer/Herbidices/Fuel/Labor per acre
(d) Mgmt/Equip. Maint./Interest/Insurance/Taxes/Licenses/Accting per acre

Figure #11. Comparative Arithmetic of Rice/ Corn
WETLAND PRESERVATION FOUNDATION

TENANT CASH FLOW PER ACRE

	Rice (a) 86 CWT	Corn (a) 4 1/2 Tons	Rice Better Than Corn
10 - year average Price per Unit over (2011-2020)	$19.41 /CWT	$179 /TON	N/A
Gross Revenue Per Acre	$1,670 /AC	$805 /AC	$865 /AC
Share Rent to Landlord (b)	(420) /AC	(200) /AC	($220) /AC
Direct Crop Expense (c)	(450) /AC	(300) /AC	($150) /AC
Indirect Expense (d)	(300) /AC	(200) /AC	($100) /AC
Tenant Net Cash Flow	$500 /AC	$105 /AC	$395 /AC

Arithmetic is not an opinion!

(a) Rice yield is always expressed in CWT; Corn yield in tons.
(b) Share Crop Rent is based on 25% of Gross Revenue.
(c) Seed/Fertilizer/Herbicides/Fuel/Labor.
(d) Management/Equipment Maintenance/Interest/Insurance/Taxes/Accounting.

Figure #12. Tenant Cash Flow per Acre.
WETLAND PRESERVATION FOUNDATION.

TENANT CASH FLOW PER ACRE

Gross Revenue Impact for Rice: Rice's higher unit price and yield result in higher gross revenue than corn's.

SHARE RENT TO LANDLORD AND EXPENSES:

(b)Share Rent to Landlord: The share rent to the landlord is $220/AC (acre) higher for rice, impacting the overall financial picture.

(c)Direct Crop Expense: Rice has higher expenses, but tenants have a higher net cash flow due to the higher gross revenue.

(d)Indirect Expense: Similar to direct expenses, the indirect expenses are higher for rice, but the overall financial outcome is favorable.

TENANT NET CASH FLOW:

Higher for Rice: The tenant's net cash flow is significantly better for rice compared to corn, reflecting the positive impact of higher gross revenue.

ADDITIONAL CONSIDERATIONS:

Yield Basis:

Consistent Measurement: Rice yield is consistently expressed in CWT (hundredweight), while corn yield is consistently expressed in tons, providing a standardized basis for comparison.

Share Crop Rent Calculation:

Typical Delta Practice: Share crop rent is calculated based on 25% of gross revenue, which is a common practice in the Delta region.

Expense Breakdown:

Direct Crop Expense (c): Includes seed, fertilizer, herbicides, fuel, and labor.

Indirect Expense (d): Encompasses management, equipment maintenance, interest, insurance, taxes, and accounting.

In conclusion, the comparison indicates that rice is financially superior to corn, considering gross revenue, expenses, and net cash flow for tenants. The higher share rent to the landlord is offset by the substantially greater revenue generated by rice cultivation. It's important for stakeholders to consider both revenue and expense components for a comprehensive financial assessment.

10-YEAR AVERAGES

Rice row
WETLAND PRESERVATION FOUNDATION

Summary of Rice Arithmetic

Figure 13 10-Year Average Arithmetic from the Wetland Preservation Foundation, outlines the rice production details for the same period, presenting the total acres, CWT (hundredweight) per acre, the price per CWT, and the gross revenue per acre. The average rice yield is 86 CWT per acre, with prices ranging from $13.89 to $22.50 per CWT. The gross revenue per acre for rice varies annually, reaching a high of $1,964.

Summary of Corn Arithmetic:

Figure 14 presents the corn arithmetic for the years 2011-2020, indicating the yield per acre (4 1/2 tons) and the corresponding price per ton delivered to Stockton. The gross revenue per acre for corn varies annually, ranging from $657 to $1,076, with a 10-year average of $806. **Corn yields are affected by factors such as soil type and subsidence, leading to variations between 4 tons and 5 tons per acre.** Actual prices per ton, obtained from the Annual Agricultural Report, influence the annual gross revenue for corn.

The 10-year average gross revenue for rice amounts to $1,670 per acre, doubling the figure observed for corn ($806).

The Wetland Preservation Foundation presents a detailed comparison between rice and corn in the Delta region, shedding light on essential factors such as revenue, cost efficiency, and net cash flow. Notably, rice cultivation stands out by allowing farmers to boost organic matter, mitigating subsidence.

Additionally, the discussion extends to the promising opportunity for farmers to engage in carbon markets, enhancing the overall sustainability and economic viability of rice farming in the Delta.

Rice Arithmetic

Year	Total Acres (1)	CWT Per Acre (1)		Price Per CWT (1)		Gross Revenue Per Acre (1)
2011	1,692	79	x's	$17.63	='s	$1,393
2012	1,634	82	x's	$17.64	='s	$1,446
2013	1,521	79	x's	$20.02	='s	$1,581
2014	1,142	89	x's	$22.00	='s	$1,858
2015	895	85	x's	$18.46	='s	$1,569
2016	1,322	89	x's	$13.89	='s	$1,236
2017	1,262	92	x's	$19.65	='s	$1,808
2018	1,694	93	x's	$20.78	='s	$1,953
2019	1,893	86	x's	$21.49	='s	$1,848
2020	2,163	87	x's	$22.50	='s	$1,964
Average	**1,522**	**86**	**x's**	**$19.41**	**='s**	**$1,670**

(1) Del Rio Partners (DRP) began planting Rice on Brack Tract in the mid 1990's; and Canal Ranch Farms (CRF) began farming Canal Ranch in 2008 and began converting to Rice cropping as lands were rehabilitated. These data are actual DRP/CRF combined Acres/Yields/Prices/Revenues per acre. (DRP and CRF sharecrop Cortopassi-owned lands.)

Corn Arithmetic

Year	4 1/2 Tons Per Acre (1)		Price Per Ton (2)		Gross Revenue Per Acre
2011	4.50	x's	$206	='s	$927
2012	4.50	x's	$239	='s	$1,076
2013	4.50	x's	$201	='s	$905
2014	4.50	x's	$200	='s	$900
2015	4.50	x's	$146	='s	$657
2016	4.50	x's	$156	='s	$702
2017	4.50	x's	$159	='s	$716
2018	4.50	x's	$166	='s	$747
2019	4.50	x's	$170	='s	$765
2020	4.50	x's	$150	='s	$675
10-Year Average	**4.50**	**x's**	**$179**	**='s**	**$806**

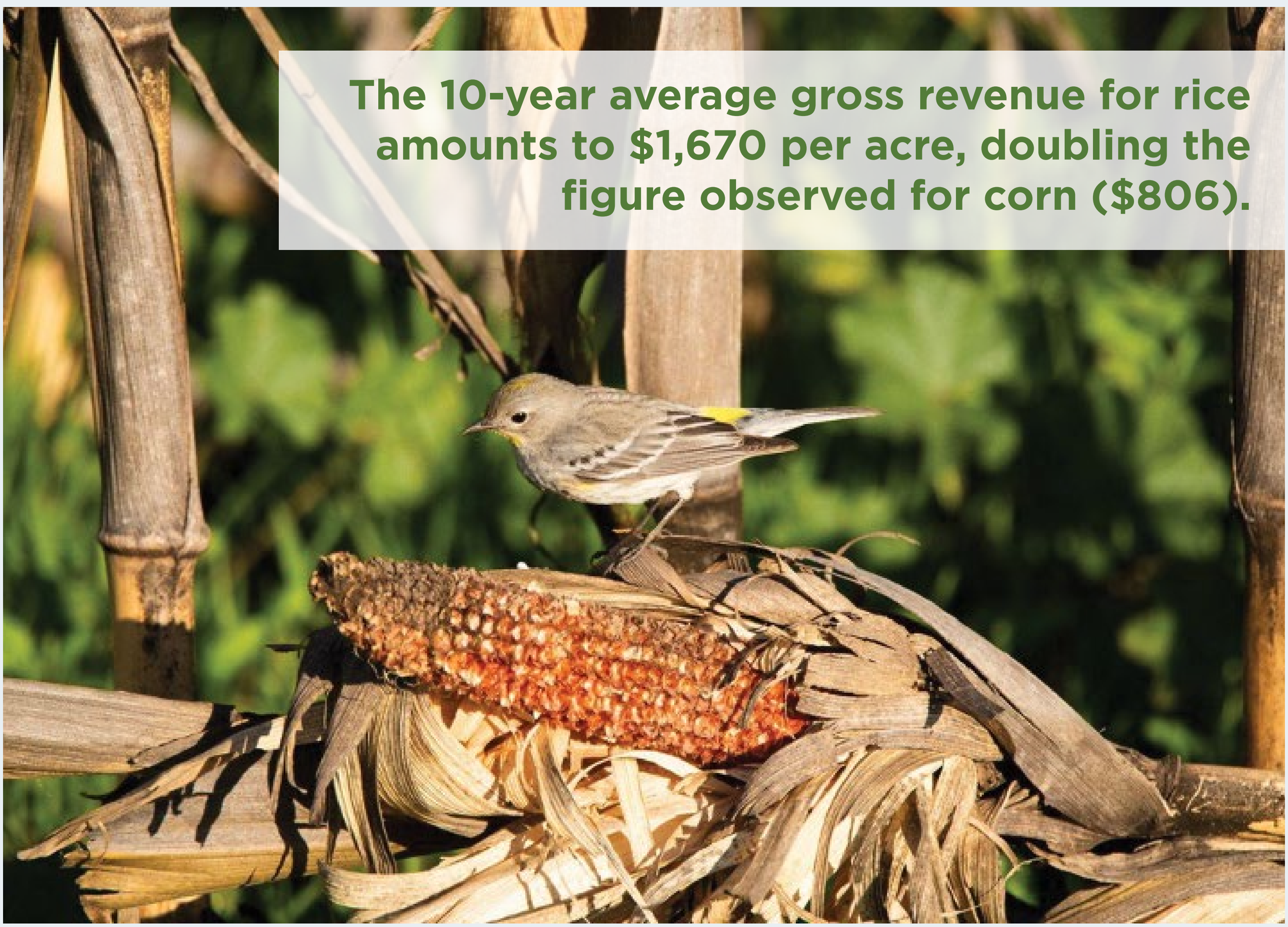
(1) On Central Delta peat soils, corn yields range between 4 tons/Acre to 5 tons/Acre depending on degree of prior subsidence and existing seepage.

(2) Actual prices per ton delivered to Stockton (San Joaquin County - Annual Agricultural Report).

Arithmetic is not an opinion!

Figure #13 & 14. 10-Year Average Arithmetic

WETLAND PRESERVATION FOUNDATION



CARBON SEQUESTRATION, AN ADDED BONUS TO RICE FARMING

This section provides farmers with educational insights into carbon emissions associated with peat soils, an exploration of carbon credits, and an overview of current participants in the agriculture carbon market. Additionally, get a glimpse into the intricacies of the process on what it entails to participate in this dynamic and evolving market.

CARBON EMISSIONS IN PEAT SOILS

In peatlands, year-round water-logged conditions slow plant decomposition to such an extent that dead plants accumulate to form peat. This stores the carbon the plants absorbed from the atmosphere within peat soils, providing a net-cooling effect and helping to mitigate the climate crisis. -IUCN

Benefits of Carbon Sequestration on Peat Soil:

The drying of peat soils stands out as a primary contributor to substantial subsidence in the Delta region, resulting in the release of **carbon dioxide** (CO_2) into the atmosphere. Modeling predictions indicate an annual emission of 1.5 to 2 million metric tons of CO_2 from approximately 200,000 acres of organic and highly organic mineral soils within the Delta during subsidence. It's noteworthy that this process also releases nitrogen dioxide and methane (Deverel, 2016).

In the broader context, **carbon sequestration** on peat soil emerges as a pivotal strategy with profound environmental and agricultural implications. Peat soil, renowned for its rich organic content, possesses a remarkable capacity to store substantial amounts of carbon. Leveraging carbon sequestration in peatlands becomes instrumental in curbing the release of greenhouse gasses into the atmosphere, contributing

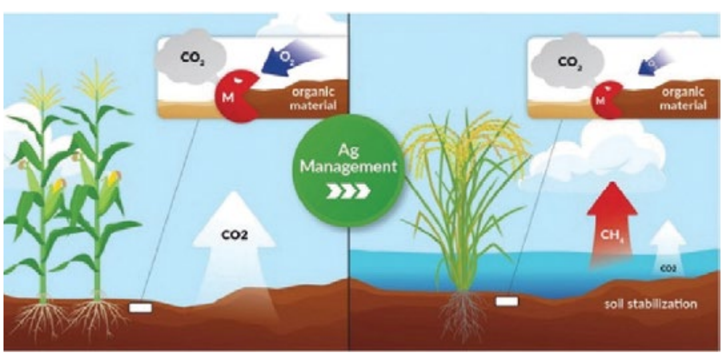
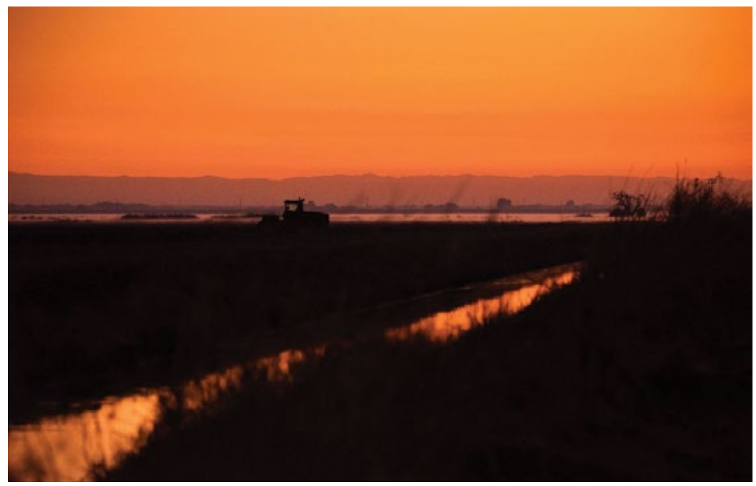


Figure #15, Hydrological management in agriculture involving controlled flooding, as observed in practices like rice farming.

WINDHAM-MYER ET AL. 2023.

significantly to the global fight against climate change.

Scientific findings emphasize that peat soil functions as a significant carbon sink, effectively reducing the overall carbon footprint. The organic matter within peatland acts as a reservoir for long-term carbon storage, preventing its conversion into carbon dioxide, a potent greenhouse gas. This underscores the dual benefit of subsidence reversal initiatives, not only

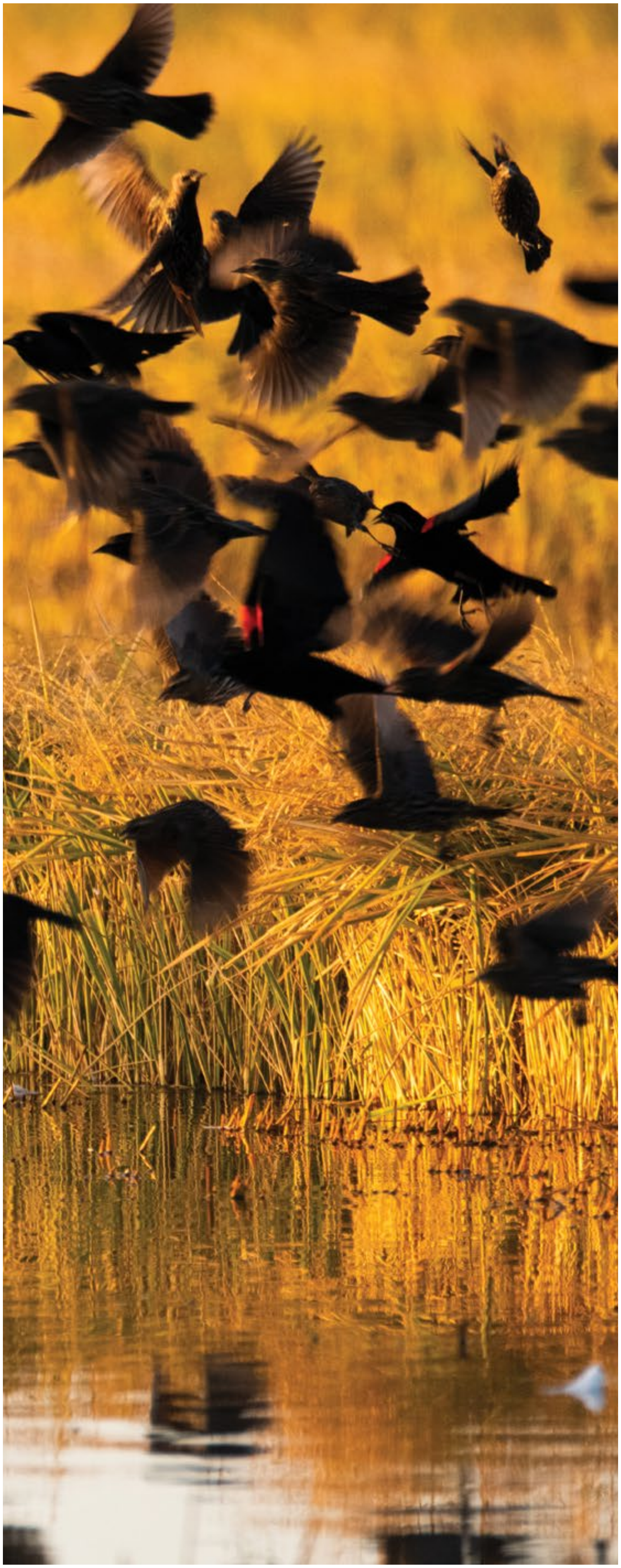


WETLAND PRESERVATION FOUNDATION

mitigating environmental impact but also optimizing the agricultural potential of peat soils (IUCN, 2021).

The study conducted on Twitchell Island found that inundating rice fields, particularly during the summer and early fall months, effectively reverses subsidence (Deverel, 2016), and a new study being conducted on Staten Island is proving that carbon sequestration in the Delta is happening.

This inundation process enhances root structure, generates voluminous organic matter, and promotes the creation of new soil (Sloop, 2018). It holds promise as a technique for reconstructing subsided Delta islands, contributing to climate change **mitigation** by extracting carbon dioxide—an essential greenhouse gas—from the atmosphere.



Red-winged Blackbird (Agelaius Phoeniceus) at the Black Hole.
WETLAND PRESERVATION FOUNDATION.

PUTTING SCIENCE INTO PRACTICE

Here, we outline the 3 out of the 10 questions farmers frequently ask about carbon sequestration and Carbon Markets. These questions have been identified by the American Farmland Trust, in their *Top 10 Things You Want to Know About Carbon Markets*, and for more detailed information, refer to the resource linked below.

What are Ag Carbon markets and why are farmers asked to join?

An agricultural carbon market functions as an environmental marketplace, allowing corporations to meet sustainability goals by purchasing carbon credits from farmers who adopt climate-smart practices. This mutually beneficial exchange helps farmers overcome financial barriers while contributing to economic and environmental benefits. The process involves buyers, typically corporations, and sellers, farmers implementing climate-smart practices, facilitated by carbon market developers as intermediaries.

How is the government involved in agricultural carbon markets?

The federal government presently lacks a direct role in carbon markets, and there is no federal carbon market or mandatory regulations for corporations to offset their greenhouse gas emissions. However, potential future regulations, like those anticipated from the U.S. Securities and Exchange Commission, may impact reporting requirements for corporations. Although a proposed "Carbon Bank" by the USDA in 2021 didn't materialize, the 2022 creation of the Partnerships for Climate Smart Commodities program demonstrates a significant federal investment aiming to support climate-smart

[1] "In a carbon market, carbon credits – which represent a standard amount of GHG reduction or sequestration – are bought and sold." This definition comes from the USDA (United States Department of Agriculture)report to support the Growing Climate Solutions Act(GCSA), passed in 2022.

Sandhill Cranes at the Black Hole, in a rice field.
WETLAND PRESERVATION FOUNDATION

practices in agriculture. On the legislative front, the Growing Climate Solutions Act (GCSA), passed in 2022, focuses on improving the quality of agricultural carbon credits without establishing a federal market or setting carbon prices. At the state level, California and northeastern states, through programs like the Regional Greenhouse Gas Initiative (RGGI), play roles in compliance with carbon offset markets, particularly in the agriculture sector.

Am I eligible to participate in agricultural carbon markets?

Eligibility criteria for participation in agricultural carbon markets vary across programs, but common factors include land ownership, acreage limits, location, targeted commodities, emphasis on climate-smart practices, and rules regarding participation in other government or private sector programs. While many programs do not exclude leased or rented land, they may require collaboration between landowners and tenants. Some programs specify minimum acreages, ranging from 10 to 500 acres, and their availability may be national or region-specific. Additionally, programs may focus on particular commodities, with an evolving trend toward corn, soybeans, wheat, grasslands, and livestock. Eligibility often hinges on the adoption of new climate-smart practices, such as cover crops, reduced tillage, and nitrogen management. Farmers should be aware of rules governing participation in other programs, including restrictions on receiving federal USDA conservation funds.

Sandhill Cranes at the Black Hole, in a flooded rice field.
WETLAND PRESERVATION FOUNDATION

DELTA RICE FARMING CASE STUDIES

Farmers in the Delta are already starting the carbon credit process. Figure 16 shows a breakdown roadmap for registering a Carbon Credit Project. This was derived from the Greenhouse Gas Project Plan initiated by The Nature Conservancy on Staten Island, CA, and HydroFocus from Davis, CA with the project's inception date noted as May 25, 2023. As mentioned earlier, the proven benefits of rice in reducing subsidence have inspired The Nature Conservancy on Staten Island, in partnership with Conservation Farms and Ranches, to kickstart carbon credit initiatives. The outlined roadmap shows an approach to navigating the intricacies of carbon credit project registration. This project focuses on mitigating greenhouse gas (GHG) emissions and addressing subsidence through strategic land-use practices, including rice cultivation, covering approximately 1847 hectares of Staten Island. This project uses The Restoration of California Deltaic and Coastal Wetlands Methodology, version 1.1 adopted in November 2017 by the American Carbon Registry (ACR). Further information about the findings of the project is coming soon!

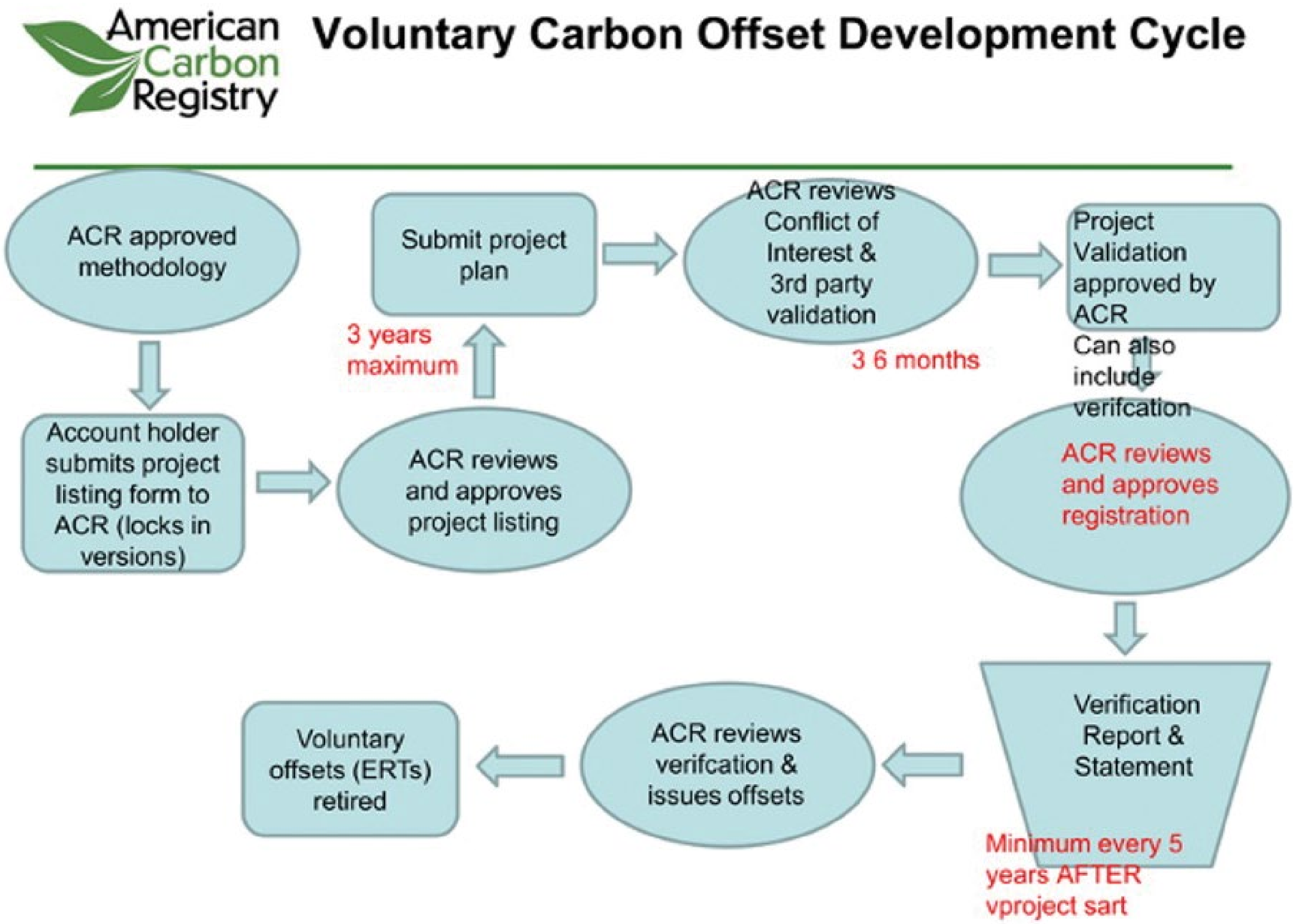


Figure #16, Voluntary Carbon Offset Developments Cycle.

HYDROFOCUS

Figure #17. Methodology For The Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emissions Reductions and Removals From The Restoration of California Deltaic and Coastal Wetlands Version 1.1 November 2017.

THE LINK TO THIS REPORT IS UNDER THE RESOURCE HUB SECTION.

SCALING UP RICE FARMING IN THE DELTA

While Twitchell and Staten Island promising results, the collection of data for carbon credits is still in its early stages. To strengthen the impact and encourage more farmers to participate, a call to action is needed. The agricultural community should actively engage in rice cultivation processes that enhance carbon sequestration. Although the carbon market may not be the primary revenue source, the long-term benefits on soil health and subsidence make it a valuable practice. Efforts are underway to streamline the process, making it faster and more financially rewarding. Encouraging more farmers to participate will not only contribute to climate change mitigation but also accelerate the development of efficient mechanisms for carbon credit collection and distribution, ensuring a sustainable and resilient agricultural future.

Data Collection and Research: There's a need for increased data collection, especially in the Delta region, to better understand greenhouse gas emissions and removals. This data is crucial for adapting and refining protocols. The focus should be on simplifying processes for the aggregation of carbon market income.

Aggregation of Projects: The protocol allows for the aggregation of projects, enabling multiple property owners to participate in a collective validation process. This encourages collaboration and can bring about economies of scale.

Management Practices: There's a necessity to closely examine management practices, especially concerning greenhouse gas emissions reductions. This includes understanding the impact of practices like rotation and alternate wet and dry cycles. Methane emissions, especially concerning rice cultivation, need careful consideration.

This call to action encourages stakeholders, researchers, and policymakers to actively engage in further research, collaboration, and implementation of sustainable practices with landowners and farmers. It emphasizes the importance of holistic approaches that consider both environmental and economic aspects, with a focus on long-term resilience and sustainability.

The dynamic nature of Carbon markets necessitates constant updates. Please revisit this handbook regularly as Restore the Delta actively seeks additional resources and updates at local, state, national, and international levels. These advocating efforts aim to assist farmers in the Delta region in effectively participating in and benefiting from the evolving carbon market.

White Egret and Black Birds on Cattails.
WETLAND PRESERVATION FOUNDATION

RICE BENEFITS FOR WATERFOWL

In this section, one can learn about how this benefits waterfowl in the day to day and in the long term when farmers plant rice. It sheds light on the reason the Delta is so important for the hundred different bird species that cross it when migrating.

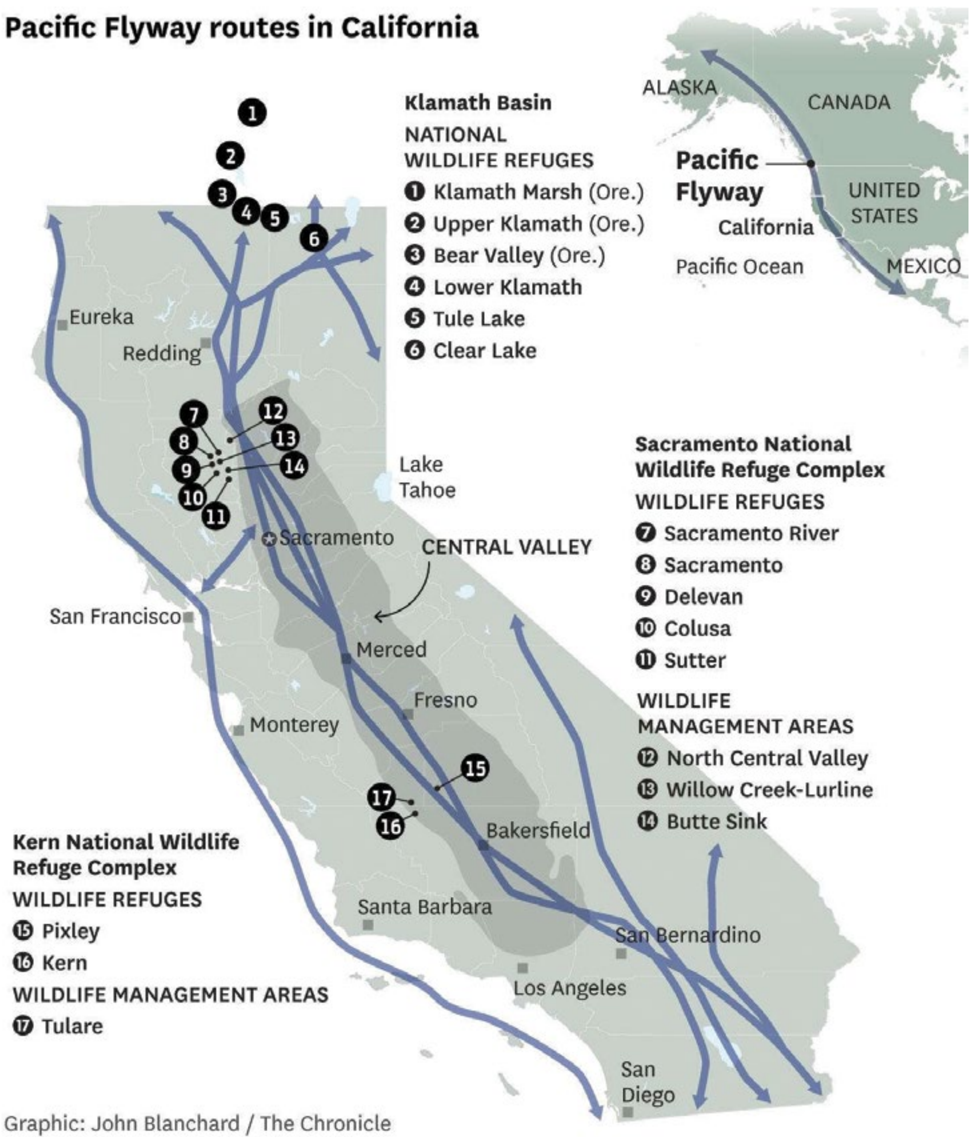


Figure #18, Pacific Flyway routes in California
SAN FRANCISCO CHRONICLE

The Delta has historically been a haven for birds with its dynamic river flows and tidal processes. However, extensive human modifications such as changes to river flows and land cover, have altered the landscape.

With more than 123,550 acres of natural land cover, including marshes, wetlands, grasslands, scrub, woodlands, and forests, the Delta remains a substantial bird habitat despite its transformations. Post-harvest flooding in cornfields contributes to additional bird habitats in the Delta, demonstrating the resilience of bird communities (Alexander, 2022).

While facing challenges from habitat loss and **fragmentation**, the Delta continues to support breeding waterfowl, shorebirds, Sandhill Cranes, and a variety of land birds. As a result of conservation efforts, including habitat suitability models and analyses, the Delta continues to be an important habitat for bird species. Despite changes over time, the Delta's **mosaic** of habitats and adaptive agricultural practices highlight its continuing importance in bird conservation.

The introduction of rice farming in the Delta aims to augment the region's vibrant **avian ecosystems** in the future. Through sustainable rice cultivation practices, we aspire to strengthen and restore critical bird habitats, further solidifying the Delta's status as a vital bird sanctuary.

THE PIVOTAL ROLE OF RICE FIELDS IN SUSTAINING WATERFOWL HABITATS

Habitat Support for Waterfowl: If Rice cultivation becomes more widespread in the Central and Southern sections of the Delta over the next few decades, it will provide a vital habitat for waterfowl during the winter months. In addition to providing additional resting and foraging grounds for ducks and geese, the flooded rice fields will contribute to the overall ecological diversity of the area. By collaborating with rice producers, similar to what has been done in the Sacramento Valley, wetland managers and rice producers can ensure the Delta becomes a more important wintering spot for waterfowl (Petrie, 2017).

Waterfowl Food Resources:

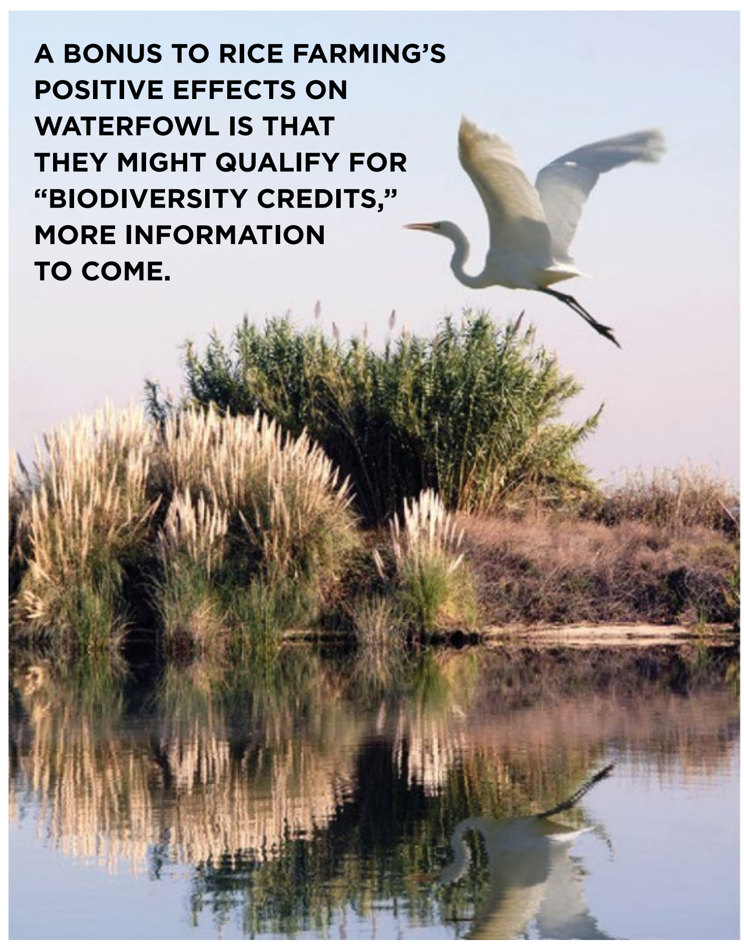
It is anticipated that the expansion of rice cultivation in the Delta can increase the availability of food for waterfowl. The region will see a proportional increase in the number of rice fields contributing to waterfowl sustenance during normal rainfall years when a higher number of rice acres are planted. A combination of the nutritional value of the rice fields will make the Delta a more substantial source of food for waterfowl, providing over 60 percent of the food resources for waterfowl, similar to the patterns observed in the Sacramento Valley (Petrie, 2017).

Growing Season Habitat and Hunter Success:

The expansion of rice fields in the Central and Southern sections of the Delta can result in increased breeding habitat for waterfowl during the growing season. More breeding mallard pairs and ducklings will find suitable areas within the expanding rice fields, complementing the dry seasonal wetlands (Petrie, 2018). This heightened local production will have a positive impact on hunter success, encouraging further investment in wetland conservation by private wetland owners. The presence of rice fields will continue to support **breeding waterfowl,** contributing to the overall health of the Delta's ecosystems (Petrie, 2017).

Shared Water Resources:

As rice cultivation rates increase in the Central and Southern sections of the Delta, the interconnected relationship between rice fields and seasonal wetlands will become more pronounced. The drain water or **"tailwater"** from expanded rice fields will serve as an even more critical water source for the growing number of nearby wetlands. This mutually beneficial relationship will strengthen, emphasizing the importance of maintaining sufficient water flows through rice fields to support the broader wetland ecosystems in the Delta (Petrie, 2017).



White Egret flying over unknown waterway.

BIRD FRIENDLY FARMING IN THE SACRAMENTO-SAN JOAQUIN DELTA:

A Comparative Analysis between Corn and Rice

Mallard Ducks flying away at the Black Hole Habitat. **WETLAND PRESERVATION FOUNDATION**

Figure 19 illustrates the different effects that two types of farming have on the land. This specific figure is compiled by one of the leading rice farmers in the Delta, Wetland Preservation Foundation. It outlines what the effects of growing Rice are compared to growing Corn.

In the winter months (November-February), conventional corn farming leaves peat soils exposed to carbon dioxide. In contrast, **bird-friendly Delta agriculture,** such as rice cultivation, shows no specific activities during this period. However, the analysis unveils a stark divergence in the ensuing months.

During March-May, conventional corn farming triggers peat oxidation, spanning 90 water days, contributing to soil degradation. Meanwhile, wildlife-friendly rice farming creates **Migratory Wintering Grounds**, providing food and water for wildlife. Although lacking cover for **brood rearing,** this period signifies a marked ecological difference.

In the critical months of June-September, rice farming shines. With Pair Water/Brood Water management, it ensures food and water for wildlife, while also providing cover for brood rearing, spanning 210 water days. This unique approach underlines its significant contributions to soil health, water quality, and carbon offset.

The latter proves to be an environmentally beneficial practice, enhancing wildlife support and reducing the ecological footprint compared to conventional agriculture.

In conclusion, rice farming emerges as a sustainable alternative not only for waterfowl habitat, but also shows remarkable benefits for soil health, subsidence, and carbon sequestration. Its capacity to support wildlife during crucial periods of migration and breeding accentuates its superiority over conventional farming practices. The timeline emphasizes the transformative impact of choosing rice farming in the Delta.

LAND USE COMPARISONS

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Water Days
Conventional Delta Ag (e.g. Corn)		(1)							(2) Peat Oxidation				90
Delta Ag Wildlife-Friendly (e.g. Rice)			(1)						(3)				210

1. **Migratory Wintering Grounds:**
   a. Food/Water (Yes)
   b. Cover (No)
   c. Brood Rearing (No)

2. **Peat Oxidation:**
   a. Soil microbes de-couple organic compounds, thereby releasing nutrients (N/P/K/ minors);
   b. Depending on soil peat percentage, loss of 1/2 to 1 inch field elevation per year;
   c. In addition to soil elevation loss, microbial oxidation releases 10-12 tons of atmospheric carbon PER ACRE PER YEAR!
   d. a/b/c above, is why the Environmental community should fully support peat land conversion to Rice in the Delta!

3. **Pair Water/Brood Water:**
   a. Food/Water (Yes)
   b. Cover (Yes)
   c. Brood Rearing (Yes)

Figure #19. Land use comparison between corn and rice, and affects waterfowl habitat. **WETLAND PRESERVATION FOUNDATION**

Flooded rice fields.
WETLAND PRESERVATION FOUNDATION

GET STARTED RICE GROWING

In this section of the *Rice Farming Handbook: San Joaquin-Sacramento Delta Region*, various resources are available to start the rice growing process.

Black Headed Gull flying a flooded rice field.
WETLAND PRESERVATION FOUNDATION

STEPS FOR CONVERSION

Contemplating a venture into rice farming involves navigating the next steps. As one embarks on the journey of securing funding for the conversion and gaining in-depth insights into the "how-to's," three invaluable resources are offered to provide support in this endeavor:

ADM Advancement Program: Archer Daniels Midland (ADM) offers a program tailored to farmers, providing essential support for an upfront funding opportunity.

Upcoming Grant from The Nature Conservancy: Stay tuned for an upcoming grant from The Nature Conservancy, aiming to further support farmers interested in converting to rice farming.

Rice Growing Manual: Access a comprehensive rice growing manual developed by the UC Cooperative Extension and UC Davis, in collaboration with industry partners and field experts. This manual serves as a valuable resource, offering insights, guidance, and updated information to understand and navigate the rice farming process effectively.

ARCHER DANIELS MIDLAND (ADM) COMPANY'S

THE PLANTING ADVANCE PROGRAM

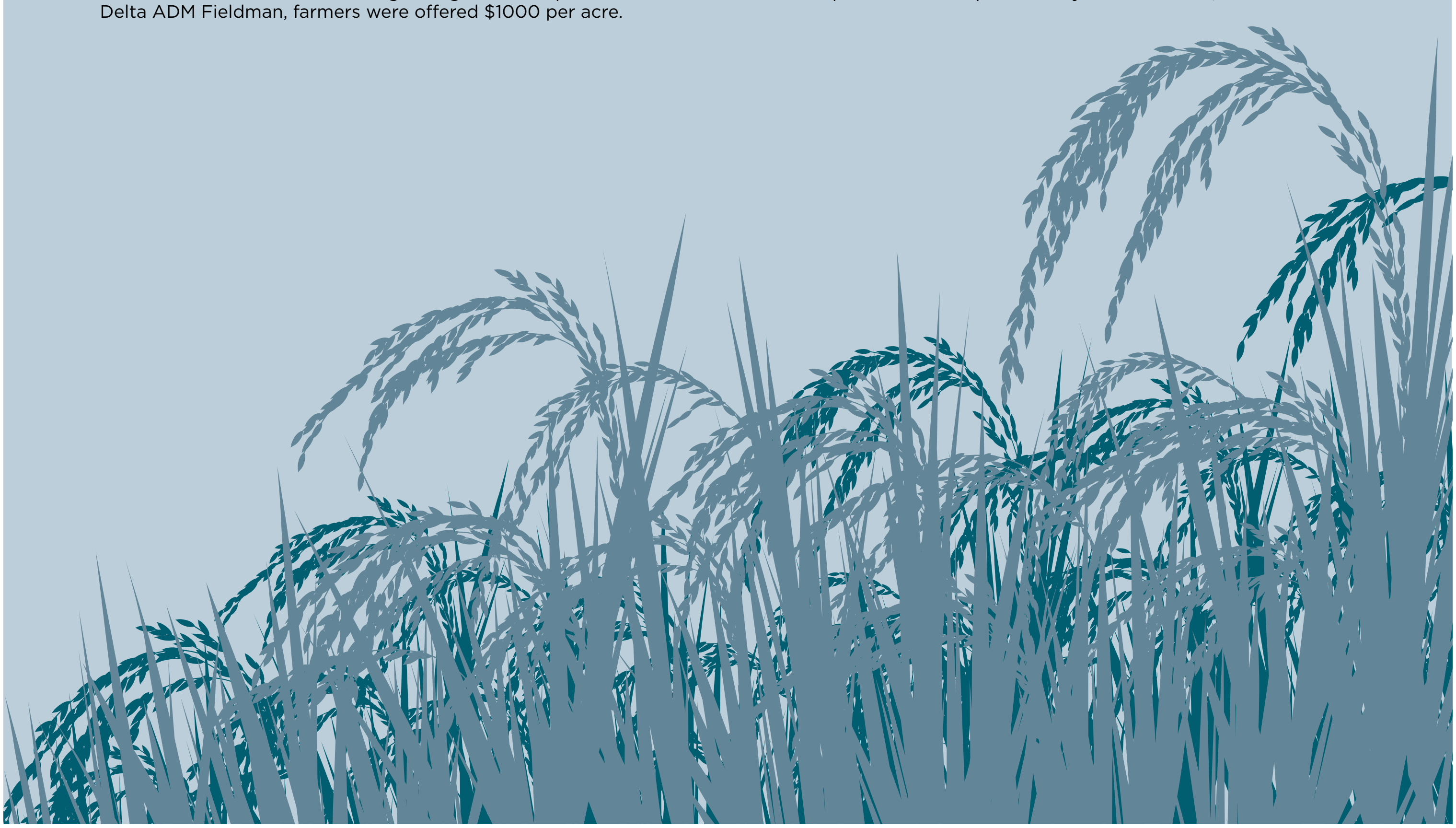
Archer Daniels Midland (ADM) is presently offering Delta Rice farmers a Planting Advance option, emphasizing their commitment to supporting farmers and ensuring financial security during uncertain times.

With a commitment to supporting farmers, ADM Rice Inc. is offering a **Planting Advance**[2] per acre before the harvest. The amount is market-dependent, but for farmers in need of additional financial support to make the transition, this could be a valuable solution.

We highly recommend reaching out to Brian Barrette, the local Delta Fieldman for ADM Rice Inc., to delve deeper into the details of this opportunity.

For more in-depth insights or any queries, please don't hesitate to contact Brian Barrett directly at Brian.barrett@adm.com or give him a call at (530) 635-0259. Brian is the dedicated contact person, and his expertise will be instrumental in exploring this opportunity further.

[2] The offered rates for the 2023 growing season depend on market conditions. As per information provided by Brian Berrette, the local Delta ADM Fieldman, farmers were offered $1000 per acre.



THE NATURE CONSERVANCY *PENDING* **RICE CONVERSION GRANT**

The Nature Conservancy at Staten Island is launching a funding project to encourage the transition of non-rice crops to rice cultivation, focusing on agricultural lands in the Delta. Grants are being initiated for farmers interested in converting to rice growing. For further inquiries or additional information, feel free to reach out to us directly or contact Jerred Dixon at jerred.dixon@cfstaten.com.

Expanding rice cultivation in the Sacramento-San Joaquin Delta

This program will expand climate resilient, wildlife-friendly rice growing in the Delta

The Sacramento-San Joaquin Delta ("Delta") is critical part of California's water supply system and globally important agricultural economy. It is also home to more than 750 species of plants and animals, serving as a critically important migration stopover and wintering site for millions of migratory birds every year.

However, flooding and sea level rise combined with ongoing land subsidence threaten the stability of Delta farming, infrastructure, communities, and ecosystems. An alternative mosaic of land management across the Delta will protect human and natural communities in the face of these threats, providing durable economic and environmental resilience in the face of climate change.

Rice farming can be an important part of a resilient future for the Delta. Rice cultivation reduces land subsidence and greenhouse gas (GHG) emissions compared to other crops in the Delta. Rice growing does this by being managed in a flooded state during the growing season, reducing overall oxidation of soils. In addition, targeted management of flooding rice fields during the non-growing season further reduces subsidence and greenhouse gas emissions, while providing critical habitat benefits for migratory birds and other species.

Top: Rice harvest in the Delta

Bottom: Sandhill Cranes using winter farmland in the Delta

2024 – 2027 Delta Rice Conversion Pilot Program

For more information contact Jerred Dixon jerred.dixon@cfrstaten.com

Figure#20, Expanding rice cultivation in the Sac-SJ Delta.
THE NATURE CONSERVANCY

This program will expand climate resilient, wildlife-friendly

This program will provide financial incentives for willing farmers in the central Delta to convert existing non-rice crops to rice cultivation, focusing on agricultural lands in the most heavily subsided areas of the Delta dominated by peat soils. Landowners or responsible lessees will be provided with contracts that pay for the cost of conversion with the commitment to grow rice under a multi-year contract. The total incentive payments will vary with the number of years participating landowners commit to growing rice.

In order to also ensure converted land provides valuable and critically needed migratory bird habitat, participating landowners will be required under contract to seasonally flood the acres enrolled, applying specific field and flooding management practices that enhance habitat value for migratory birds in the non-growing season. These field management practices will include slight incorporation of post-harvest stubble and shallow flooding during fall after harvest, winter, and late winter/spring before planting.

The goal for this program will be to support the conversion of up to 5,000 acres of rice, to be completed by planting season 2027. The benefits of this program will be reduced subsidence and annual GHG emissions and significantly enhanced wildlife habitat on 5,000 acres of farmland in the Delta.

By participating in this rice conversion program, landowners can increase the long-term sustainability of their farming operation by reducing subsidence and diversifying, contribute to California's greenhouse gas emissions goals, and play a vital role in protecting migratory birds along the Pacific Flyway, all while still growing a profitable crop.

Top Left: This program will focus on farmlands in the central Delta where land subsidence is highest.

Top Right: Rice harvest at Staten Island. TNC and Conservation Farms & Ranches will implement this program in partnership with the Delta Conservancy by building off its experience converting to and growing rice on Staten Island starting in 2019. Since then, we have converted 2,800 acres of corn to rice and experienced very high quality and yield rice crops that are in high demand.

Though this we've determined first hand the costs and challenges of the conversion process. We will bring this experience to setting the incentive payments of this program and to assist willing farmers through the entire conversion process.

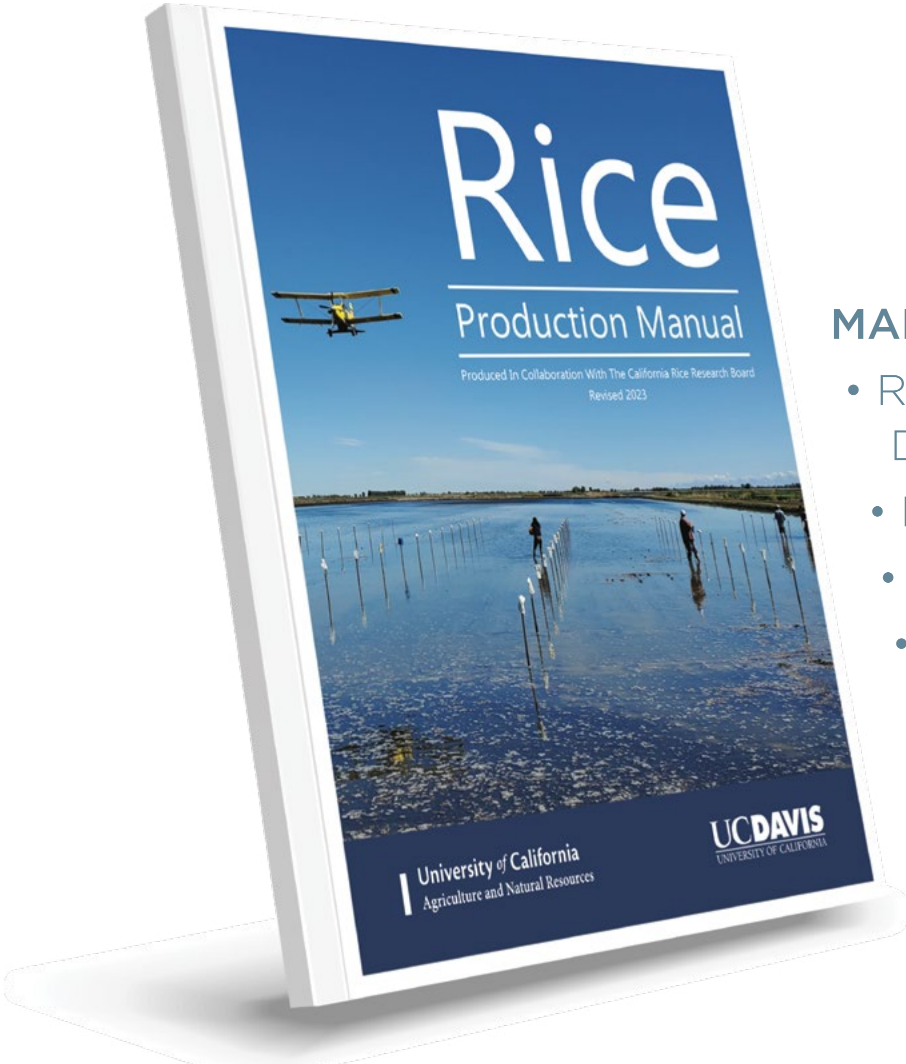
For over a decade, TNC has also worked with farmers across the Central Valley on wildlife-friendly farming, through its BirdReturns and other programs. The practices and tools we've developed over the years will be used to work with farmers in this program to maximize the habitat value of their farmlands.

The Nature Conservancy

For more information contact Jerred Dixon jerred.dixon@cfrstaten.com

Figure#21, Expanding rice cultivation in the Sac-SJ Delta, page 2

THE NATURE CONSERVANCY



MANUAL INCLUDES:

- RICE GROWTH AND DEVELOPMENT
- PEST MANAGEMENT
- FIELD LAYOUT
- LAND FORMATION
- VARIETY SELECTION

... AND MORE!

RICE PRODUCTION MANUAL: A COMPREHENSIVE GUIDE FOR FARMERS

The Rice Production Manual is regularly updated by the UC Cooperative Extension UC Davis and the California Rice Research Board for farmers' benefit. It has been included in this *Rice Farming Handbook: San Joaquin-Sacramento Delta Region* as a tool for farmers to understand the dynamic process of rice growing. This longstanding collaborative effort aims to provide science-based solutions, encouraging farmers to explore diverse cultivation methods each year to achieve improved yields. The manual covers various key topics, addressing the evolving needs of the agricultural community.

Rice Growth and Development: Delve into the intricate stages of the rice life cycle, from germination and seedling growth to the ripening stage. Understand the yield components that influence the final grain production, empowering farmers to make informed decisions at each growth phase.

Pest Management: Gain crucial insights into effective pest management strategies. The manual provides a detailed exploration of diseases, invertebrates, and weeds that can impact rice crops. Learn preventive measures, cultural methods, and the proper use of herbicides for successful pest control.

Field Layout and Land Formation: Discover best practices for field development, including historical perspectives, site selection, leveling, and soil fertility management. Efficient land formation sets the foundation for a successful rice crop.

Variety Selection and Use: Navigate through the diverse rice varieties with guidance on selection, plant characteristics, and harvest considerations. Understand the environmental effects on head rice yield and the importance of sampling for harvest moisture content.

This manual is a result of the California Rice Production Workshops, which offers a wealth of information for both novice and experienced farmers. With detailed explanations, illustrations, and contributions from various partners and experts throughout the years it is a comprehensive tool that goes beyond basic farming guidelines.

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Bonus: Agronomy Fact Sheet

The University of California Cooperative Extension had created Agronomy Facts with the explicit purpose of educating farmers on the intricacies of rice farming and offering invaluable insights into what to expect throughout the entire process. Developed with precision and care, these resources serve as an essential guide for farmers, providing a comprehensive understanding of the nuances involved in rice cultivation. These pages are designed to empower farmers with knowledge, ensuring a well-informed and successful journey into the world of rice farming. Please refer to **Supplementary** pages for more information.

UNIVERSITY OF CALIFORNIA | Agronomy Research & Information Center

Agronomy Fact Sheet — Fact Sheet # 17

Delta Rice Production – Challenges and Opportunities

The Delta region of California is located at the confluence of the Sacramento and San Joaquin rivers. The Delta spans approximately 738,000 acres, where over 400,000 acres are in agricultural production. While the region is defined by its waterways, the Delta is also unique for its fertile soils which range from mineral to organic. The mineral soils are the result of alluvial deposits from waterways. The organic soils formed from decomposed plant matter. Delta soils were reclaimed in the mid- to late-1800's when levees were constructed to contain water within channels, allowing Delta "islands" to be farmed.

Over time, some areas of the Delta with organic soils have experienced carbon oxidation, resulting in land subsidence. Land subsidence threatens levee stability, water quality, and water distribution within the Delta and to other parts of California. Keeping soils flooded mitigates soil carbon loss and land subsidence, but most crops cannot grow under flooded conditions. Rice is one exception because of its unique cellular structure that allows gas diffusion through the plant, even under flooded conditions. Research has demonstrated that the flooded conditions of rice cultivation can greatly reduce, if not stop, carbon oxidation and land subsidence in the Delta.

The predominant rice-growing region in California is the Sacramento Valley, but rice acreage in the Delta is growing, and yields are comparable with statewide averages (Table 1). Rice establishment practices differ between the Sacramento Valley and the Delta due to varying environmental conditions, like soils and climate. In the Sacramento Valley, rice is grown on mineral soils with a high clay content. In the Delta, rice is grown on soils with a high organic matter content (approximately 20-40%) and low bulk density (i.e. mass per unit of volume, approximately 0.5-0.8 g/cm^3). Sacramento Valley fields are planted by flying soaked seed onto flooded fields (i.e. water-seeding). This planting practice presents challenges in the Delta because the lightweight, organic soil can go into suspension and then bury the seed when it settles, resulting in a reduced stand. Additionally, winds can affect crop establishment in a water-seeded system by preventing root anchoring into the soil or by dislodging seedlings. To overcome these challenges, Delta rice is drill-seeded into moist soil, as growers would plant wheat (Fig. 1).

Table 1. Delta and statewide rice acreage and yield (as hundredweight per acre, cwt/ac).

California Rice Production						
	2022	2021	2020	2019	2018	2017
SJC* Acreage	8933	7970	4040	4060	3620	3060
Proportion of statewide acreage in the Delta	N/A	2%	1%	0.9%	0.7%	0.7%
Average SJC* Yield (cwt/ac)	101	86	88	81	86	82
Average Statewide Yield (cwt/ac)	N/A	91	87	85	87	84

**Rice acreage and yield according to the San Joaquin County (SJC) Agricultural Commissioner's Crop Reports. Rice acreage in SJC is primarily in the Delta region. Delta acreage in other counties is not included in these statistics. At the time of publishing, 2022 CDFA statewide data were not yet available (N/A).*

The San Francisco Bay is a strong influence on weather patterns in the Delta. Cool tempera-

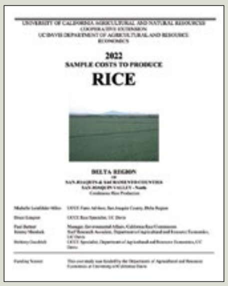
University of California — 1 — UC Cooperative Extension

Snow Geese at the Black Hole
WETLAND PRESERVATION FOUNDATION.

RESOURCE HUB

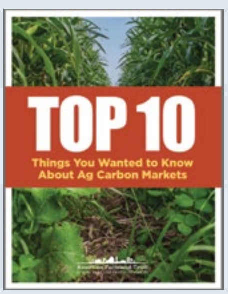
Here is the list of all the resources mentioned in this handbook.
With images, and links, for easy access. .

Keep in mind that this section of the handbook will be dynamic, evolving as new incentives and resources for farmers emerge. Stay tuned for updates and the latest developments in our commitment to fostering sustainable agriculture and promoting the growth of rice cultivation.

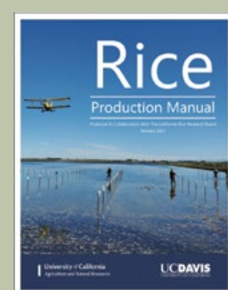


[Sample Cost to Produce Rice in the Delta SJ & Sac Valley North]

[The Restoration of California Deltaic and Coastal Wetlands Methodology, version 1.1]



[Top 10 Things You Want to Know About Carbon Markets]



[Rice Production Manual]

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C: (916)516-4011

Two pheasants in a grass field at the Black Hole,
WETLAND PRESERVATION FOUNDATION

CONCLUSION

Congratulations on reaching this point! As we conclude, it's clear that rice cultivation in the Delta offers multifaceted benefits. Not only does it serve as a powerful tool for subsidence mitigation, preserving land elevation, and reducing flood risks, but it also proves to be economically advantageous, providing stability. Additionally, rice fields create essential habitats for waterfowl, support biodiversity, and create a new form of carbon sink. Revenue sources from the environmental benefits of rice farming are in development, which will make rice even more profitable. There are many positive impacts from rice farming in the Delta region.

SUPPLEMENTARY MATERIALS

Supplement 1. Agronomy Fact Sheet, Fact sheet #17-Delta Rice Production-Challenges and Opportunities

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Agronomy Fact Sheet **Fact Sheet # 17**

Delta Rice Production – Challenges and Opportunities

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Over time, some areas of the Delta with organic soils have experienced carbon oxidation, resulting in land subsidence. Land subsidence threatens levee stability, water quality, and water distribution within the Delta and to other parts of California. Keeping soils flooded mitigates soil carbon loss and land subsidence, but most crops cannot grow under flooded conditions. Rice is one exception because of its unique cellular structure that allows gas diffusion through the plant, even under flooded conditions. Research has demonstrated that the flooded conditions of rice cultivation can greatly reduce, if not stop, carbon oxidation and land subsidence in the Delta.

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The San Francisco Bay is a strong influence on weather patterns in the Delta. Cool temperatures affect how fast the crop develops and may delay flowering and harvest, which can impact yield (Fig. 2). Also, cold nighttime temperatures between panicle initiation (i.e. when the grain head begins to form at the base of the stem) and flowering can result in blanking. Blanking is a term used to describe when individual grains do not fill, which lowers yield. Nighttime temperatures peak in late-July, and a nighttime temperature less than 58°F (depending on variety) is considered cold for rice grain development. To overcome the cool conditions, Delta growers plant early in the season (April or May) so that panicle development and flowering occur ahead of nighttime temperatures decreasing. Growers also plant very-early and early maturing varieties, which mature roughly 15 days ahead of intermediate and late-maturing varieties in the Delta region. Variety options are limited but may expand with continued variety selection for cold tolerance.

Figure 1. Delta rice is drill-seeded, in contrast to the water-seeding done in the Sacramento Valley.

Windy conditions in the Delta can interfere with pesticide applications since pesticides cannot be sprayed when winds are high. Delta growers adapt to these challenges by making applications before dawn, when winds are calm.

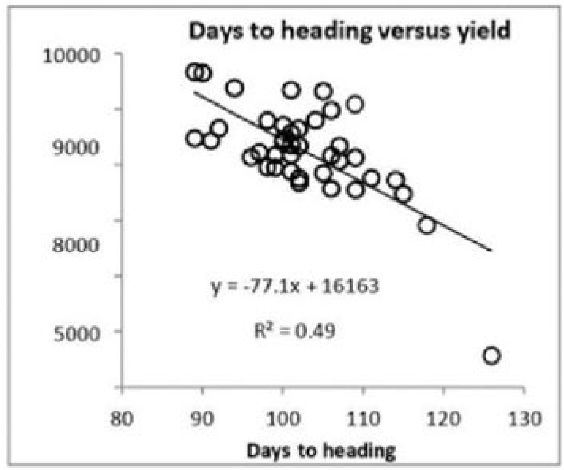

Figure 2. Relationship between days to 50% heading and grain yield. Data are from the Delta variety trial (2010-2014).

For more on this topic:

- ✓ CA Department of Food and Agriculture. CA Agricultural Production Statistics. https://www.cdfa.ca.gov/Statistics/.
- ✓ Deverel, S. J., Dore, S., and Schmutte, C. 2020. Solutions for subsidence in the California Delta, USA, an extreme example of organic-soil drainage gone awry, Proc. IAHS, 382, 837–842, https://doi.org/10.5194/piahs-382-837-2020.
- ✓ San Joaquin County Agricultural Commissioner. Annual Crop Report. https://www.sjgov.org/department/agcomm/general-info/crop-reports.

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UC CE University of California Cooperative Extension

Authors: Michelle Leinfelder-Miles and Bruce Linquist

2023

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Agronomy Fact Sheet Fact Sheet #18

Delta Rice Production – Planting and Fertility Practices

Rice production practices in the Delta are uniquely adapted to the local conditions, including cooler temperatures and soils with high organic matter. Variety selection, planting practices, and fertility management that are suitable for the region help ensure successful production.

Variety selection

UC Cooperative Extension evaluates varieties in the Delta for cold-tolerance and adaptability (Fig. 1). Very-early and early maturing varieties, like M-105, M-206, and CM-101 have performed well in trials. They have good agronomic characteristics and consistent quality across different harvest moistures. The most widely planted variety in the Delta and across the state is M-206. While CM-101 is a very good variety for the Delta, a contract is required, so it is not widely planted. Among the newer varieties, M-210 is early maturing, blast resistant, and may be a good option for the Delta. M-209 and M-211 are not suitable for the Delta because they are late to mature and susceptible to cold temperatures.

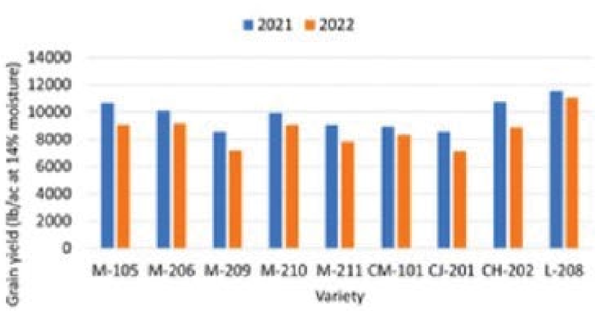

Figure 1. Yield from UCCE Delta variety trials.

Planting practices

Delta rice is planted in either April or May, depending on seasonal rainfall and when growers can start bringing equipment onto the fields. Rice is drill-seeded into moist soil, as growers would plant wheat, where row spacing is about 6 inches and seeding rate is around 150 pounds per acre. When employing drill-seeding, growers must be mindful of planting depth and soil moisture. Typical seeding depth is about 1.5-2 inches. Research has shown that rice seedlings do not emerge well and may come up twisted and bent when planted too deep. Rice emergence is most successful when growers “plant to moisture”, which means that seed is planted at the interface of dry and moist soil. Some growers may drill-seed into dry soil and then irrigate with a brief flush of water to help germinate seed. This practice, however, can result in an uneven stand and may make weeds more problematic by giving them a head-start to grow before the rice has emerged. A better practice if a grower “misses the moisture” would be to flush the field ahead of planting, allow some time for the soil surface to dry, and then plant to moisture.

Fertility management

For rice grown on high organic matter soil, research indicates that there is no benefit to applying nitrogen (N), phosphorus (P), or potassium (K) fertilizer at planting. While some growers may apply starter fertilizer at planting through the grain drill, all fertilizer could be applied just before the permanent flood is established (roughly the 3-4 leaf stage, or about 3-5 weeks after planting).

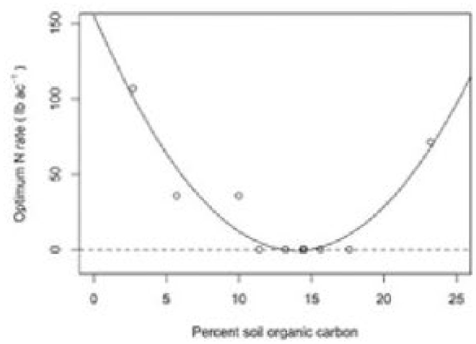

Figure 2. Relationship between soil organic carbon and optimum N fertility rate. (Data from Espe et al., 2015. Soil Science Society of America Journal).

Determining the correct N fertilizer rate is important. Applying too little N results in poor crop yields. Too much N results in delayed crop maturity, lodging (which lowers grain quality and slows harvest operations), and blanking. Research has indicated that soils with 12 to 18% carbon (roughly 24 to 36% organic matter) do not require N fertilizer; however, soils with lower or higher organic carbon contents do require N fertilizer (Fig. 2). Rice yields did not improve in trials where P fertilizer was applied, indicating that P fertilizer may not be necessary in the Delta (Fig. 3). In contrast, K fertilizer will be needed under some circumstances. Soils in the Delta may be low in K, and K is removed from the system in large quantities after harvest, especially in fields where the straw is baled. In trials, yields were reduced when no K was applied in one of two fields (Fig. 3). The data show that K could either be applied at planting or just before permanent flood with similar yield results. Trial results may not apply to all areas of the Delta, and growers should use soil and leaf sampling to guide their fertilizer decisions. Evaluate leaf samples at panicle initiation to determine if topdressing fertilizer is necessary.

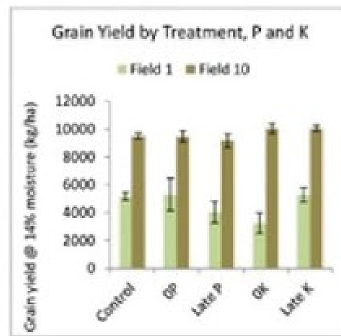

Figure 3. Yield response to P and K fertilizer. The control received both P and K fertilizer at planting. The late P and K received P and K fertilizer just before permanent flood.

For more on this topic:

✓ Espe et al. 2015. Indigenous Nitrogen Supply of Rice is Predicted by Soil Organic Carbon. Soil Science Society of America Journal. doi: 10.2136/sssaj2014.08.0328.

✓ Leinfelder-Miles, M. et al. 2022. Sample Costs to Produce Rice, Delta Region. UC Cooperative Extension and UC Davis Department of Agricultural and Resource Economics. https://coststudies.ucdavis.edu/en/current/commodity/rice/.

✓ UC Agronomy Fact Sheets. https://agric.ucdavis.edu/fact-sheets.

Agronomy Research and Information Center

http://agric.ucdavis.edu/

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2023

Delta Rice Production – Pest Management

Rice pest management practices in the Delta reflect the conditions and pest pressures of the region. Operations described below are typical for the Delta drill-seeded system but will vary across farms and seasons.

Weed management

Weeds are the most problematic pests in Delta rice fields. Grasses – like barnyardgrass and watergrasses (*Echinochloa* spp.) and sprangletop (*Leptochloa fascicularis*) – are the most challenging weeds (Fig. 1), but broadleaf weeds and sedges must also be managed. The Delta system also has weeds that are not found in other regions, like nutsedges (*Cyperus* spp.). In the drill-seeded system, growers manage weeds with pre-plant cultivation and ground application of herbicides before the permanent flood is established. Herbicides are applied when the rice has about three to four leaves. The flood should be applied within a few days after herbicide application to avoid impacts to the rice. Later in the season, an aerial herbicide application may be applied to manage weeds that escape the ground application, but often this application is not needed.

Figure 1. Early watergrass (top panicle) and barn-yardgrass (center panicle) are two typical weeds in the Delta system.

Wetland plants like cattails (e.g. *Typha* L.) can become weedy in the Delta system, particularly if they emerge ahead of the rice crop and outcompete the rice. Cattails are difficult to control because they propagate by seed and underground rhizomes that become new plants if divided, as from tillage. Herbicide application can help to manage cattail pressure, but application timing is critical. Research has shown that control can be achieved if cattails are small (i.e. less than three feet tall).

Figure 2. Weedy rice is a significant pest because it reduces crop yield and quality. Weedy rice may be observed as light-green patches of plants that stand taller than the cultivated variety.

Weedy rice is rice with undesirable characteristics, like grain shattering and seed dormancy (Fig. 2). It is sometimes called red rice because some types have a red pericarp. Weedy rice has been identified in the Delta region and should be managed with cultural practices, like using certified seed, rogueing plants, and equipment sanitation. Reductions in the weed seed bank have been observed where post-harvest management included mowing but no tillage, followed by winter flooding. These practices keep seed on the soil surface where it may be eaten by migratory waterfowl or deteriorate in the water. Herbicide spot spraying for in-season management is possible, but there are limited products registered for use.

Arthropod management

Among the arthropod pests, true armyworms (*Mythimna unipuncta*) may present serious problems in some years by feeding on vegetation or damaging grain panicles. UC Cooperative Extension has been monitoring populations in the Delta since 2016 (Fig. 3). While armyworm populations may undergo two generations during the season in the Sacramento Valley, only one generation has been observed in the Delta system. Scouting is an important part of management, and insecticides are registered for use. See the armyworm fact sheet for more information on this pest. Other insect and arthropod pests are generally not problematic in the Delta.

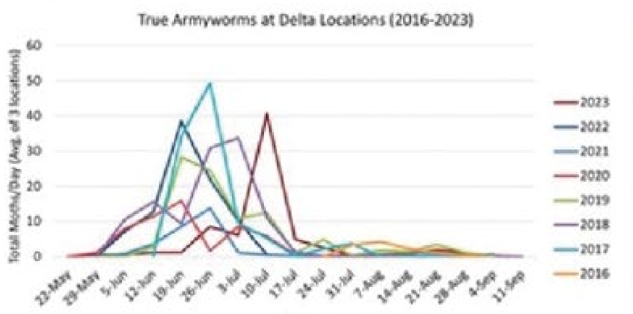

Figure 3. UCCE monitors true armyworms in Delta rice fields. Pest pressure varies from year to year.

Disease management

Diseases that have been observed in the Delta include stem rot (*Sclerotium oryzae*), aggregate sheath spot (*Rhizoctonia oryzae-sativae*), and rice blast (*Magnaporthe oryzae*); though, disease pressure is highly variable across the region and over time. Stem rot will manifest as black lesions along the water line at late-tillering. Aggregate sheath spot will manifest as gray or green lesions on the lower leaf sheaths at the water line. Both diseases that can be more problematic on low potassium soils, which occur in the Delta. Rice blast will often appear as diamond-shaped lesions on the leaves mid-season and may present as lesions on the node below the panicle later in the season. It is important to scout for both of these diseases at late-tillering. Fungicides are registered and are most effective when applied between late-boot and early-heading. There is no varietal resistance for stem rot, but M-210 is blast resistant and has performed well in Delta variety trials. The biology and management of these diseases is described in more detail in separate fact sheets.

For more on this topic:

- ✓ California Weedy Rice. https://caweedyrice.com/.
- ✓ Delta Crops Resource Management, Rice. https://ucanr.edu/sites/deltacrops/Rice/.
- ✓ UC Agronomy Fact Sheets agric.ucdavis.edu/fact-sheets.
- ✓ UC Integrated Pest Management: Rice. https://ipm.ucanr.edu/agriculture/rice/.

Agronomy Research and Information Center

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University of California Cooperative Extension

Author: Michelle Leinfelder-Miles

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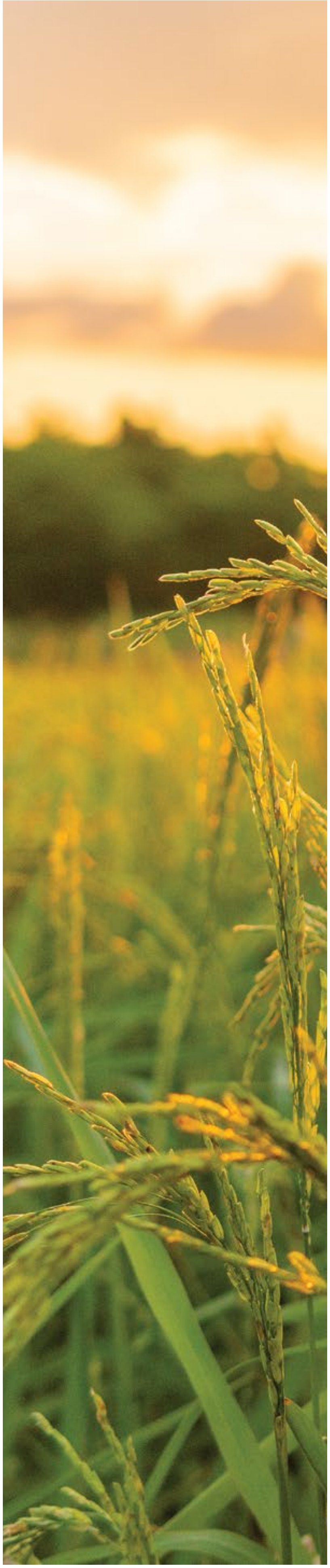

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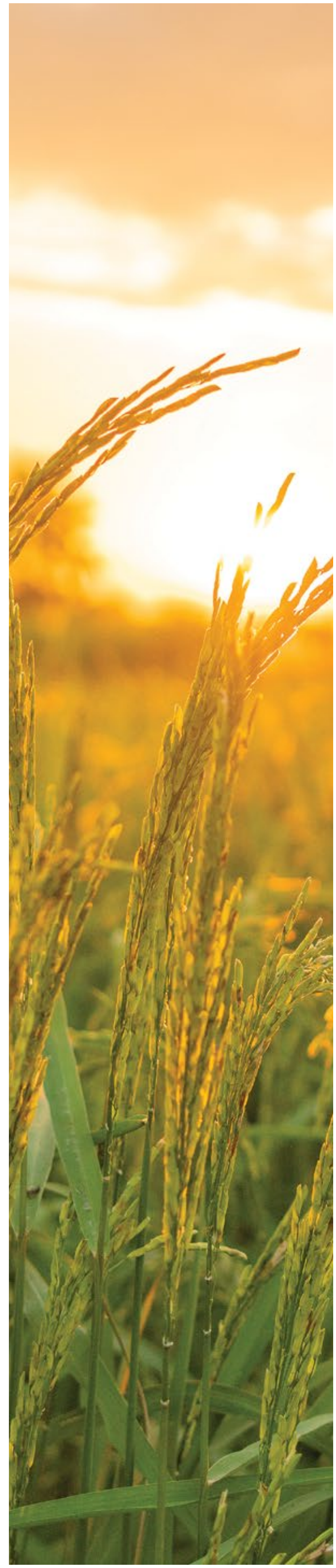

GLOSSARY:

Aerobic: requiring oxygen.

Agriculture carbon market: An environmental market developed to help corporations meet climate and sustainability goals by paying farmers to adopt practices that reduce greenhouse gas emissions or sequester carbon. This paper uses the terms ag carbon market and ag carbon program interchangeably.

Anthropogenic Accommodation Space: space in the Delta that lies below sea level and is filled neither with sediment nor water, serves as a useful measure of the regional consequences of Delta subsidence and sea level rise.

Avian ecosystems: Bird-friendly Delta agriculture refers to farming practices in the Delta region that actively support various bird species. By providing supplementary food sources and fostering a balanced ecosystem, these practices contribute to increased yields for farmers. This approach creates a symbiotic relationship between agriculture and bird populations.

Brood rearing: period immediately after hatching when special care and attention must be given to chicks.

Carbon dioxide: Important heat- trapping gas, also known as greenhouse gas.

Carbon sequestration: a natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form.

Carbon sink: is anything, natural or otherwise, that accumulates and stores some carbon-containing chemical compound for an indefinite period and thereby removes carbon dioxide from the atmosphere.

Consolidation: the process by which the volume of a saturated or unsaturated soil decreases due to applied stress.

Fragmentation: the process or state of breaking or being broken into small or separate parts.

Greenhouse Gas Emission (GHG): A gas that, upon entering the Earth's atmosphere, retains heat and contributes to the greenhouse effect. Climate change arises from an excess of greenhouse gasses in the atmosphere, necessary to maintain the Earth's temperature but reaching problematic levels. Greenhouse gases originating from agricultural activities encompass carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N_2O).

Mean sea level: an average surface level of one or more among Earth's coastal bodies of water from which heights such as elevation may be measured.

Microbial oxidation: is a process involving the microbial-driven decomposition of organic matter, releasing gaseous carbon dioxide (CO_2) as a byproduct.

Migratory wintering grounds: location where birds in the Pacific Fly to during the winter months.

Mitigation: the action of reducing the severity, seriousness, or painfulness of something.: "the emphasis is on the identification and mitigation of pollution

Mosaic: a pattern or images made of small irregular pieces, in the contents of this book, the Delta islands lay in a mosaic patterned, divided by rivers, sloughs, and levees.

Oxidation: the process resulting from oxidizing.

Peat soils: Peat is an accumulation of partially decayed vegetation or organic matter.

Peat-based: Peat is a type of organic-rich soil that consists of partially decomposed organic matter, derived mostly from plant material, which has accumulated under conditions of waterlogging, oxygen and nutrient deficiency, and high acidity.

Subsidence: the gradual caving in or sinking of an area of land.

Tailwater: Tailwater refers to waters located immediately downstream from a hydraulic structure.

Waterlogged: saturated with water.

We value your input and would love to hear your feedback on how we can enhance this handbook to meet your needs.

Our goal is to make this handbook as interactive as possible, shaping it to be a collaborative resource where we conduct research and deliver content that matters most to you.

Your insights are crucial in ensuring that this handbook remains a valuable and dynamic tool. Let us know what you'd like to see more of, and together, we can create a truly impactful resource.

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