International Rice Industry Sustainability Report

A comparison of sustainability and conservation agriculture practices across the United States, Brazil, India, Pakistan, Thailand, Uruguay, and Vietnam

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Contents

Executive Summary

This report highlights the differences in sustainability and conservation agriculture practices between the U.S. and other top rice exporting countries, including Brazil, India, Pakistan, Thailand, Uruguay, and Vietnam to differentiate rice exported by the U.S. from global competitors.

US producers implement a variety of practices that support beneficial environmental and economic outcomes, including:
-Conservation tillage
-Rice straw incorporation/retention
-Certified seeds
-Direct seeding
-Dry seeding
-GNSS and/or laser land leveling
-4R and nutrient management plans
-Sulfate-containing fertilizer
-Urease inhibitors
-Crop rotation
-Winter flooding

A literature review and expert opinions revealed that U.S. producers may differentiate themselves from the other top rice producing countries in this report based on their use of conservation tillage, rice straw incorporation/retention, use of certified seeds, GNSS or laser land leveling, 4R and nutrient management plans, direct seeding, dry seeding, use of sulfate-containing fertilizer, use of urease inhibitors, crop rotation, rice-crawfish rotation, and winter flooding. These practices have positive environmental and economic benefits that U.S. producers can communicate to global markets. Additionally, U.S. grown rice has the highest percentage of actual yield to potential yield ratio, low GHG emissions, low water use, and low water stress compared to other top rice exporting countries in this report, highlighting efficient production techniques that reduce environmental impacts.

Introduction

Rice is a staple food source for more than half the world's population, accounting for 21% of global calorie intake. As the world's population continues to increase, reaching an estimated 8.6 billion people in 2030, rice will remain a crucial dietary component for our growing population.[1]

The importance of sustainability has grown significantly among stakeholders, influencing all aspects of agriculture, including rice production. Consumers, particularly younger generations who will soon have the majority of purchasing power, increasingly prefer goods associated with sustainability.[2] As more individuals worldwide rise out of poverty and can afford higher quality goods, the demand for sustainably produced goods is likely to increase. This trend presents a market opportunity for rice producers using sustainability and conservation agriculture practices.

Rice is a staple food source for more than half the world's population, accounting for 21% of global calorie intake.

Sustainability-related regulations are rapidly emerging, reflecting this increased demand. For example, the European Union has enacted the Corporate Sustainability Reporting Directive (CSRD) that aims to identify and address potential and actual adverse human rights and environmental impacts in a company's direct operations and value chain to identify impacts, risks, and opportunities as well as satisfy investor and other stakeholder needs.[3] This significant shift towards managing environmental, social, and financial impacts underscores an opportunity for U.S. rice exporters to document and communicate their sustainability-related practices and environmental outcomes as they seek to expand into new markets.

This report aims to highlight the differences in sustainability and conservation agriculture practices between the U.S. and other top rice exporting countries, including Brazil, India, Pakistan, Thailand, Uruguay, and Vietnam, to differentiate rice exported by the U.S. from global competitors.

Egret in rice field, Source Dr. Steve Linscombe

Methodology

This report was informed by a literature review of global and regional rice sustainability and conservation agriculture frameworks, peer-reviewed research, and expert opinion (see table below). The goal of this research was to collect a comprehensive list of sustainable and conservation agriculture practices currently used in rice production for the U.S., Brazil, India, Pakistan, Thailand, Uruguay, and Vietnam. Data collected on rice production practices included source, year, region, sub-region, method of practice implementation, practice boundary, current adoption rates, best practices for measuring outcomes, and environmental, social, and economic impacts. Both qualitative and quantitative data were collected on the environmental, social, and economic impacts of the practices, when available. Each practice was categorized into a focus area based on the sustainability outcomes and the intention behind the practice. The focus area categories include biodiversity, energy use and air quality, land use and soil conservation, and water use and quality.[a]

The report leverages Dr. Steve Linscombe's industry contacts to provide an estimate of current practice adoption and to ensure that the research accurately reflects the practices occurring in each expert's specific region. Experts engaged include:

Region	Contact
United States	Dr. Bruce Linquist, Professor and Vice Chair of Outreach and Extension on the Plant Sciences Executive Committee at the University of California, Davis
United States	Dr. Jason Bond, Extension and Research Professor at Mississippi State University
United States	Dr. Jarrod Hardke, Professor and Extension Rice Agronomist at the University of Arkansas
United States	Dr. Justin Chlapecka, Assistant Professor of Agronomy at the University of Arkansas
United States	Dr. Ronnie Levy, State Rice Specialist at Louisiana State University
United States	Dr. Sam Rustom, Assistant Professor at Texas A&M University
United States	Mr. Todd Fontenot, LSU AgCenter Extension Agent for Crawfish Production
Pakistan	Mr. Shahrukh Khan, National Coordinator for Pakistan at Helvetas Organization
Pakistan	Dr. Jam Nazir Ahmed, Professor at the University of Agriculture Faisalabad
Pakistan	Dr. Aziz Ahmad, Assistant Professor at the University of Sindh
India	Dr. M. Arumugam Pillai, Professor and Head of Department of Plant Breeding and Genetics at Tamil Nadu Agriculture University
India	Dr. R. Mahender Kumar, Principal Scientist and PI of AICRIP (Agronomy) at the Indian Institute of Rice Research
Thailand	Dr. Manoch Kongchum, Associate Professor at Louisiana State University
Brazil	Mr. Richard Bacha, Professor and Director Emeritus- Agricultural and Rural Extension Company of Santa Catarina, Brazil
Uruguay	Mr. Gonzalo Zorrilla de San Martin, Independent Researcher and previous Director of National Rice Research Program at the Instituto Nacional de Investigacion Agropecuaria
Vietnam	Dr. Hung Van Nguyen, Senior Scientist at the International Rice Research Institute

[a] The complete research dataset is housed in a separate Excel tracker titled *Rice Sustainability Research Practices*. This report is based on the practices most common in each region and does not include every practice captured within the research tracker.

Comparative Analysis

This comparative analysis highlights the regional differences among sustainability and conservation agriculture practices within top global rice exporting countries, identifying the adoption rates of the practices within each region, as available.

Sustainability and conservation agriculture practices are often region specific. For example, cover crops may be appropriate in temperate regions with distinct growing seasons, but the practice may not be applicable in tropical regions where producers can double or triple crop. Practices may not be directly comparable across geographies, and therefore the lack of adoption of a practice in a given region does not necessarily indicate a practice change opportunity or a lack of sustainable rice production.

Sustainability Practice Impacts

The following four tables provide a list of practices and their associated impacts. Each practice is categorized into a single focus area (land use and soil conservation, water use and quality, energy use and air quality, and biodiversity) although it may be relevant to one more than one. For this section, each row of each table summarizes the definitions and outcomes found in the literature for all top rice exporting countries included in this report. When impacts vary by region or source, the table provides a range of estimated practice impacts to best reflect these differences.[b] When conflicting information was found, for example, if a source claimed that yield decreased and another claimed it was maintained for a given practice, the tables denote that yield "may" decrease.

The impact areas, or outcomes driven by the implemented practices (e.g., soil carbon, soil conservation, GHG emissions, yield, etc.) in each table vary by focus area and are included based on the specific outcomes of the practices. The impacts are used to compare practices across different regions and focus areas.

The practices in the table are ranked as high, medium, or low impact based on the number of impact areas where the practice has a positive effect as well as the quantitative value of the impact. Negative impacts and uncertainty counted against the practice during the ranking process.

Key:

Identified as a **high impact** sustainability practice	Practice affects 5 or more impact categories and/or there is a significant quantitative impact in a single category (50% or greater).
Identified as a **medium impact** sustainability practice	Practice affects 3-4 impact categories.
Identified as a **low impact** sustainability practice	Practice affects 0-2 impact categories.

[b] A comprehensive list of impacts can be found in the Excel tracker titled *Rice Sustainability Research Practices.*

Land Use and Soil Conservation

Table 1: Practices related to land use and soil conservation and their identified environmental, economic, and social impacts.

Practice	Definition	Impact Categories						
		Soil Carbon	GHG Emissions	Soil Conservation	Nutrient Use	Water Use	Economic Impact	Social Impact
Biochar Application	A soil amendment derived from organic materials.	Increases SOC up to 43%[4,5]	Reduces CH4 emissions up to 20%[4,6]	Improves soil quality[7,8]	Increases nitrogen use efficiency by 12.4%[9]	N/A	May increase yield[4,5,6,8,9]	N/A
Conservation Tillage (including Zero-Till)	Any tillage and planting system that reduces tillage and soil disturbance. May include no-till and strip-till.	Increases SOC[10,11,12,13,14,15]	Reduces CH4 emissions 21%-39%[14,16]	Reduces erosion[17]	Increases P and K levels in soil[13]	20%-30% water savings[17]	Increases yield 5%-17%, reduces energy requirements, particularly tractor use[17,18]	N/A
Cover Crop	A crop planted for seasonal cover of agricultural soils.	Increases SOC[14]	N/A	Reduces erosion[19]	Legume cover crop increases soil N[19]	N/A	Increases yield[14,19]	N/A
Organic Fertilizer Application	Fertilizer derived from organic materials such as animal manure in replacement of synthetic fertilizers.	Increases SOC[20]	Reduces CH4 and N_2O emissions[21,22]	N/A	Increases nutrient use efficiency[23]	N/A	Increases yield[24]	N/A
Rice Straw Incorporation & Retention	Rice straw incorporation or retained in soil.	Increases SOC[25]	Reduces emissions by 35% compared to burning[26]	Reduces erosion[19]	Improves soil health[19,27,28,29]	Increases water use efficiency[30]	Increases yield to next crop[19,25,30]	Improves air quality compared to burning[25]
Use of Certified Seeds	Seeds that undergo third-party testing to ensure pristine quality.	N/A	N/A	N/A	N/A	N/A	Increases yield, net income, and productivity[23]	N/A

Water Use and Quality

Table 2: Practices related to water use and quality and their identified environmental, economic, and social impacts.

Practice	Definition	Impact Categories				
		Water Use	Water Quality	GHG Emissions	Economic Impact	Social Impact
Computer-Aided Irrigation Designs	Use of technology networks to measure and collect data on irrigation systems.	Increases irrigation efficiency, reduces water use up to 40%[31,32]	N/A	Reduces CH_4 emissions, reduces energy use from pumps[31,33,34]	High initial cost, lower subsequent operational costs,[31] energy efficiencies[34]	N/A
Direct Seeding	Method of sowing where rice seeds are planted directly in the field.	Reduces water use 12%-20% compared to transplanting[35,36]	N/A	Reduces emissions[35]	Reduces costs,[35] increases yield[38]	Reduces labor from transplanting[15,35,37]
Dry Seeding[c]	Planting rice in rows or broadcasting seeds.	Reduces water use[39]	N/A	Reduces CH_4 emissions up to 60%[40,41]	N/A	Reduces labor over transplanting and wet seeding[39]
Furrow Irrigation	Rice field is 'bedded' or 'hipped' to allow water movement across the field.	Improves water use efficiency[10,42]	N/A	N/A	Reduces labor and expenses over flooding[42]	N/A
GNSS Land Leveling	Provides leveling solutions using orbiting satellites.	Higher flooding accuracy over LLL, reduces water use, improves irrigation efficiency by 21%[43]	N/A	N/A	Cost reduction compared to LLL[44]	N/A
Laser Land Leveling	Laser-guided technology used to level fields.	Reduces water use[10,22,35,45]	N/A	Reduces methane emissions[42]	Increases yield,[10,45] expensive,[35] reduces seed rates[35]	N/A
Traditional Land Leveling	Leveling the planting area.	Improves water coverage[23,46,47]	N/A	N/A	Increases yield[47]	N/A
Multiple Inlet Irrigation	Each area between the levees is simultaneously irrigated.	Reduces total water usage by an average of 25%[10]	N/A	Reduces emissions[11]	Increases yield,[48] reduces energy requirement[11]	N/A
Tailwater Recovery	Water is collected and recirculated on the field.	Improves water use efficiency[10,49]	Limits release of pesticides to surface water[50]	N/A	Increases yield, reduces labor needs[49]	N/A
Water Seeding	Seed is pre-germinated and broadcast onto drained or standing water in the fields.	N/A	N/A	N/A	Reduces risk of herbicide drift[53]	Reduces labor[51]

[c] Dry seeding is included under Energy Use and Air Quality instead of Water Use and Quality with direct seeding because the main practice benefit is a reduction in GHG emissions.

Energy Use and Air Quality

Table 3: Practices related to energy use and air quality and their identified environmental, economic, and social impacts.

Practice	Definition	Impact Categories				
		GHG Emissions	Nutrient Use	Water Use	Economic Impact	Social Impact
4R Nutrient Management, Nitrogen Efficiency, Nutrient Management Plans	Applying fertilizer at the right source, right rate, right time, and in the right place.	Reduces emissions[23,47]	Improves nutrient use efficiency[10,11,23,46,47,52,53]	N/A	Increases yield,[52] reduces input costs[53]	N/A
Alternate Wetting and Drying	Flood initiation and recession.	Reduces emissions up to 70%[12,27,35,54,55,56,57,58,59,60,61,62.63.64]	N/A	Reduces water use 15%-30%[10,12,15,22,23,27,54,56,58,62,63]	May decrease yield[59,62]	N/A
Electric Irrigation Systems	Electric irrigation system.	May decrease emissions[65]	N/A	N/A	Deceases energy use[65]	N/A
Leaf Color Charts	Chart used to determine the N fertilizer needs of rice crops.	N/A	Improves nutrient use efficiency and minimizes N loss[66,67]	N/A	Rice yield increases by 2 tons per hectare[66]	N/A
Precise Fertilizer Application	Specific application and timing of fertilizer without affecting surrounding areas.	Reduces emissions[47]	Improves nutrient use efficiency[22]	Avoids unintentional runoff[47]	N/A	N/A
Sulfate Containing Fertilizer	Sulfate-containing fertilizers or amendments.	Reduces CH_4 emissions by up to 45% compared to non-sulfur fertilizer[41]	N/A	N/A	N/A	N/A
Urease Inhibitors	Inhibitor to reduce N loss.	Reduces N2O emissions by 1.67 kg per hectare,[68] reduces ammonia loss by 90%[69]	Reduces nitrogen loss[70,71]	N/A	Increases yield 8.9%-18.1% compared to urea-fertilizer[70]	N/A

Biodiversity

Table 4: Practices related to biodiversity and their identified environmental, economic, and social impacts.

Practice	Definition	Impact Categories				
		Biodiversity Impact	Weed and Pest Impact	Environmental Impact	Economic Impact	Social Impact
Crop Rotation	Rotating rice crops with other cash crops.	Increases species diversity[72]	Reduces pest pressure[72]	Improves soil fertility[36]	Reduces weed/pest control costs[72]	N/A
Integrated Livestock Rotation	Integration of livestock with rice cultivation, open crop-pasture.	Increases species diversity[73]	Reduces pest and weed pressure[47]	Improves soil fertility[73,74]	Increases yield up to 10%,[73] provides additional revenue[74]	Can reduce poverty and malnutrition[74]
Rice-Crawfish Rotation	Crawfish production in winter flooded fields. May include soybean rotation.	Increases species diversity[75]	Reduces pest and weed pressure[75]	Improves soil fertility[75]	Increases income, decreases rice yield[75]	N/A
Rice-Fish Integrated Farming System	Introduction of fish into paddy fields.	Increases species diversity[76]	Reduces pest and weed pressure[76,77,78]	Improves soil fertility,[78] may decrease GHG emissions[78,79]	Increases income[76,77,78,79,80]	Can create employment opportunities[77]
Riparian Buffers	An area adjacent to a body of water is managed differently from farmland, primarily to provide conservation benefits.	Increases species diversity[10]	N/A	Improves water quality[10]	N/A	N/A
Winter Flooding	Flooding rice fields post-harvest during winter fallow season.	Creates habitat for migratory birds[10]	Reduces winter weeds[10]	Improves water quality, increases soil retention[10]	N/A	N/A

Most Common Cropping Systems by Country

Cropping systems are dependent on a variety of factors, including whether the fields are rainfed or irrigated, if multicropping occurs, the degree of mechanization, and whether the rice is direct-seeded or transplanted. The dominant cropping system for rice in each region is listed in the table below.[81,82] It should be noted that other production systems may be used in the same location (e.g., it is still common for rice in Thailand and Vietnam to be transplanted).

Identifying the most common cropping system is integral to understanding the sustainability practices that are applicable within each top rice exporting country.

Table 5: Most Common Cropping System by Country and Subregion

Region	Irrigation method	Single or double crop	Mechanization level	Seeding method
USA	Irrigated	Single crop	High	Direct seeded
Brazil North	Rainfed	Single crop	High	Direct seeded
Brazil South	Irrigated	Single crop	High	Direct seeded
India Indo-Gangetic Plain	Irrigated	Single crop	Intermediate	Transplanted
India Southern	Irrigated	Double crop	Intermediate	Transplanted
Pakistan[82]	Rainfed	Single crop	Intermediate	Transplanted
Thailand	Irrigated	Double crop	Intermediate	Direct seeded
Uruguay	Irrigated	Single crop	High	Direct seeded
Vietnam	Irrigated	Double crop	Intermediate	Direct seeded

International Sustainability Practice Adoption

This section compares the adoption rates of common sustainability and conservation agriculture practices across the four sustainability focus areas for the U.S., Brazil, India, Pakistan, Thailand, Uruguay, and Vietnam.

The table identifies the practices with the highest environmental, social, and/or economic impact and their prevalence by country. In some instances, estimated adoption rates for each practice by region were unavailable. The adoption rates in the U.S. columns below are averages of all rice producing states, source data may be found in the Excel tracker titled *Rice Sustainability Research Practices*.

It should be noted that a lack of adoption or lack of applicability for a specific practice in a country may indicate that the practice is not appropriate for the region due to the level of mechanization, climate, cropping system, or other factors. Regionally specific practices make it difficult to directly compare sustainability practices from country to country.

All adoption rates are provided by the relevant regional experts mentioned previously in this report. When such data was unavailable, estimates were derived from peer-reviewed research.

Key:

Identified as a high impact sustainability practice	Practice affects 5 or more impact categories and/or there is a significant quantitative impact in a single category (50% or greater).
Identified as a medium impact sustainability practice	Practice affects 3-4 impact categories.
Identified as a low impact sustainability practice	Practice affects 0-2 impact categories.
Common adoption	Practice is implemented on over 50% of the rice area.
Moderate adoption	Practice is implemented on 16%-50% of the rice area.
Minimal adoption	Practice is implemented on 1%-15% of the rice area.
No adoption	Practice is not implemented on any rice acreage given available data but may still be appropriate for the region.
No estimate provided	Practice may be occurring, but estimates were not available from industry experts.
Not applicable (N/A)	Practice is likely not viable in the region. There was no evidence found through peer-reviewed literature and expert opinions indicating the practice is occurring within this region.

Land Use and Soil Conservation

Table 10: Global Land Use and Soil Conservation Practice Adoption

Practice	U.S.	Brazil	India	Pakistan	Thailand	Uruguay	Vietnam
Biochar Application	1%	1%	No estimate provided	No estimate provided	0%	N/A	No estimate provided
Conservation Tillage (including Zero-Till)	41%	54%	3%	No estimate provided	N/A	90%	N/A
Cover Crop	2%	1%	N/A	N/A	N/A	N/A	N/A
Organic Fertilizer Application	8%	N/A	No estimate provided	No estimate provided	1%	N/A	No estimate provided
Rice Straw Incorporation & Retention	76%	42%	No estimate provided	No estimate provided	4%	100%[d]	7%
Use of Certified Seeds	96%	No estimate provided	No estimate provided	No estimate provided	50%	95%	3%

Conservation tillage was identified as a high impact sustainability practice in the *Sustainability Practice Impacts* section above, but it may not be viable in regions such as India, Pakistan, Thailand, and Vietnam where rice is commonly transplanted. Rice producers in the U.S. and Uruguay may claim that the majority of the rice from those regions use conservation tillage, a practice that increases soil organic carbon, reduces CH_4 emissions from 21%-39%, reduces erosion, increases P and K levels in the soil, reduces water use by 20%-30%, and increases yield from 5%-17% when compared to full till.[13,16,17]

The majority of rice producers in the U.S. and Uruguay use certified seeds, a practice that increases income and productivity compared to seeds that are not third-party certified.[23] This practice provides a direct comparison between countries because it is viable in all regions.

[d] 100% of straw is untouched when pastures are planted following rice.

Rice producers in the U.S. and Uruguay may claim that the majority of the rice produced in those regions uses conservation tillage, a practice that increases soil organic carbon, reduces CH_4 emissions, reduces erosion, increases P and K levels in the soil, reduces water use, and increases yield when compared to full till.

Drilling no-till, Source: Dr. Steve Linscombe

Cover crops may not be viable in regions that use winter flooding as well as regions that double or triple crop, such as Southern India, Thailand, and Vietnam.[81]

Rice straw incorporation and retention was identified as a high impact sustainability practice and it is viable for most cropping systems allowing a more direct comparison of sustainability across the globe.[81] From the countries examined in this report, the majority of producers in the U.S. and Uruguay use rice straw incorporation and retention, a practice that increases soil organic carbon, improves soil health, increases water use efficiency, increases yield for the next crop when compared to straw removal and reduces GHG emissions by 35% and improves air quality when compared to straw burning.[25,26,30]

Rice straw incorporation, Source: Dr Steve Linscombe

The majority of producers in the U.S. and Uruguay use rice straw incorporation and retention, a practice that:
-Increases soil organic carbon, water use efficiency, and yield
-Improves soil health and air quality, and
-Reduces GHG emissions

Water Use and Quality

Table 11: Global Water Use and Quality Practice Adoption

Practice	U.S.	Brazil	India	Pakistan	Thailand	Uruguay	Vietnam
Computer-Aided Irrigation Designs	26%	No estimate provided	No estimate provided	No estimate provided	0%	N/A	No estimate provided
Direct Seeding	100%	No estimate provided[e]	28%	No estimate provided	75%	100%	14%[f]
Dry Seeding	78%	N/A	N/A	N/A	58%[39]	No estimate provided	N/A
Furrow Irrigation	16%	N/A	N/A	N/A	N/A	N/A	N/A
GNSS and Laser Land Leveling	77%	No estimate provided	No estimate provided	No estimate provided	10%[g]	No estimate provided	0%
Traditional Land Leveling	N/A	N/A	N/A	N/A	70%	0%	N/A
Multiple Inlet Irrigation	20%	N/A	N/A	N/A	N/A	N/A	N/A
Tailwater Recovery	8%	N/A	N/A	N/A	N/A	N/A	N/A
Water Seeding	19%	23%	N/A	N/A	N/A	N/A	N/A

Computer-aided irrigation designs, GNSS and laser land leveling, multiple inlet irrigation, and tailwater recovery each require a high level of mechanization and/or high initial capital investment. These practices may not be viable in developing countries and/or regions with lower levels of mechanization such as Northern Brazil, India, Pakistan, Thailand, and Vietnam.

All rice produced in the U.S. and Uruguay employs direct seeding, a technique that reduces water use from 12%-20%, reduces GHG emissions, reduces inputs costs, increases yield, and reduces labor over transplanting rice. [15,35,36,37,38] This practice allows for direct comparison across different countries because these values are calculated using a transplanted baseline scenario. It should be noted that Yuan et al. (2021) described the primary production system of Brazil, and Vietnam as direct seeded rice but this was not reflected in by expert opinions of Mr. Richard Bacha (Brazil) or Dr. Hung Van Nguyen (Vietnam). This practice represents a differentiation opportunity for U.S rice when competing with rice grown in India and Pakistan, regions that primarily grow transplanted rice as well as Thailand and Vietnam where transplanting is common.

[e] Expert opinion on this practice was not available, but Yuan et al. (2021) describes direct seeding as the most common production method in Brazil.
[f] This value is from the expert opinion of Dr. Hung Van Nguyen, Senior Scientist at the International Rice Research Institute. It differs from Yuan et al. (2021), which described direct seeding as the most common cropping system of Thailand.
[g] Adoption for laser land leveling only.

Dry seeding (direct dry seeding) was identified as a high impact sustainability practice that is occurring in the U.S. and Uruguay (although no qualitative data were available for dry seeding, the practice is common). Dry seeding can differentiate producers in the U.S. because it reduces CH_4 emissions up to 60% compared to water seeding.[40,41] This practice is also occurring Thailand, but it takes place mostly in rainfed regions, making a direct comparison more difficult.[39]

Dry seeding can differentiate producers in the U.S. because it reduces CH4 emissions up to 60% compared to water seeding.

Laser land leveling, Source: Dr. Steve Linscombe

The majority of rice produced in the U.S. is grown with GNSS or laser land leveling practices that reduce water use, improve water coverage, and increase yield.

The majority of rice produced in the U.S. is grown with GNSS or laser land leveling[h] practices that reduce water use, improve water coverage, and increase yield.[35,43,44,45] These technologies, while not common across other locations in this report, enables U.S. rice producers to use water saving technologies that are more efficient than traditional leveling techniques.

[h] There are differences between GNSS and laser land leveling (see *Sustainability Practice Impacts* section above), but the adoption metrics from industry experts combined the practices into a single adoption rate.

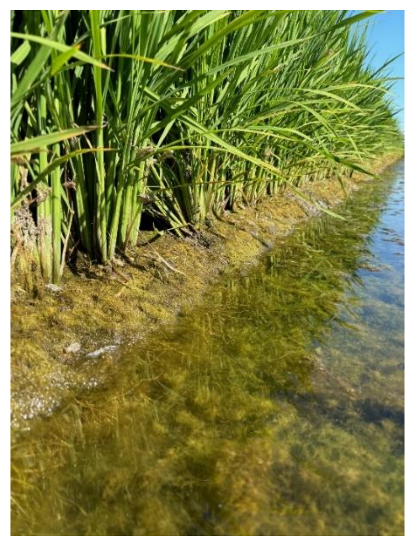
Energy Use and Air Quality

Table 12: Global Energy Use and Air Quality Practice Adoption

Practice	U.S.	Brazil	India	Pakistan	Thailand	Uruguay	Vietnam
4R Nutrient Management, Nitrogen Efficiency, Nutrient Management Plans	54%	N/A	No estimate provided	N/A	100%[i]	No estimate provided[j]	0%
Alternate Wetting and Drying	9%	No estimate provided	No estimate provided	No estimate provided	5%	0%	3%
Electric Irrigation System	37%	N/A	N/A	N/A	N/A	N/A	N/A
Leaf Color Charts	N/A	N/A	No estimate provided	No estimate provided	N/A	N/A	No estimate provided
Precise Fertilizer Application	13%	N/A	N/A	N/A	N/A	5%	No estimate provided
Sulfate Containing Fertilizer	57%	N/A	N/A	N/A	N/A	N/A	N/A
Urease Inhibitors	73%	0%	No estimate provided	No estimate provided	0%	N/A	No estimate provided

Alternate wetting and drying was identified as a high impact sustainability practice that is viable across different regions and therefore can be compared across top rice exporting countries. Although alternate wetting and drying has low adoption in the U.S., producer employing this practice may claim it reduces GHG emissions up to 70% and reduces water use 15%-30%.[10,12,15,22,23,27,35, 54,55,56,57,58,59,60,61,62,63,64]

Although alternate wetting and drying has low adoption in the U.S., producer employing this practice may claim it reduces GHG emissions up to 70% and reduces water use 15%-30%.



Alternate wetting and drying, Source: Dr Steve Linscombe

Electric irrigation systems are not viable in rainfed production systems such as Northern Brazil and Pakistan. While there are U.S. states whose producers use electric irrigation systems, those electricity grids are primarily powered by fossil fuels.[85]

[i] Adoption of nutrient management plans.

[j] Unable to obtain adoption as a percentage of rice hectares. However, Mr. Gonzalo Zorrilla de San Martin, independent researcher and previous Director of National Rice Research Program at the Instituto Nacional de Investigacion Agropecuaria, stated that nutrient management plans are common in Uruguay.

Leaf color charts are not viable in regions of higher industrialization such as the U.S., Brazil, and Uruguay, although their use has similar impacts to 4R nutrient management plans, nitrogen efficiency, and nutrient management plans making these practices comparable across regions.

The majority of rice produced in the U.S. and Thailand employs 4R, nitrogen efficiency, or nutrient management plans resulting in a reduction in emissions, improved nutrient use efficiency, increased yield, and reduced input costs when compared to rice grown without a nutrient management plan. [10,11,23,46,47,52,53]

In the U.S., the majority of the rice is produced with sulfate-containing fertilizers[k] that reduce GHG emissions compared to non-sulfate fertilizers.[41] This is a technology that is not being practiced by other top rice producing countries in this report.

In the U.S., the majority of the rice is produced with sulfate-containing fertilizers that reduce GHG emissions compared to non-sulfate fertilizers.

The majority of the rice grown in the U.S. uses urease inhibitors, reducing N_2O emissions, ammonia loss, and nitrogen loss, and increasing yield 8.9-18.1% over fertilizer applied without urease inhibitors.

The majority of the rice grown in the U.S. uses urease inhibitors, a high impact sustainability practice that reduces N_2O emissions by 1.67 kg per hectare, reduces ammonia loss by 90%, reduces nitrogen loss, and increases yield 8.9%-18.1% over urea fertilizer applied without urease inhibitors.[68,69,70,71] This is a technology that is not being practiced by other top rice producing countries in this report, but it should also be noted that urease inhibitors may not be viable in countries without established supply chains.

These efficient fertilizer application techniques and technologies allow U.S. producers to differentiate their rice from global producers in this report due to the positive environmental and economic outcomes they provide.

[k] According to Dr. Sam Rustom, sulfate containing fertilizer are “common” in Texas rice production, but no quantitative value was provided.

Biodiversity

Table 13: Global Biodiversity Practice Adoption

Practice	U.S.	Brazil	India	Pakistan	Thailand	Uruguay	Vietnam
Crop Rotation	70%	42%	45%	N/A	N/A	20%	N/A
Integrated Livestock Rotation	N/A	42%	No estimate provided	N/A	N/A	95%	N/A
Rice-Crawfish Rotation	48%[l]	N/A	N/A	N/A	N/A	N/A	N/A
Rice-Fish Integrated Farming System	N/A	N/A	No estimate provided	No estimate provided	1%	N/A	No estimate provided
Riparian Buffers	1%	N/A	N/A	N/A	N/A	N/A	N/A
Winter Flooding	40%	N/A	N/A	N/A	N/A	N/A	N/A

In the U.S., the majority of rice produced is under a crop rotation which increases species diversity, reduces pest pressure, improves soil fertility, and reduces weed/pest control costs compared to rice. planted continuously on the same field.

Crop rotation and winter flooding may not be viable in regions such as Southern India, Thailand, or Vietnam where double or triple cropping more common. The viability of these practices in specific regions and production systems makes it difficult to compare biodiversity practices across the top rice producing countries included in this report.

U.S. producers may differentiate themselves from other top rice exporting countries in this report through crop rotations, rice-crawfish rotation farming systems, and winter flooding, conveying that they adopted biodiversity practices that work within their growing regions.

In many parts of the U.S., the majority of rice is grown using winter flooding, which creates habitat for migratory birds, reduces winter weeds, improves water quality, and increases soil retention compared to fields that are not flooded in the winter.

The majority of rice produced in the U.S. is under a crop rotation which increases species diversity, reduces pest pressure, improves soil fertility, and reduces weed/pest control costs compared to rice planted continuously on the same field.[36,72]

[l] Rice-crawfish rotation in Louisiana and Texas only.

Winter flooding[m], a practice used throughout the U.S., creates habitat for migratory birds, reduces winter weeds, improves water quality, and increases soil retention compared to fields that are not flooded in the winter.

In certain areas of the U.S. rice fields are flooded in the winter is used for crawfish production. This practice increases species diversity, reduces pest and weed pressure, improves soil fertility, and increases income.[75]

Integrated livestock rotation may be a biodiversity-related practice that U.S. producers could adopt because it is already occurring in highly mechanized rice producing countries (Brazil and Uruguay). Additionally, fish production in winter flooded fields may be a biodiversity practice option for producers. Research from UC Davis suggests that winter flooded fields can support migratory birds and other wildlife, while adding an additional revenue stream.[86]

Geese in rice field, Source: Dr. Steve Linscombe

[m] Winter flooding is "common" in Texas rice production, according to Dr. Sam Rustom, but no quantitative adoption value was provided.

Sustainability Metrics by Country

The table below outlines the available sustainability-related metrics of rice produced in each top rice exporting country. [81] This section uses metrics that are normalized by 1 Mg of rice, when available, similar to the analysis done in a life cycle assessment using a functional unit. There are sections below the table that reference data on a per hectare basis, when available, for additional context.

Sustainability Metrics Key

	High sustainability impact
	Medium-high sustainability impact
	Medium-low sustainability impact
	Low sustainability impact
	Not available (N/A)

The water stress analysis was conducted utilizing the WRI Aqueduct Water Risk Atlas tool. The rice growing regions input into the tool were taken from the crop production maps published by the USDA.[87] The analysis measured the ratio of total water demand to available renewable surface and groundwater supplies. Water stress levels range from low to extremely high, with extremely high stress indicating that a country is using at least 80% of its available water supply.[87]

Water Stress Key

	Arid and low water use (N/A)
	Low water stress (<10%)
	Low-medium water stress (10-20%)
	Medium-high water stress (20-40%)
	High water stress (40-80%)
	Extremely high water stress (>80%)

Table 14: Sustainability Metrics by Country

	United States	Brazil		India		Pakistan	Thailand	Uruguay	Vietnam	
		Northern	Southern	Indo-Gangetic Plain	Southern				Double Crop	Triple Crop
Human labor (h/Mg rice)[81]	1	25	7	141	170	N/A	30	4	31	87
Yield (Mg/ha)[81]	8.7	3.5	8.1	4.5	2.8 first 4.3 second	3.8[88]	4.8 first 4.6 second	8.9	4.2 first 7.1 second	6.9 first 5.3 second 4.1 third
Yield (% of actual to potential)[81]	69.3%	38.3%	54.7%	46.1%	41.1%	N/A	50.3%	61.4%	56.4%	57.2%
GHG emissions (Mg CO2e/ Mg rice)[81]	0.6	0.3	0.8	0.8	1.2	N/A	0.9	0.5	0.9	0.7
Energy use (GJ/ha)[81]	23.4	20.8	10.9	14.3	14.4	N/A	15.2	16.4	19.1	17.2
Nitrogen input (kg/Mg rice)[81]	12.0	1.5	5.1	22.1	35.8	N/A	10.7	0.6	7.2	1.1
Pesticide use (applications /Mg rice)[81]	0.8	0.9	0.9	0.9	1.4	N/A	1.1	0.4	1.6	1.3
Water use (mm/Mg rice)[81]	147.3	303	173	233	364	N/A	263	146	191	148
Water Stress Analysis[87]	Low Stress	Low stress	Low stress	Extremely high stress	Extremely high stress	High stress	Extremely high stress	Low stress	Low-medium stress	Low-medium stress

Ratio of Actual to Potential Yield

Rice produced in the U.S. has the highest ratio of actual yield to potential yield[n] of any top rice exporting country in this report. This represents a differentiation opportunity to communicate the efficient production systems that have been developed for these specific regions. This efficiency is due to a high level of mechanization and sophisticated crop management techniques, as well as access to ag inputs and extension services.[81]

Rice produced in the U.S. has the highest ratio of actual yield to potential yield of countries researched, largely due to a high level of mechanization and sophisticated crop management techniques, as well as access to ag inputs and extension services.

Yield

Rice produced in the U.S. has the second highest yield of any single cropping system when compared to other top exporting countries in this report. The efficient production techniques used in the U.S. optimize the amount of energy, nutrients, and other inputs used and reduce the loss of natural habits, conserving biodiversity. [81]

Labor

Rice produced in the U.S. uses the lowest human labor input of any region in this report, making the most efficient use of human labor. This is due to large field sizes, high levels of mechanization, and direct seeding.[81]

GHG Emissions

Rice produced in the U.S. has the third lowest GHG emissions of the countries in this report, representing a differentiation opportunity in the export market. The U.S., however, has higher GHG emission on a per hectare basis due to higher inputs and high level of mechanization.[81]

Energy

Rice production in the U.S. is among the most energy intensive compared to other top rice exporting countries in this report, representing an opportunity for improvement through adopting new practices and technologies that reduce energy use and/or use renewable energy sources such as electric irrigation, computer-aided irrigation designs, irrigation flow meters, multiple inlet irrigation, and reduced or zero tillage.[81]

Nitrogen

Nitrogen inputs in U.S. rice production are among the highest of the rice exporting countries included in this report. Uruguay has the lowest nitrogen input of any in this report yet has a similar level of mechanization, yield, and percentage of max yield compared to U.S. production, suggesting there may be an opportunity for U.S. producers to increase their nitrogen use-efficiency while maintaining yield.[81] It should also be noted that U.S. rice producers widely employ urease inhibitors that improve the uptake of urea fertilizer.

[n] "Yield potential is determined by solar radiation, temperature, water supply, cultivar traits, and in the case of water-limited crops, also by precipitation and soil properties and landscape characteristics influencing water balance."[81]

Pesticide Applications

The U.S. has the second lowest rate of pesticide application, representing an opportunity to differentiate from other top rice exporting countries in this report. Reducing pesticide use can have positive impacts on biodiversity, water quality, air quality, and human health.[89] On a per hectare basis, however, rice from Uruguay and Northern Brazil has the lowest number of applications, followed by India, Thailand, and the U.S.[81]

Water Use and Water Stress

The majority of rice produced in the U.S. uses the second lowest amount of water compared to the other top rice exporting countries in this report, and it is produced in areas with low water stress. This represents an opportunity to communicate the efficient use of natural resources and the low strain on water resources of rice grown in this region.[81,87]

Summary of Differentiation Opportunities

U.S. rice growers may be able to differentiate their product in the global market by conveying the impacts of sustainability practices that are common and appropriate for their region and cropping system as well as average metrics for rice produced in their regions.

Table 15: Summary of Differentiation Opportunities for U.S. Rice

Land Use and Soil Conservation	Water Use and Quality
Conservation tillage: (compared to full till) • Increases soil organic carbon • Reduces CH_4 emissions • Reduces erosion • Increases P and K levels in the soil • Reduces water use • Increases yield **Rice straw incorporation/retention:** (compared to straw removal) • Increases soil organic carbon • Reduces GHG emissions compared to burning • Reduces erosion • Improves soil health • Increases water use efficiency • Increases yield **Certified seeds:** (compared to seeds that are not third party certified) • Increases yield and net income **Percentage of actual yield to potential:** • Highest actual yield to potential yield ratio **Yield:** • Highest yield of any single crop system (except Uruguay)	**Direct Seeding:** (compared to transplanting) • Reduces water use from 12%-20% • Reduces GHG emissions • Reduces inputs and labor costs • Increases yield **Dry seeding:** (compared to water seeding) • Reduces CH_4 emissions up to 60% • Reduces water use **GNSS and/or laser land leveling:** (compared to traditional leveling techniques) • Reduces water use • Improves water coverage • Increases yield • **Water use:** U.S. hybrid rice uses the least amount of water of locations in this report (except Uruguay) **Water stress metrics:** • Low water stress region

Energy Use and Air Quality	Biodiversity
4R, nitrogen efficiency, nutrient management plans: (compared to not using an NMP) • Reduces GHG emissions • Improves nutrient use efficiency • Increases yield • Reduces input costs **Sulfate containing fertilizers:** (compared to non-sulfate fertilizer application) • Reduces GHG emissions **Urease inhibitors:** (compared to N fertilizer application without urease inhibitors) • Reduces N_2O emissions by 1.67 kg/ha • Reduces ammonia loss by 90% • Reduces nitrogen loss • Increases yield 8.9-18.1% **GHG Emissions:** • Lower emissions compared to others in this report (except Northern Brazil and Uruguay)	**Crop rotation:** (compared to continuous rice) • Increases species diversity • Reduces pest pressure • Improves soil fertility • Reduces weed/pest control costs **Rice-crawfish rotation:** (compared to continuous rice) • Increases species diversity • Reduces pest and weed pressure • Improves soil fertility • Increases income but can decrease rice yield **Winter flooding:** (compared to no winter flooding) • Creates habitat for migratory birds • Reduces winter weeds • Improves water quality • Increases soil retention

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Appendix A: Research Gaps and Additional Considerations

This section includes gaps in the research and expert opinions as well as gaps and/or resources that would enable U.S. rice producers to strengthen the claims of sustainability practices.

Adoption Potentials

There is limited practice adoption data from Pakistan, as noted by Mr. Shahrukh Khan, National Coordinator for Pakistan at Helvetas Organization, Dr. Jam Nazir Ahmed, Professor at the University of Agriculture Faisalabad, and Dr. Aziz Ahmad, Assistant Professor at the University of Sindh.

There is also limited practice adoption data from Texas, as noted by Dr. Sam Rustom, Assistant Professor at Texas A&M University, although in some instances he was able to provide qualitative estimates.

Opportunities for Research

There is not a set of standardized metrics to measure the sustainability outcomes of rice production globally. A list of metrics was developed for this report, housed in the Excel tracker titled *Rice Sustainability Research Practices*, that could be used to quantify the sustainability-related impacts of rice grown in specific regions. Many of these data points are not available globally. This represents an opportunity for U.S. rice growers to develop a program that tracks sustainability metrics to differentiate their product in a global market.

There is a lack of quantitative data on the impacts of 4R, nitrogen efficiency, nutrient management plans, and urease inhibitors; but qualitative data was available. This is an opportunity to draw distinction between U.S. and other top rice exporting countries because these practices are widespread in California, Mississippi, and Missouri. Potential research could focus on specific metrics, such as reductions in GHG emissions, eutrophication, lower input costs, and increases in yield, as well as documenting the instances of these practices in other U.S. rice growing regions where they are most likely already occurring.

GNSS and laser land leveling are widespread practices in the U.S., but quantitative data on their environmental impacts was not readily available. This represents another research opportunity to communicate the work U.S. rice producers are already doing with tangible metrics.

Missouri is the only location where an expert opinion was received for an estimate of crop rotation. This practice may be occurring in other Southern states, but it is not well documented. This represents an opportunity to research the occurrence as well as the tangible outcomes of the practice.

There is a lack of research on the sustainability impacts of the rice crawfish rotation in Louisiana. Improving this body of research would allow rice producers in Louisiana to differentiate themselves further based on this practice.

There is a lack of peer reviewed research found for sustainability and conservation agriculture practices in rice production in Uruguay and Pakistan.

Sustainability Best Management Practices for U.S. Rice Producers

To further differentiate U.S. rice producers in the sustainability landscape, USA Rice may consider developing a set of best management practices to encourage sustainable rice production. This is already implemented in other countries (Thailand's Cost Reduction Operating Principles, Vietnam's One Must Do, Five Reductions, Vietnam's One-Million Hectares of High-Quality and Low-Emission Rice by 2030) to help producers maintain profitability and enter new markets.

Appendix B: Regulatory Landscape- Sustainability

This appendix provides an overview of the regulatory landscape as it relates to rice and sustainability.

Sustainability Regulations in the U.S.

The U.S. does not have specific "sustainability" regulations but rather has numerous laws and regulations that relate to the four key sustainability focus areas outlined by USA Rice.

1. Land use and soil conservation
2. Water use and quality
3. Energy use and quality
4. Biodiversity

Key regulations in the U.S. related to **land use and soil conservation** include:

- **Soil and Water Resources Conservation Act (RCA)**: This act provides the USDA with broad strategic assessment and planning authority for the conservation, protection, and enhancement of soil, water, and related natural resources.[1]
- **Soil Conservation Act:** This act led to the creation of the Soil Conservation Service (now known as the Natural Resources Conservation Service or NRCS) within the USDA. A primary goal of the act was to control soil erosion by implementing measures to prevent soil degradation and loss.[2]

Key regulations in the U.S. related to **water use and quality** include:

- **Clean Water Act (CWA):** This act regulates the discharge of pollutants into U.S. waters and sets quality standards for surface waters, impacting how rice farmers manage water use and runoff.[3]
- **Soil and Water Resources Conservation Act (RCA)**: See section above as it relates to water conservation.
- **State-Level Water Rights and Regulations**: Individual states have their own water laws and regulations that govern water allocation, use rights, and intra-state water transfers.[4]

Key regulations in the U.S. related to **energy use and air quality** include:

- **Energy Policy Act**: This act promotes energy efficiency and renewable energy sources, impacting agricultural practices and encouraging farmers to adopt energy-saving technologies.[5]
- **Clean Air Act (CAA)**: The Clean Air Act regulates air emissions from stationary and mobile sources, impacting how rice farmers manage energy use to reduce air pollution.[6]
- **California Senate Bill 253 and 261:** California recently passed two bills that would require U.S. companies doing business in California to disclose their greenhouse gas emissions (SB 253) and their climate-related financial risk (SB 261) if their annual gross income is above certain thresholds (over $1B for SB 253 and over $500M for SB 261). For very large-scale rice producers, they may have new reporting requirements for their GHG emissions and or their climate-related financial risks. The California Air Resources Board is still finalizing their rulemaking, and regulations are anticipated around July 2025 at the earliest.[7]

Key regulations in the U.S. related to **biodiversity** include:

- **Endangered Species Act (ESA)**: This act protects threatened and endangered species and their habitats, which can affect land use and farming practices for rice farmers.[8]
- **Food Security Act (aka the Farm Bill)**: Includes various conservation programs, such as the Conservation Stewardship Program (CSP) and Environmental Quality Incentives Program (EQIP), which promote practices that enhance biodiversity.[10]
- **Migratory Bird Treaty Act (MBTA)**: Protects migratory bird species, which can influence farming practices to ensure habitats are preserved[11].

Further information can be found in the U.S. Sustainability Alliance's recently developed resource "U.S. Sustainable Agriculture: Laws, Policies, and Programs," featuring key events and laws and regulations by focus area.[11]

Sustainability Regulations from Top Importers of U.S. Rice

The countries in the table to the right were the top importers of U.S. rice in 2024, according to USDA's Foreign Agricultural Service (FAS).[12] This section explores various laws and regulations that relate to sustainability expectations within top U.S. rice importing countries.

Market	Total Value (USD)
Mexico	$442.91 Million
Japan	$295.66 Million
Haiti	$267.69 Million
South Korea	$198.79 Million
Canada	$175.31 Million
Saudi Arabia	$128.42 Million
Iraq	$85.5 Million
Colombia	$83.44 Million
Honduras	$83.19 Million
Venezuela	$81.86 Million

World Trade Organization (WTO)

At a high level, the WTO provisions theoretically permit sustainability regulations, but they set criteria to ensure these regulations do not unfairly discriminate against exporters from other countries. Although there is no specific agreement addressing environmental issues, WTO rules allow members to implement trade-related measures to protect the environment, provided certain conditions are met to prevent the misuse of these measures for protectionist purposes.[13]

Because of this, top U.S. rice importing countries often lack trade-related regulations specific to sustainability, as this could unintentionally lead to discriminatory policies that are prohibited by the WTO. A few of these countries, however, have developed regulations, trade agreements, and sustainability disclosures that relate to environmental impacts and may indirectly impact imported rice from the U.S.

Japan's MIDORI Act

The **MIDORI Act** in Japan, developed by the Ministry of Agriculture, Forestry, and Fisheries (MAFF), was enacted to facilitate the implementation of the **MIDORI Strategy for Sustainable Food Systems**. The MIDORI Act aims to promote sustainable agricultural practices and enhance the sustainability of food systems in Japan. Notably, one of the key performance indicators of the MIDORI Act is to achieve 100% sustainable sourcing of import materials by 2030, particularly for food processors in Japan. Japan has not yet publicly released how it intends to meet this performance indicator.[14]

For domestic rice growers in Japan, MAFF has developed a Visualization Label that communicates to consumers "the degree of farmer's efforts to reduce environmental burden with the number of stars on the label, by comparing them to average farming practices in the region." [64] Rice growers were part of the initial pilot in 2022. MAFF also provides a calculation tool for farmers and their stakeholders to calculate the GHG emissions or soil carbon sequestration occurring on farm. Biodiversity conservation efforts are included as an evaluation target for rice.

In 2022 and 2023, early feedback on the Visualization Label has shown that "95% of survey respondents had a favorable impression of such stores that sell agricultural products with the Visualization Label." [15]

With the MIDORI Act's key performance indicator to advance sustainable sourcing of import materials, as well as the roll out of sustainability labeling for domestic agricultural products, including rice, Japan is paving the way to enable more sustainability insights to be obtained within its food sector. [15]

United States-Korea Free Trade Agreement (KORUS FTA)

Within the KORUS FTA Chapter 20 on the environment, the agreement defers to existing environmental laws and regulations within each country by stating that "recognizing the right of each Party to establish its own levels of environmental protection and its own environmental development priorities, and to adopt or modify accordingly its environmental laws and policies, each Party shall strive to ensure that those laws and policies provide for and encourage high levels of environmental protection and shall strive to continue to improve its respective levels of environmental protection, including through such environmental laws and policies."[16]

The KORUS FTA also looks to voluntary and incentive-based programs to further advance environmental protection. It states that "the Parties recognize that flexible, voluntary, and incentive-based mechanisms can contribute to the achievement and maintenance of high levels of environmental protection, complementing the procedures set out in Article 20.4."[16]

South Korea's Eco-Friendly Agriculture Promotion Act

South Korea's Act on the Promotion of Environment-Friendly Agriculture and Fisheries and the Management of and Support for Organic Foods, Etc., also known as the Eco-friendly Agriculture Promotion Act, aims to foster sustainable practices in agriculture and fisheries while safeguarding both producers and consumers. The act intends to promote sustainable agriculture and fisheries by emphasizing environmental conservation and pollution reduction, encouraging the adoption of eco-friendly practices that minimize the use of synthetic chemicals, establishing a system for managing and certifying eco-friendly and organic products, and building consumer confidence in the safety of agricultural and fishery products.[17]

To meet the requirements of this act, the U.S. and South Korea have an organic equivalence arrangement where both countries recognize each other's certification systems for processed foods. Therefore, USDA organic certification generally qualifies under the South Korea Eco-Friendly Agriculture Promotion Act.[17]

United States-Mexico-Canada Agreement (USMCA)

Similar to the approach taken in the KORUS FTA of focusing on existing environmental protection laws in each respective country, the USMCA Environmental Chapter, Article 24.1 states that the objective of the chapter is "to promote mutually supportive trade and environmental policies and practices; promote high levels of environmental protection and effective enforcement of environmental laws; and enhance the capacities of the Parties to address trade-related environmental issues, including through cooperation, in the furtherance of sustainable development." [18]

Furthermore, in Article 24.15 on Trade and Biodiversity, it includes that "each Party shall promote and encourage the conservation and sustainable use of biological diversity, in accordance with its law or policy." It also provides that "Each Party shall make publicly available information about its programs and activities, including cooperative programs, related to the conservation and sustainable use of biological diversity." [18]

International Sustainability Standards Board and Sustainability Disclosure Adoption

When considering sustainability regulations that exist in rice importing countries, it is important to watch for the implementation of the International Sustainability Standards Board sustainability disclosure requirements. Of the top U.S. rice importing countries identified by USDA, Mexico, Japan, South Korea, and Canada are all in various stages of developing sustainability disclosure requirements within their national jurisdictions. These requirements, however, are typically not being implemented on rice exporters, but rather large domestic companies and publicly traded companies within the importing countries. Though these sustainability disclosure requirements are not being imposed on rice exporters directly, it is important to be aware of their scope, reporting requirements, and timelines as companies that are required to report may request information from their value chain.

What is the ISSB?

The International Sustainability Standards Board (ISSB) is a standard-setting body established by the IFRS Foundation in 2021. Its primary goal is to develop and implement global sustainability-related financial reporting standards that meet the needs of investors and the financial markets. IFRS sustainability disclosure standards include IFRS S1, which focuses on general sustainability disclosures related to financial risks and opportunities, and IFRS S2, which focuses on climate-related risks and opportunities, including greenhouse gas emissions disclosures. National jurisdictions may adopt these disclosure standards as they are written or adapt them to meet the needs of their jurisdiction. The following sections provide a brief overview of the status of ISSB/IFRS sustainability disclosure standard adoption for top U.S. rice importing countries.

Mexico

The Consejo Mexicano de Normas de Información Financiera y Sostenibilidad (CINIF) issued its first sustainability standards in May 2024, aligning with the ISSB's IFRS S1 and IFRS S2.

The standards apply to companies listed on Mexican stock markets (including both domestic and foreign issuers) and private companies, including subsidiaries of foreign multinationals that report their financial statements under Mexican Financial Reporting Standards.

In 2025, private companies must include sustainability information in their financial statement footnotes. In 2026, issuers on Mexican stock markets must submit separate annual sustainability reports in accordance with IFRS S2.[19]

Japan

The Sustainability Standards Board of Japan (SSBJ) issued its inaugural sustainability disclosure standards on March 5, 2025. These standards align closely with the ISSB's IFRS S1 and IFRS S2 to enable international comparability.

The SSBJ standards apply to all companies listed on Japan's Prime Market, which includes around 1,635 companies as of March 2025 and large companies with significant turnover and assets.[20]

2025-2026 is the voluntary adoption phase for early adopters, and from 2027 onward, mandatory reporting begins for companies listed on Japan's Prime Market.

South Korea

The Korea Sustainability Standards Board (KSSB) has published draft sustainability disclosure standards, which align closely with the ISSB's IFRS S1 and IFRS S2.

The standards apply to all companies listed on the Korea Exchange (including those on the KOSPI and KOSDAQ markets) and large companies with significant turnover and assets.

In 2026, climate-related disclosures become mandatory for listed companies. In 2027, large companies are required to fully implement the sustainability-related disclosures.[21]

Canada

The Canadian Sustainability Standards Board (CSSB) published its finalized Canadian Sustainability Disclosure Standards (CSDS) in December 2024. These standards, CSDS 1 and CSDS 2, largely correspond to IFRS S1 and IFRS S2.

The standards apply to companies listed on Canadian stock exchanges and large companies with significant turnover and assets in 2025, voluntary adoption phase begins for early adopters and in 2026 mandatory reporting begins for companies listed on Canadian stock exchanges.[22]

Sustainability Regulations within Rice Exporting Countries

Similar to the US, top rice exporting countries do not typically have "sustainability" regulations but do have several environmental laws and regulations that impact their agriculture industries. This document reviewed laws and regulations within four top rice exporting countries – Thailand, Pakistan, Brazil, and India[o] – that relate to the four key sustainability focus areas outlined by USA Rice.

1. Land use and soil conservation
2. Water use and quality
3. Energy use and quality
4. Biodiversity

Research has been compiled and summarized by rice exporting country and focus area.

Thailand

Key regulations in Thailand related to **land use and soil conservation** include:

- **Land Development Act B.E. 2551 (2008)**: This act includes provisions for soil and water conservation, aiming to prevent soil erosion, maintain soil fertility, and improve land use efficiency.[23]
- **Agricultural Land Reform Act B.E. 2518 (1975)**: This act stipulates what crops can be grown and how land can be used.[24]

Key regulations in Thailand related to **water use and quality** include:

- **Environmental Quality Act B.E. 2535:** This act is a foundational piece of environmental legislation in Thailand, covering a wide range of pollution issues including water pollution, air pollution, and waste management. While not explicitly focused on rice production, its provisions impact rice farming practices through regulations related to water quality, pesticide use, and pollution control.[25]
- **Water Resources Act B.E. 2561 (2018)**: This act governs the management and use of water resources in Thailand. It includes provisions for water usage rates, charging, and exemptions for different types of water use. It also includes provisions to ensure water quality standards are met.[26]
- **Fertilizer Act B.E. 2518 (1975)**, amended by the **Fertilizer Act (No. 2) B.E. 2550**: This act regulates the production, import, and use of fertilizers in Thailand, including provisions to protect water quality.[27]

Key regulations in Thailand related to **energy use and air quality** include:

- **Environmental Quality Act B.E. 2535:** See "water use and quality" section.

[o]Vietnam and Uruguay were excluded from the research at the request of USA Rice.

- **National Greenhouse Gas Reduction Target**: As part of the Paris Agreement, Thailand's nationally determined contribution (NDC) is to reduce GHG emissions by 30-40% from a business-as-usual (BAU) scenario by 2030. Thailand also has long-term goals GHG reduction goals, including carbon neutrality by 2050 and net-zero emissions by 2065[55]. Rice production is among the sectors where Thailand is targeting emission reductions to achieve its goal of carbon neutrality by 2050. The Agriculture and Cooperatives Ministry is promoting low-carbon rice cultivation to cut greenhouse gas (GHG) emissions, tackle global warming and boost competitiveness in the global market.[28]
- **Proposed Regulations to Watch in Thailand: Thailand's Draft Climate Change Act:** In November 2024, Thailand's Ministry of Natural Resources and Environment (MNRE) launched a public hearing on its draft Climate Change Act following revisions made after an earlier hearing on a previous draft of the act. The revised version introduced the Carbon Border Adjustment Mechanism (CBAM), modeled after the EU's system. The new draft also updated the Emissions Trading Scheme (ETS) and enhances carbon-tax provisions. These initiatives aim to minimize carbon leakage, promote fair competition for domestic industries, and encourage lower greenhouse gas (GHG) emissions.[29]
    - **Emission Trading Scheme (ETS)**: This is a market-based approach where a cap is set on the total amount of greenhouse gases that can be emitted by covered entities. Companies receive or buy emission allowances, which they can trade with others. If a company emits less than its allowance, it can sell the excess; if it emits more, it must buy additional allowances. If the ETS goes into effect and includes Thai rice farmers, those rice farmers may face increased costs and increased competition from rice producers in countries with less strict carbon regulations.
    - **Carbon Tax**: This is a direct tax on the carbon content of fossil fuels. It imposes a fee on the production, distribution, or use of fossil fuels based on their carbon content. The tax incentivizes businesses and consumers to reduce their carbon footprint by making carbon-intensive activities more expensive. On January 21, 2025, the Thai Cabinet approved a draft Ministerial Regulation proposed by the Ministry of Finance (MoF). Thailand's carbon tax on fuel does not increase the price of fuel for rice farmers. The tax, set at 200 baht per ton of carbon emissions, is incorporated into the existing oil tax structure without affecting the cost of oil products.[30]

Key regulations in Thailand related to **biodiversity** include:

- **Master Plan for Integrated Biodiversity Management B.E. 2558 – 2564 (2015-2021):** This plan outlines strategies to conserve biodiversity, including measures specific to agricultural practices. This includes biodiversity-related international obligations Thailand are parties to, existing and ongoing international biodiversity-related obligations and agreements, and Thailand's policies and development directions.[31]

Pakistan

Key regulations in Pakistan related to **land use and soil conservation** include:

- **Punjab Rice (Restrictions on Cultivation) Ordinance, 1959**: This ordinance regulates the cultivation of rice in Punjab to prevent waterlogging, salinity, and land degradation. It allows the Board of Revenue to impose restrictions on rice cultivation in specified areas.[32]

Key regulations in Pakistan related to **water use and quality** include:

- **West Pakistan Rice (Restrictions on Cultivation) Ordinance, 1959:** This law bans rice cultivation in specific areas of Sindh province, Pakistan. This ordinance, enacted in 1959, allows the Board of Revenue to prohibit or impose restrictions on rice cultivation in specific areas. The Sindh government has been actively enforcing this ban in 10 districts on the left bank of the Indus River, typically announced at the end of April or early May. The ban is aimed at limiting waterlogging, salinity, and drought-like conditions caused by rice farming.[33]

- **National Water Policy (NWP) 2018**: This policy provides guidelines for sustainable water management, including agricultural water use. It aims to balance water demand and supply, promote conservation, and minimize wastage.[34]

Key regulations in Pakistan related to **energy use and air quality** include:

- **National Greenhouse Gas Reduction Target**: As part of the Paris Agreement, Pakistan's nationally determined contribution (NDC) is to reduce emissions by 50% by 2030, with 15% of the reduction coming from domestic resources and the remaining 35% contingent on international support.[4].
- **Alternative and Renewable Energy Policy (AREP) 2019**: The policy aims to increase the share of renewable energy in Pakistan's energy mix to 30% by 2030. This includes solar, wind, biomass, and small hydropower projects[24].
- **Pakistan Climate Change Act, 2017**: This act establishes the Pakistan Climate Change Council and the Pakistan Climate Change Authority, which are responsible for developing and implementing policies to mitigate climate change, including reducing greenhouse gas emissions[59].
- **Punjab Smog Policy (2017):** This law poses a complete ban on open burning of rice stubble and requires disposal of crop residue in an environmentally friendly manner.[35]

Key regulations in Pakistan related to **biodiversity** include:

- **National Biodiversity Strategy and Action Plan (NBSAP)**: This plan, covering 2017-2030, outlines strategies to conserve biodiversity, promote sustainable use of natural resources, and integrate biodiversity considerations into agricultural practices. It includes measures to enhance sustainable agriculture, conserve pollinators, and manage soil biodiversity.[36]
- **Provincial Wildlife Acts:** Each province in Pakistan has its own wildlife protection laws, such as the Punjab Wildlife Act, Sindh Wildlife Protection Ordinance, and Balochistan Wildlife Protection Act. These laws regulate activities that could harm wildlife and their habitats.[37]

Brazil

Key regulations in Brazil related to **land use and soil conservation** include:

- **Forest Code (Código Florestal):** This is one of the most significant pieces of environmental legislation in Brazil. It requires rural landowners to preserve a portion of their land as native vegetation. The amount varies by biome: 20% in most areas, 35% in the Cerrado, and 80% in the Amazon. This regulation affects how much land can be used for rice farming and other agricultural activities.[38]
- **Agroecological Zoning (ZAE):** Brazil uses agricultural zoning to manage land use. This includes guidelines on where specific crops, like rice, can be grown to minimize environmental impact.[39]

Key regulations in Brazil related to **water use and quality** include:

- **National Water Resources Policy (Law No. 9,433/1997)**: This policy establishes guidelines for the sustainable use of water resources and includes requirements for water use permits and the implementation of water charges to promote efficient use. It also contains measures to protect water quality.[40]

- **National Irrigation Policy (Law No. 12,787/2013):** This law promotes efficient irrigation practices and the sustainable use of water in agriculture. It also encourages the adoption of modern irrigation techniques to reduce water consumption and improve crop yields.[41]
- **Forest Code (Código Florestal): Also included as a land use regulation**, the Forest Code includes provisions for protecting water bodies and maintaining riparian buffers. These regulations help prevent water pollution and ensure the sustainable use of water resources.[42]
- **Law No. 7,802/1989**: This law covers all aspects of pesticide management, including production, transportation, storage, use, and disposal of residues and packaging.[43]

Key regulations in Brazil related to **energy use and air quality** include:

- **National Greenhouse Gas Reduction Target**: As part of the Paris Agreement, Brazil's nationally determined contribution (NDC) is to reduce GHG emissions by 53% by 2030, compared to 2005 levels. This includes efforts in the agricultural sector to adopt practices that reduce emissions.[44]
- **Law 12.187/2009- 2009 National Policy on Climate Change (Política Nacional sobre Mudança do Clima – PNMC)**: This law established Brazil's commitment to reducing greenhouse gas emissions and resulted in the adoption of an Agricultural Sector Plan for Climate Change Mitigation and Adaptation for the Consolidation of a Low-Carbon Economy.[45]
- **Law No. 10,438/2002**: This law establishes the Incentive Programme for Alternative Sources of Electricity (PROINFRA), which aims to increase the share of renewable energy in Brazil's energy mix.[46]
- **Law No. 14,300/2022**: This law sets the legal framework for distributed generation, including net metering, which allows farmers to generate their own renewable energy and feed excess power back into the grid.[47]

Key regulations in Brazil related to **biodiversity** include:

- **Forest Code (Código Florestal)**: Also referenced under previous focus areas, this law requires rural landowners to preserve a portion of their land as native vegetation, which supports continued protection of biodiversity.[48]
- **Law No. 5,197/1967**: This law primarily focuses on the protection of wildlife in Brazil and may impact rice farmers through habitat protection provisions.[49]

India

Key regulations in India related to **land use and soil conservation** include:

- **National Policy for Farmers, 2007:** This policy focuses on improving agricultural productivity, promoting sustainable farming practices, and addressing various challenges in the agricultural sector.[50]
- **Environment Protection Act, 1986**: This law covers several key environmental focus areas aimed at protecting and improving the environment and focuses on preventing, controlling, and abating environmental pollution, including air, water, and soil pollution.[51]

Key regulations in India related to **water use and quality** include:

- **National Water Policy**: This policy emphasizes efficient water use and management practices, including for agricultural purposes. It encourages the adoption of water-saving technologies and practices.[50]
- **Water (Prevention and Control of Pollution) Act, 1974**: This act aims to prevent and control water pollution, ensuring the quality and wholesomeness of water resources. It established the Central and State Pollution Control Boards to enforce these regulations.[52]

- **State-Level Acts (e.g., Haryana Preservation of Subsoil Water Act, Punjab Preservation of Subsoil Water Act)**: These acts aim to reduce dependence on groundwater by restricting early rice cultivation and promoting sustainable irrigation practices. For example, the Punjab Preservation of Subsoil Water Act prohibits early rice transplantation and encourages delayed planting to align with monsoon rains.[53]

Key regulations in India related to **energy use and air quality** include:

- **National Greenhouse Gas Reduction Target**: As part of the Paris Agreement, India's nationally determined contribution (NDC) is to reduce the emissions intensity of its GDP by 45% by 2030 compared to 2005 levels. The NDC includes various adaptation measures to enhance climate resilience across specific sectors including agriculture.[54]
- **Energy Conservation Act, 2001**: This act promotes efficient use of energy and conservation practices across various sectors, including agriculture.[55]
- **Integrated Energy Policy, 2006**: This policy outlines strategies for sustainable energy use and includes measures to improve energy efficiency.[56]

Key regulations in India related to **biodiversity** include:

- **Biological Diversity Act, 2002**: This act aims to conserve biological diversity, ensure sustainable use of its components, and promote fair and equitable sharing of benefits arising from the use of biological resources.[57]
- **National Agroforestry Policy, 2014**: This policy promotes the integration of trees and shrubs into agricultural landscapes, which can enhance biodiversity and provide additional income for farmers.[58]
- **Wildlife (Protection) Act, 1972**: This act provides a comprehensive legal framework for the protection of wildlife and their habitats. It includes provisions for the establishment of protected areas such as national parks, wildlife sanctuaries, and conservation reserves.[59]
- **Environment Protection Act, 1986**: Also referenced in the land use section, this act provides a broad framework for environmental protection, including the conservation of wildlife habitats.[60]

EU Sustainability Regulations

Though the EU was not included in the top importing regions for U.S. rice and is not a competing rice exporting region, it is important to consider the sustainability-related regulations coming out of the EU, as they may be used as frameworks for future sustainability regulations in other jurisdictions. The following regulations are of note.

EU Corporate Sustainability Reporting Directive (CSRD)

The CSRD came into force in 2023 and aims to enhance and standardize sustainability reporting across the EU, ensuring that companies provide transparent and comparable information on their environmental, social, and governance (ESG) impacts. The law currently applies to EU listed companies, large EU companies and non-EU companies with significant operations in the EU.[61]

Companies that are required to report must do so according to the European Sustainability Reporting Standards (ESRS), developed by the European Financial Reporting Advisory Group (EFRAG). These standards require companies to disclose information on their sustainability risks, opportunities, and impacts, including:

- Environmental factors (e.g., greenhouse gas emissions, energy use)
- Social factors (e.g., labor practices, human rights)
- Governance factors (e.g., business ethics, anti-corruption measures).

Companies are required to submit their reports in a digital format to facilitate accessibility and analysis, and published sustainability reports must be audited to ensure accuracy and reliability.

Corporate Sustainability Due Diligence Directive (CSDDD)

The CSDDD aims to foster sustainable and responsible corporate behavior by ensuring companies identify and address adverse human rights and environmental impacts throughout their operations and global value chains. The law currently applies to large EU companies and non-EU companies with significant operations in the EU.[62]

As part of the CSDDD, large companies must adopt and implement transition plans for climate change mitigation aligned with the 2050 climate neutrality objective of the Paris Agreement. Companies must also conduct risk-based human rights and environmental due diligence, which includes:

- Integrating due diligence measures into their policies and risk management systems
- Identifying and addressing actual and potential negative impacts in their operations, subsidiaries, and value chains
- Preventing, mitigating, and remediating adverse impacts
- Engaging with stakeholders and establishing accessible complaints procedures

Companies will be held accountable for non-compliance and liable for violations of their due diligence obligations.

Global practitioners and members of the food and agriculture sector continue to watch these and other sustainability laws regulations to identify trends in sustainability reporting requirements and anticipate potential upcoming data collection and reporting needs.

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