“Potential for Use Nitrogen Index for Ecuador and Conservation Practices for Climate Change and Conservation of our Biosphere”

Dr. Jorge A. Delgado
Soil-Plant-Nutrient Research Unit, USDA/ARS
Thank You!

USAID, SANREM, Virginia Tech, INIAP and Universidad Estatal de Bolivar

Dr. Jorge A. Delgado
Soil-Plant-Nutrient Research Unit, USDA/ARS
Nitrogen inputs are needed and crucial for maintaining agricultural production.

Nitrogen is one of the most dynamics and mobile elements. It is also susceptible to losses via several pathways.

With average worldwide recoveries of 50%, we need to continue developing tools that can help us improve the management of N.

Develop nutrient management systems that minimize the loss of nutrients to ground and surface water while maintaining a profitable agricultural economy.
Cooperators - Locations

- China
- Argentina
- Japan
- Mexico
- Nicaragua
- Puerto Rico
- Bolivia
- Ecuador
- Spain
- Switzerland
- Canada
- Switzerland
- Spain
- Bolivia
- Ecuador
- Puerto Rico
- Nicaragua
- Mexico
- Argentina
- Japan
- China
“Example of Hot Spots Across the Globe”

“Cooperators – Locations”
Atmospheric Concentrations of trace gases from 1000 A.D.

From IPCC (2001)

Mosier, ARS
Ammonia emission from fertilizer

NH₃ emission from synthetic fertilizer use

Lemunyon NRCS
Selected Cooperators - Locations

China
Luancheng County
Inst. Agric. Modern.
Selected Cooperators - Locations

Location of Spain (Valencia Study sites) and Argentina (Study Sites), (Lavado et al, 2010).
Figure 5. Spatial distribution of the nitrate content in the groundwater of Spain (Varela, 1991).
Dairy cattle in México: 2.2 million
Dairy cattle in La Laguna: 0.44 million
Average herd size: 1,300 cows
Manure production: 7.5 million of ton/year (as excreted)
0.925 million of ton/year (dry matter)
Selected Cooperators - Locations

Gross N Balance in Dairy Farms at La Laguna

13,800 ton of volatilized N

46,000 ton of excreted N

32,200 ton N incorporated into the soil

7,200 ton N extracted by forage crops

25,000 ton N susceptible to being lost

Figueroa et al., 2009
Average Nitrate Concentration of Ground Water

Martínez et al., 2006. Agrofaz 6:379-386
Runoff from potato farms blamed for fish kills on Canadian island

Kathy Birt

Gerald MacDougall, manager of forest, fish and wildlife for the Prince Edward Island Department of Environment, cleans up dead fish from a recent Dunk River fish kill.
“Example of Hot Spots Across the USA”

“Cooperators – Locations”
Hundreds of dead fish surface in Tamarac country club's waterways

Fertilizer or pesticides suspected in deaths of scores of fish in Tamarac

By Joel Marino Staff Writer
July 28, 2008

Residents confused, worried about dead fish
Source:
Department of Environmental Protection
Maine
CORRELATION BETWEEN NITRATE CONTENT OF NEBRASKA GROUND WATERS AND SEVERAL FACTORS

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>r value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overlying soil clay content</td>
<td>-0.49**</td>
</tr>
<tr>
<td>2. Irrigation well density</td>
<td>0.43**</td>
</tr>
<tr>
<td>3. Total fertilizer use</td>
<td>0.28**</td>
</tr>
<tr>
<td>4. Irrigation well dept</td>
<td>-0.28**</td>
</tr>
<tr>
<td>5. Water pH</td>
<td>-0.23**</td>
</tr>
<tr>
<td>6. Cattle density</td>
<td>0.18*</td>
</tr>
<tr>
<td>7. Human density</td>
<td>0.06</td>
</tr>
</tbody>
</table>

(1) Individual well water nitrate level related site characteristics 1, 4, and 5 above and to average county wide statistics for characteristics 2, 3, 6, and 7. Water sampled from 480 wells, 1971-1972.
NH$_3$ emissions and NH$_4^+$ in air and precipitation (1995-1998)

1990 Annual Anthropogenic NH$_3$ Emissions, AQPP CHRONOS 21-km North American Grid, Prepared by CEPS

Lemunyon, NRCS
Fig. 1. Mississippi–Ohio–Missouri (MOM) River Basin in the United States, showing location and general extent of Gulf of Mexico hypoxia in Louisiana coastline and location of high nitrogen loadings in the basin (>1000 kg N km⁻² yr⁻¹) (nitrogen loading source location from Goolsby et al., 1999).
Nitrogen Cycle and N loss pathways
How do we manage nitrogen in order to increase Nitrogen use efficiencies and reduce nitrogen loss to the environment?
How is \( \text{NO}_3^- \) Leached from the Soil?  
How Can \( \text{NO}_3^- \) Leaching be Minimized?

How is \( \text{N}_2\text{O} \) Produced in the Soil?  
How Can \( \text{N}_2\text{O} \) Emissions be minimized?

Nitrification

\[
\text{NH}_4^+ \xrightarrow{\text{NH}_2\text{OH}} \text{NH}_2\text{OH} \xrightarrow{[\text{HNO}] \xrightarrow{[X]} \text{NO}} \xrightarrow{\text{NO}} \text{NO}_2^- \xrightarrow{\text{NO}} \text{N}_2\text{O} \xrightarrow{\text{N}_2} \text{N}_2\text{O}
\]

Main Controls:
- Substrate
- Oxygen
- Water
- Temperature

Denitrification

\[
\text{N}_2\text{O} \xrightarrow{\text{NO}} \xrightarrow{\text{NO}_2^-} \text{NO}_3^-
\]

Main Controls:
- Substrate, available carbon, \( \text{O}_2 \) (water & \( \text{O}_2 \) demand), \( T \)
### Effect of N fertilizer on N$_2$O and CH$_4$ uptake

<table>
<thead>
<tr>
<th>System</th>
<th>N$_2$O-N (g ha$^{-1}$ d$^{-1}$)</th>
<th>CH$_4$-C (g ha$^{-1}$ d$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native grassland</td>
<td>0.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Fertilized grassland</td>
<td>0.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Irrigated wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>6.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Control</td>
<td>2.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Irrigated Corn (Maize)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>16.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Control</td>
<td>1.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Effect of N fertilizer and NI on N$_2$O

<table>
<thead>
<tr>
<th></th>
<th>Irrigated Corn (Maize)</th>
<th>Irrigated wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urea</td>
<td>Urea</td>
</tr>
<tr>
<td>Urea + nitrapyrin</td>
<td>980</td>
<td>Urea</td>
</tr>
<tr>
<td>Urea + ECC</td>
<td>483</td>
<td>Urea + ECC</td>
</tr>
<tr>
<td>Control</td>
<td>108</td>
<td>Urea + DCD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
</tr>
</tbody>
</table>

Delgado and Mosier 1996, J. Environmental Quality
Control Release Urea (Meister)
Potato Yield

N Application Rate (kg N/ha) & Method
Control Release Urea  (Meister)
Potato Yield

Delgado et al. 1998, Shoji et al. 2001
“Nitrogen Management”
Figure 13. Effect of N fertilizer rate applications on yield and N uptake by irrigated corn (Adapted from Bock and Hergert, 1991). Potential N available to leach (NAL) assuming major pathway for losses is leaching. The NAL was estimated as NAL = N applied – N uptake.
Figure 5. Essential components of NO$_3$-N leaching index (NLI) (From Shaffer and Delgado, 2002).
Residual soil NO3-N (RSN) for Potato - Small Grain cropping sequence

<table>
<thead>
<tr>
<th>RSN (kg NO3-N/ha)</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>102</td>
</tr>
<tr>
<td>Grain</td>
<td></td>
<td>125</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

(P < 0.05)

Effect of winter cover rye on potential soil erosion in fine and coarse sandy loams

- Fallow
- Winter cover crop

Growing Season for a lettuce-winter cover rye cropping sequence and residual soil NO3-N

- 5/18: a
- 8/4: a
- 4/1: b

Fine Sandy loam
Coarse Sandy loam
Figure 3. Mean Nitrous Oxide ($N_2O$) and nitrate leaching ($NO_3^-N$) from a 10 year site specific simulation of a dryland wheat – fallow rotation in Colorado (wheat); corn-corn rotation in Ohio (corn) and a corn-soybean rotation in Ohio (soy). The simulated scenarios were: 1) aboveground crop residue kept in the field (residue retained); 2) removing aboveground crop residue (residue removed); and 3) aboveground crop residue kept in the field but removal of a similar amount of N from the fertilizer input (residue retained, decrease fertilizer).

*Delgado et al. 2010 J. Nutrient Cycling*
Figure 3. Mean Nitrous Oxide (N\textsubscript{2}O) from a 10 year site specific simulation of a dryland wheat – fallow rotation in Colorado (wheat); corn-corn rotation in Ohio (corn) and a corn-soybean rotation in Ohio (soy). The simulated scenarios were: 1) aboveground crop residue kept in the field (residue retained); 2) removing aboveground crop residue (residue removed); and 3) aboveground crop residue kept in the field but removal of a similar amount of N from the fertilizer input (residue retained, decrease fertilizer).

Delgado et al. 2010 J. Nutrient Cycling
Table 2. 15N applications, recoveries and losses in irrigated cover crop studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>N source</th>
<th>Applied $^{15}\text{N}$ (kg N ha$^{-1}$)</th>
<th>Soil recovery (% $^{15}\text{N}$)</th>
<th>Plant recovery (% $^{15}\text{N}$)</th>
<th>Lost (% $^{15}\text{N}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>Wheat$^a$</td>
<td>Fertilizer</td>
<td>95</td>
<td>27</td>
<td>47</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Potato$^b$</td>
<td>Wheat residue</td>
<td>37</td>
<td>79</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Colorado</td>
<td>Wheat$^a$</td>
<td>Fertilizer</td>
<td>95</td>
<td>25</td>
<td>49</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Potato$^b$</td>
<td>Wheat residue</td>
<td>41</td>
<td>79</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Colorado</td>
<td>Barley$^a$</td>
<td>Fertilizer</td>
<td>95</td>
<td>28</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Potato$^b$</td>
<td>Barley residue</td>
<td>35</td>
<td>69</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Washington</td>
<td>Mustard</td>
<td>Fertilizer</td>
<td>56</td>
<td>24</td>
<td>34</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Potato$^c$</td>
<td>Mustard residue</td>
<td>142</td>
<td>66</td>
<td>29</td>
<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>Fertilizer</td>
<td></td>
<td></td>
<td>26 $\pm$ 2</td>
<td>43 $\pm$ 7</td>
<td>31 $\pm$ 8</td>
</tr>
<tr>
<td></td>
<td>Crop residue</td>
<td></td>
<td></td>
<td>73 $\pm$ 7</td>
<td>14 $\pm$ 11</td>
<td>13 $\pm$ 6</td>
</tr>
</tbody>
</table>

Delgado et al. 2010 J. Nutrient Cycling
**Take Home Message**

**Sorghum Sudan:**

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Ctw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td>233 b</td>
</tr>
<tr>
<td>Fallow</td>
<td>274 b</td>
</tr>
<tr>
<td>Sorghum sudan-HS</td>
<td>308 ab</td>
</tr>
<tr>
<td>W-Mustard</td>
<td>225 b</td>
</tr>
<tr>
<td>Sorghum-sudan</td>
<td>390 a</td>
</tr>
<tr>
<td>Sorghum-sudan-hay</td>
<td>386 a</td>
</tr>
</tbody>
</table>

*Delgado et al. 2007 J. Soil and Water Conservation*
New Concepts for Nitrogen Management

New Nitrogen Index

Mexico, Spain, Ecuador, Bolivia, California, Caribbean, .....
Team Efforts Across Nations – Case Scenarios

Ecuador
Rendimiento vs dosis de N

\[ y = -3 \times 10^{-5} x^3 + 0.0049 x^2 + 0.5703 x + 29.284 \]

\[ R^2 = 0.9597 \]

0 20 40 60 80 100 120 140

Dosis de N lb/acre

Rend bushels/acre

Eficiencia agronomía N vs Dosis N

\[ y = -0.0096 x^2 + 2.2486 x - 33.465 \]

\[ R^2 = 0.9722 \]

-60 -40 -20 0 20 40 60 80 100 120

Dosis de N lb/acre

Eficiencia agronomía N %

N lixiviado vs dosis N

\[ y = 0.0045 x^2 - 0.3289 x + 8.7429 \]

\[ R^2 = 0.9264 \]

0 20 40 60 80 100 120

Dosis de N lb/acre

N lixiviado lb/acre
“Conservation Practices to Mitigate and Adapt to Climate Change”

Dr. Jorge A. Delgado
Soil-Plant-Nutrient Research Unit, USDA/ARS

Photo NASA
The Soil and Water Conservation Society invited the authors to review the science of conservation practices and their potential for climate change mitigation and adaptation.
Conservation practices to mitigate and adapt to climate change

Jennifer Marquis, Peter M. Gimblett, Mark A. Horning, Tom Goodfellow, Don Recousky, Rattan Lal, Neetish K. Khanna, Charles W. Rice, Dan Torrey, and Paul Salois

Climate change, in combination with the expanding human population, presents a formidable food security challenge. How will we feed a world population that is expected to grow by an additional 2.4 billion people by 2050?

Population growth and the dynamics of climate change will also exacerbate other issues, such as desertification, deforestation, erosion, degradation of water quality, and depletion of water resources. Future climate models project that the temperatures and precipitation patterns of the future will differ from those of today, which will further stress agricultural systems and food security (IPCC, 2007).

Addressing climate change will require significant changes in agriculture and food systems. Approximately 30% of the world’s greenhouse gas emissions come from agriculture, with 10-15% from land use change (IPCC, 2007). Agriculture is a major contributor of greenhouse gases, including carbon dioxide, methane, and nitrous oxide.

To mitigate climate change, it is necessary to reduce greenhouse gas emissions from agriculture and to adapt to the changes that have already occurred. Adaptation strategies include developing new crops that are more resistant to climate change, improving irrigation systems, and increasing the efficiency of energy use in agricultural production.

In conclusion, the challenge of feeding a growing population while mitigating and adapting to climate change is a complex one. It will require significant investments in research, technology, and policy to ensure that the future generation has access to food security and a sustainable environment.
“Conservation Practices to Mitigate and Adapt to Climate Change”

- Jorge A. Delgado USDA ARS, Fort Collins, Colorado.
- Peter M. Groffman Cary Institute of Ecosystems Studies, Milbrook, New York.
- Mark A. Nearing USDA ARS, Tuscon, Arizona.
- Tom Goddard Government of Alberta, Canada.
- Don Reicosky USDA ARS (Former)
- Rattan Lal The Ohio State University, Columbus, Ohio.
- Charles W. Rice Kansas State University, Manhattan, Kansas.
- Dan Towery is the owner of Ag Conservation Solutions, Lafayette, Indiana.
- Paul Salon SWCS, New York Chapter.
The 20th century’s Green Revolution showed that science-based solutions could provide answers to global challenges to the benefit of societies.

Despite the success of the Green Revolution, today there are new concerns, and the threat of climate change is among the most severe threats that face our planet in the 21st century (USDA NRCS 2010).
Climate change is occurring, and the implementation of sound conservation practices will be key for each country’s health, social stability, and security.
Major World Challenges Related to Soil and Water Conservation

- Extreme weather events are creating environmental problems, accelerating the rate of erosion and threatening agricultural production needed for food security.
Additionally, climate change can increase the potential for higher erosion rates, which is also of concern because erosion has been reported to lower agricultural productivity by 10% to 20% (Quine and Zhang 2002; Cruse and Herndel 2009).
Major World Challenges Related to Soil and Water Conservation

• Key world agroecosystems that rely on significant amounts of irrigation water are being threatened because water resources are being depleted, a result of water use exceeding water storage replacement.
• Since irrigated systems have, on average, double the yields of non-irrigated systems, the depletion and salinization of these key world resources results in additional pressure to increase agricultural productivity.
Additionally, there are reports that for some regions, the melting of glaciers may affect the availability of water that is used for cities and/or irrigated lands. This presents a serious concern because, on average, irrigated systems have yields that are twice those of nonirrigated systems (Rangely 1987; Bucks et al. 1990; Tribe 1994).

Photo EPA (Kilimanjaro)
Another concern that could affect the maximization of yields is energy costs, which are expected to rise in the future and which may reduce key fertilizer and agrochemical inputs at a farm level (UNEP GRID-Arendal 2009).
Nonirrigated systems could also see their yields potentially reduced due to these stresses since it has been reported that for every increase in temperature of 1°C (1.8°F), there is a potential reduction in yield, not only from heat stress, but also from the interaction of heat stress and drought stress that may be put on crops (Peng et al. 2004; Auffhammer 2011; Lobell et al. 2011).

For example, across Africa, an increase in temperature of 1°C under drought conditions could affect 100% of the maize area, potentially reducing yields by at least 20% (Auffhammer 2011; Lobell et al. 2011).
Population growth and the development of new, stronger economies, such as those of China and India, are increasing the demand for world resources. By 2050, the world population is expected to increase by 2.4 billion people, and as the economies of countries with large populations improve, even more pressure will be put on the world’s agricultural systems. This increased demand for resources coupled with climate change could threaten the potential to achieve food security.
Due to anticipated impacts from climate change, deforestation, erosion, depletion of water resources, and other environmental problems, as well as potentially higher fuel prices, which could impact agricultural inputs, food security will increasingly become a concern in the coming decades.

• This could become an even greater concern if extreme events, such as droughts or floods, or even extreme pest or disease outbreaks (e.g., blight, a potato disease that contributed to the infamous potato famine in Ireland) begin to occur on systems that are already stressed.
The Carbon and Nitrogen Cycles and Agricultural Influences on Greenhouse Gases

Greenhouse Gases Contributed by Agriculture are an Important Factor in Climate Change.

Agriculture plays an important role in the GHG fluxes of CO$_2$, N$_2$O and CH$_4$, contributing 6% of total United States GHG emissions, a total of 427.5 Tg CO$_2$ equivalents (table 2; figure 2) (USEPA 2010b).
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

• Teach the Value of Soil Carbon.

Understanding the relationship between carbon (C) sequestration and soil and water quality benefits is key. Conservationists, farmers, policy advisors, K-12 and university students—in short, the general public—should have an understanding of how soil carbon can assist in climate change mitigation and adaptation.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

• Develop Communication that Connects Science to Land Managers.
  - Better communication with farmers and farmers’ groups is key to increasing the efficiency of soil and water conservation programs.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

• Develop Communication that Connects Science to the Public.

- Better communication with the general public is essential to increasing awareness of the benefits of soil and water conservation programs.
Principles for Communication of Soil and Water Conservation Programs

• Improve Historical Context.
  - Development of long-term data records, programs, and studies are important for developing conservation programs that will contribute to climate change mitigation and adaptation.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

**Principles for Communication of Soil and Water Conservation Programs**

- Ongoing Training Essential.
  - Education programs and the mentoring of new personnel are important for maintaining an educated workforce that will compete to develop the most efficient management practices.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

• Enhance Exchange.
  - Forums for exchanging information between farmers, professional societies, scientists, conservation practitioners, and the general public, and to discuss the advantages and disadvantages of recent advances, are needed to continue advancing the field of soil and water conservation and are important for climate change mitigation and adaptation.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Cover the Surface.
  - Harvesting of plant residues should be avoided if soil function will be compromised.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

*Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation*

• Soil Function Improves with Soil Carbon.
  - Soil C sequestration is beneficial for the environment.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Surface Residue Protects.
  - Conservation agriculture increases sustainability.
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Value Perennial Crops.
  - A large number of peer-reviewed manuscripts report that perennial bioenergy crops (e.g., switchgrass) can contribute to C sequestration and better protect the environment than grain cropping used for energy.
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Off-Field Remediation Practices Are Helpful.
  - Off-the-field conservation practices can contribute to climate change mitigation and adaptation (e.g., riparian forest buffer, wetland).
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Improve Landscape Diversity with Agroforestry.
  - Agroforestry can contribute to landscape diversity, benefiting the environment.
Effectiveness Enhanced with Landscape-Targeting Precision Conservation.

- We need to account for spatial and temporal variability and avoid a one-size-fits-all approach if we are to maximize conservation. The scientific literature has many examples that show that to maximize conservation, managers will need to consider the effects of climate change on yield, productivity, and the environment. These effects are likely to be mixed and to vary greatly by region, by field, within field, and by crop type.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Promote Energy Efficiency.
  - Green programs can save energy at the farm level (e.g., wind, solar, and biomass programs).
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• Value Water More.
  - Water-use efficiency needs to be increased, and water quality needs to be protected.
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Greater Diversity Needed.
  - Diverse cropping systems will be key to mitigating and adapting to climate change. Development of new varieties that can be used for tolerance of drought, temperature stress, and other effects of climate change will be needed.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

**Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation**

• Minimize Gas Losses.
  - *Practices that can reduce emissions of methane (CH$_4$) and other greenhouse gases at the farm level will contribute to sustainability.*
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

• “Tighter” Nutrient Cycles.

- Practices that can capture nutrients and energy from manure contribute to conservation. Cycling of crop residues, use of cover crops, and increasing fertilizer-use efficiencies are some examples of ways to contribute to tighter nutrient cycles.
Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Development of New Science and Technologies

• Research Pays Dividends Long Term.
  - Research programs greatly contribute to soil and water conservation, making them important for climate change mitigation and adaptation.
The majority of this table is adapted from Eagle et al. (2010). Other results from Adler et al. (2007) life cycle analysis of bioenergy systems and from a matrix of conservation practices developed by USDA Natural Resources Conservation Service (NRCS), West Technology Center, were also incorporated, as well as additional comments from the authors of this document. The effect of management practices on soil carbon sequestration (CS), the net flux of nitrous oxide and methane greenhouse gas (GHG) emissions, and on the change in upstream and process emissions (UPE, fuel, fertilizer, etc.) are estimated. All estimated values were expressed as equivalents of carbon dioxide. A positive, high, and very high sequestration potential are represented by +, ++, and ++++, respectively, while net equivalent emissions are represented by −. The net carbon sequestration impact (NCSI) is the sum of CS, GHG and UPE.

<table>
<thead>
<tr>
<th>Management practice*</th>
<th>CS</th>
<th>GHG</th>
<th>Additional benefits to the producer and environment</th>
<th>UPE</th>
<th>NCSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agroforestry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windbreaks for crops</td>
<td>++</td>
<td></td>
<td>Improves crop and livestock protection wildlife habitat. Provides alternative income source.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and livestock</td>
<td></td>
<td></td>
<td>Has potential to contribute to adaptation (e.g., minimize impacts of extreme wind storms).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silvopasture with</td>
<td>++</td>
<td></td>
<td>Provides annual income from grazing; long-term income from wood products. Has potential to contribute to adaptation (e.g., provide a viable income and serve as a tool against a changing climate).</td>
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<tr>
<td>rotational grazing</td>
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<tr>
<td>Riparian forest buffer</td>
<td>++</td>
<td></td>
<td>Improves water quality and wildlife habitat. Provides alternative income source (specialty crops, hunting fees).</td>
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<td></td>
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<td></td>
<td>Has potential to contribute to adaptation (e.g., use targeted, strategically located riparian forests to reduce impacts of extreme events due to higher water flow).</td>
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<tr>
<td>Livestock</td>
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<tr>
<td>Organic soil amendments (especially manure)</td>
<td>+</td>
<td></td>
<td>Provides nutrients for crops; improves water quality when nutrient management plans are followed and manure is not over applied. Has potential to contribute to adaptation (e.g., result in higher nutrient cycling capacity and soils with improved soil quality that may be able to adapt better and maintain productivity in a changing climate).</td>
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<tr>
<td>Rotational grazing</td>
<td>++</td>
<td></td>
<td>Reduces water requirements. Helps withstand drought. Increases long-term grassland productivity. Has potential to contribute to adaptation (e.g., provide economic alternative due to higher-quality forage).</td>
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<tr>
<td>Improve grazing</td>
<td>++</td>
<td></td>
<td>Potentially increases carbon sequestration on land, depending on previous crop(s) grown. Has potential to contribute to adaptation (e.g., provide economic alternative due to improved grasslands and soils with improved soil quality that may be able to adapt better and maintain productivity in a changing climate).</td>
<td>na</td>
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<tr>
<td>management rangeland</td>
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<tr>
<td>Cropland</td>
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<tr>
<td>Change from</td>
<td>+</td>
<td></td>
<td>Improves soil, water, and air quality. Reduces soil erosion and fuel use; saves expenses, time, and labor.</td>
<td></td>
<td></td>
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<tr>
<td>conventional</td>
<td></td>
<td></td>
<td>Has potential to contribute to adaptation (e.g., provide economic alternative due to savings in energy).</td>
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<tr>
<td>to conservation tillage</td>
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<tr>
<td>Change from</td>
<td>+</td>
<td></td>
<td>Improves soil, water, and air quality. Reduces soil erosion and fuel use; saves expenses, time, and labor.</td>
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<tr>
<td>conventional to no-till</td>
<td></td>
<td></td>
<td>Has potential to contribute to adaptation (e.g., provide economic alternative due to savings in energy).</td>
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<tr>
<td>Improved irrigation</td>
<td>+</td>
<td></td>
<td>Improves air quality, reduces water quantity usage. Has potential to contribute to adaptation, since saving water (reduced usage) will be crucial in the coming decades to deal with a changing climate in drier regions and to respond to droughts.</td>
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<td>management</td>
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<tr>
<td>Crop diversity crop rotation</td>
<td>+</td>
<td></td>
<td>Reduces erosion and water requirements. Improves soil and water quality, reduces nitrogen and other fossil-fuel-intensive inputs. Has potential to contribute to adaptation (e.g., provide economic alternative that may be able to adapt better and maintain productivity in a changing climate that could bring new pests and diseases due to warmer weather).</td>
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<tr>
<td>Crop conversion to pasture</td>
<td>++</td>
<td></td>
<td>Reduces erosion and increases carbon sequestration. Has potential to contribute to adaptation (e.g., provide economic alternative that may be able to adapt better and maintain economic productivity in a changing climate).</td>
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<tr>
<td>Effective nitrogen management</td>
<td>na</td>
<td></td>
<td>Reducing losses of reactive nitrogen can contribute to improved water quality; saves expenses.</td>
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</tr>
</tbody>
</table>
The scientific literature suggests that with use of good policies, conservation programs, and practices we could have a better opportunity to achieve food security (good air, soil and water quality), while with bad policies and/or a lack of policies/conservation practices for climate change mitigation and adaptation, we will have lower air quality, soil quality and water quality, and there will be less potential to achieve food security.
All of this information is available at the SWCS website (http://www.swcs.org/) and also published in the *Journal of Soil and Water Conservation* (http://www.jswconline.org/).
Thank You!