Roles of Nuclear and Isotopic Techniques in Climate Change Adaptation and Mitigation Studies

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MYANMAR SOIL FERTILITY AND FERTILIZER MANAGEMENT CONFERENCE
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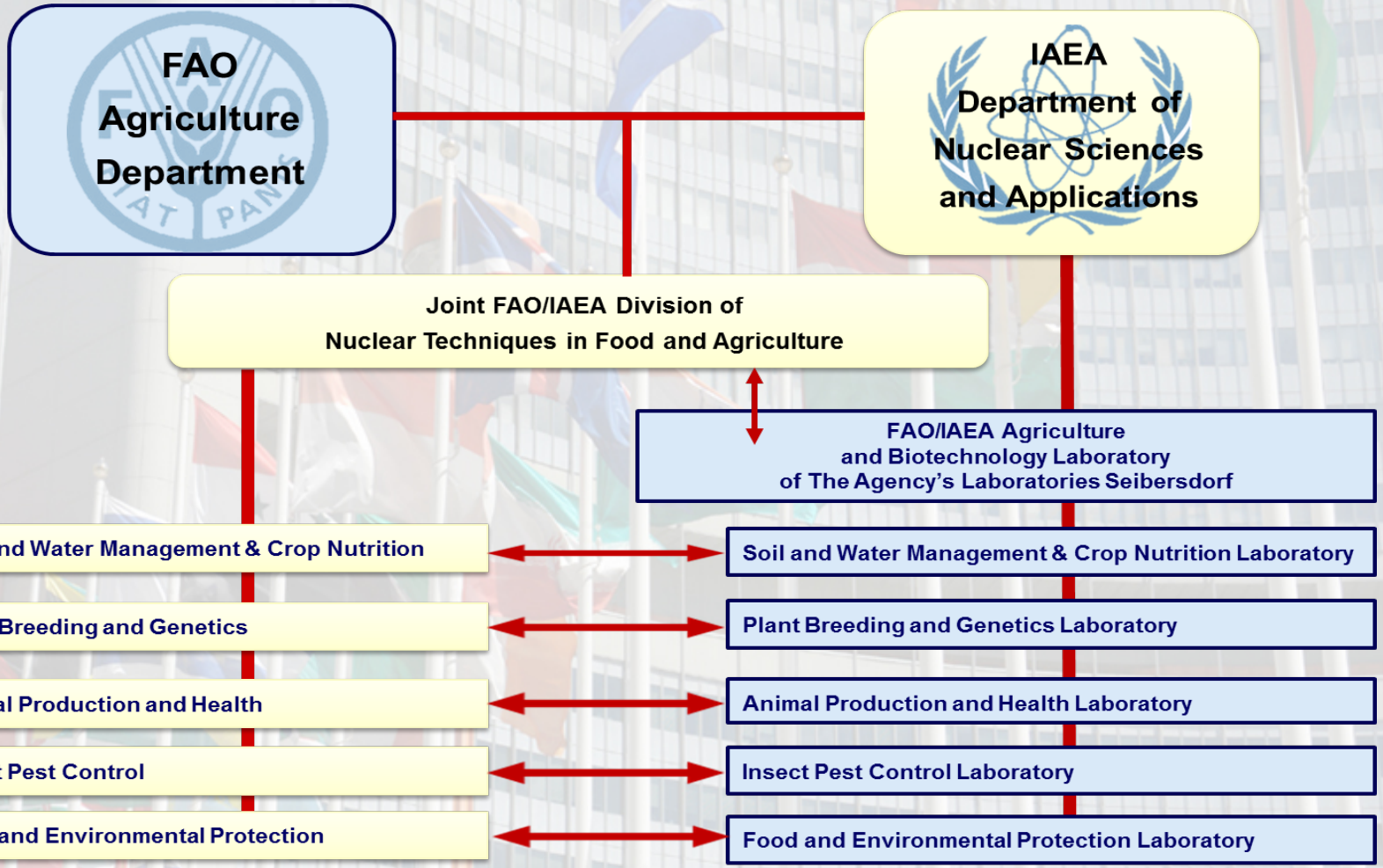
Outline

- The Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture
- Applications of nuclear and isotopic techniques for climate change studies
- IAEA 2018-2019 Technical Cooperation projects

Organizational Chart



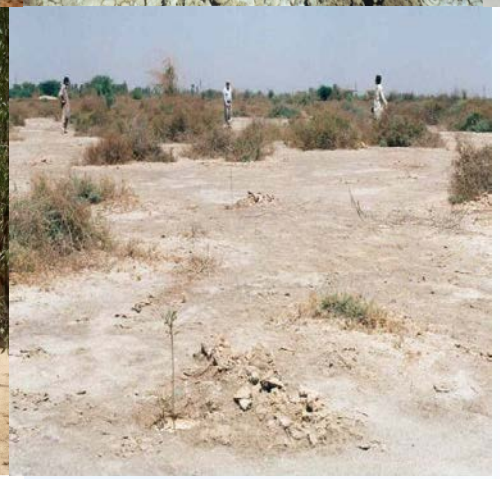
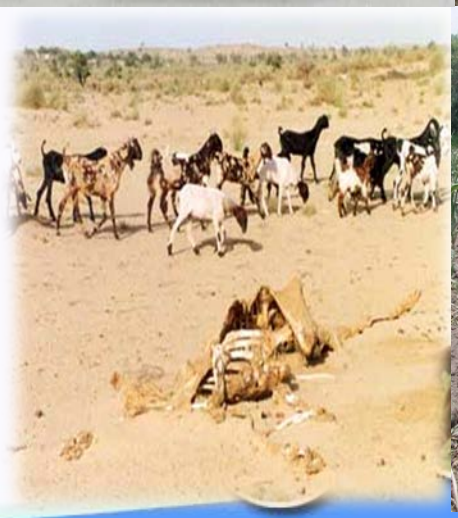
Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme

- **Vienna Headquarters**
  - Develop, implement and coordinate research projects (CRPs).
  - Provide technical support to IAEA Technical Cooperation (TC) Projects.

- **Seibersdorf Laboratory**
  - Develop, adapt and transfer new technologies to Member States.
  - Conduct training courses & fellowship training.
  - Provide analytical support & external quality assurance.

Major issues/challenges

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Land Degradation and Soil Erosion	Salinity and Nutrient toxicities	Flood and Water Scarcity	Low Soil Fertility and Poor Crop Nutrition
			
			

What are isotopes?

They are atoms of an element which have different mass number but the same atomic number.

atomic number: number of protons (Z)
mass number: sum of protons and neutrons

proton: positive charge; same mass as neutron
neutron: no charge; same mass as proton
electron: negative charge; no mass (very little mass)

mass number

$$^{12}_{6}C$$

atomic number

Isotopes

Two types of isotopes:

- Stable isotopes
- Unstable isotopes (radioactive isotopes, radionuclides)

Isotope	Protons	Neutrons	Atomic Number	Mass Number	
^{13}N	7	6	7	13	radioactive
^{14}N	7	7	7	14	stable
^{15}N	7	8	7	15	stable
^{16}O	8	8	8	16	stable
^{17}O	8	9	8	17	stable
^{18}O	8	10	8	18	stable

Nuclear techniques for climate change and soil and water management studies

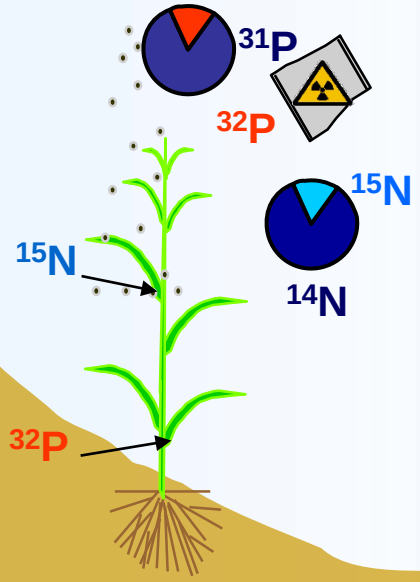
Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

^{15}N

To quantify biological nitrogen fixation to save N fertilizers

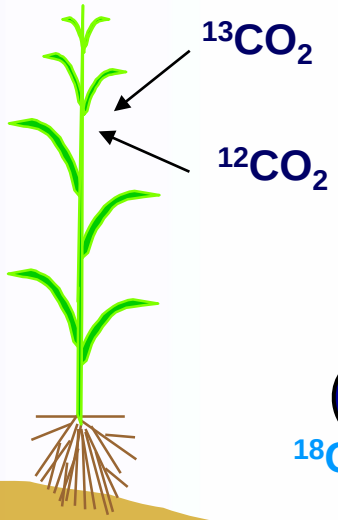
^{15}N

To quantify the flow and fate of N fertilizers to improve fertilizer use by crops



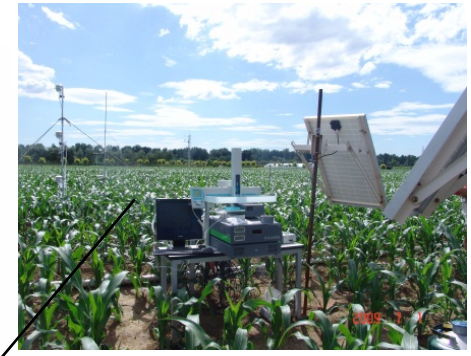
^{13}C

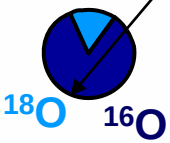
Carbon isotope discrimination to assess adaptation of crops tolerant to drought and salinity



^{18}O ^{2}H

To estimate sources and fluxes of water to improve WUE

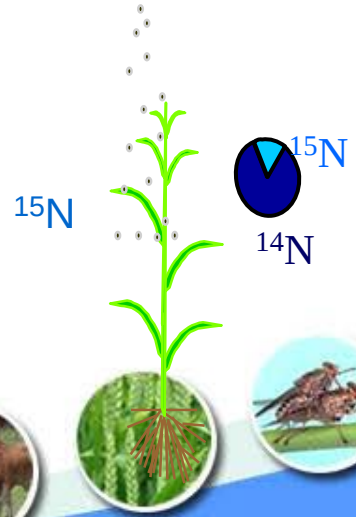




To assess soil organic carbon storage

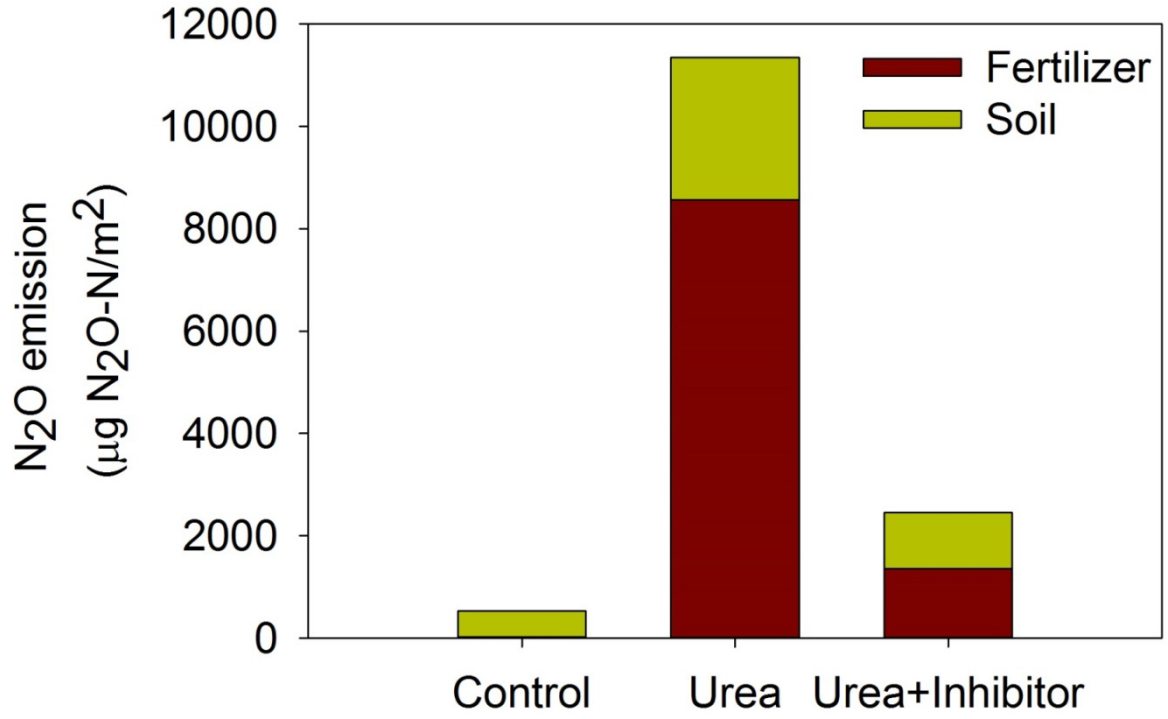
Stable Isotope Techniques

- **Nitrogen-15**
  - **Biological Nitrogen Fixation**
  - **Fertilizer Use Efficiency**
  - **Greenhouse gas emission**



N-15 Isotopic Technique for GHG study

N-15 technique precisely measure N_2O emissions and identify the nitrogen source (fertilizer versus soil N) enable us to adjust fertilizer N rate to crop need and demand

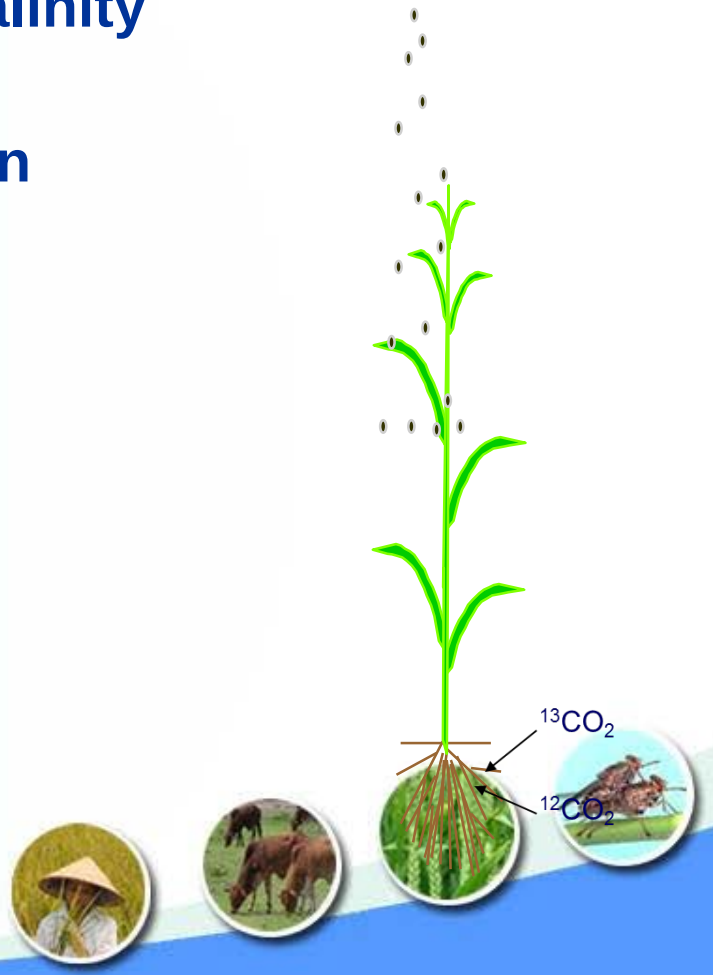


Stable Isotope Techniques

- **Carbon-13**
  - **Crop tolerance to drought and salinity (CID)**
  - **Soil organic carbon sequestration**
  - **Identification of origins of land degradation (CSSI of fatty acids)**

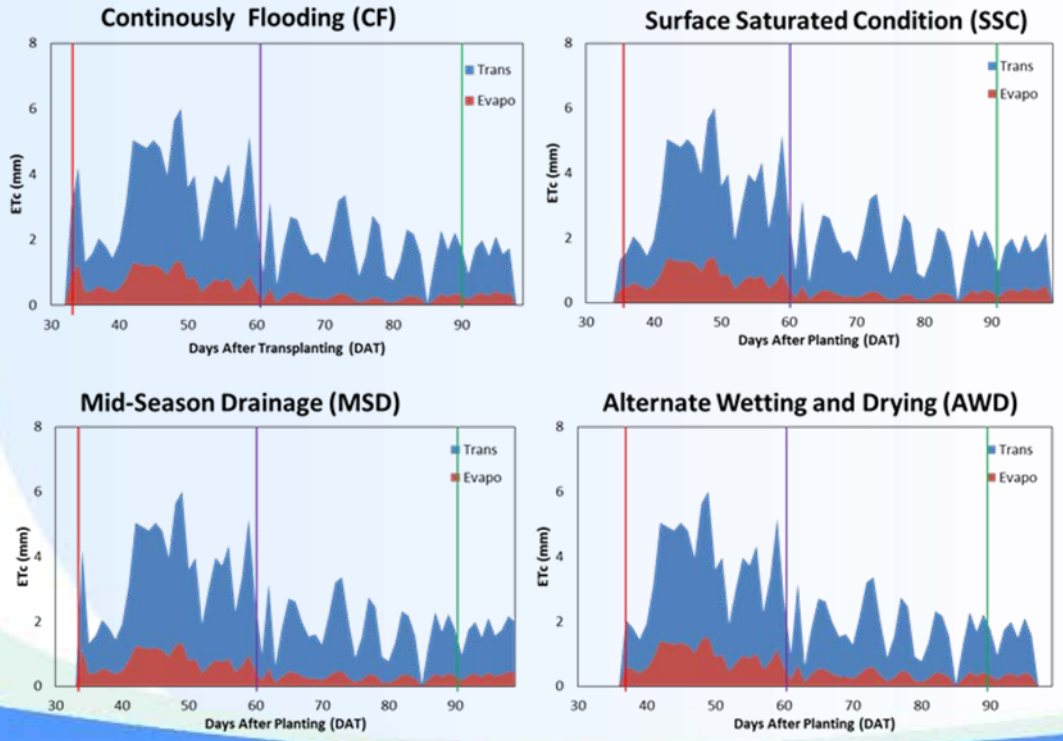
C_3 plants: $\delta\ ^{13}C = -26‰$

C_4 plants: $\delta\ ^{13}C = -12\ ‰$



Nuclear Techniques for Assessing ET, Water Movement, Sources and Quality

- **Oxygen-18 / Deuterium**
  - **Agricultural water management:**
    - ✓ **Separating evaporation and crop transpiration to improve water use efficiency**



Precipitation
-5‰

Transpiration water
-2‰

Leaf water
+15‰

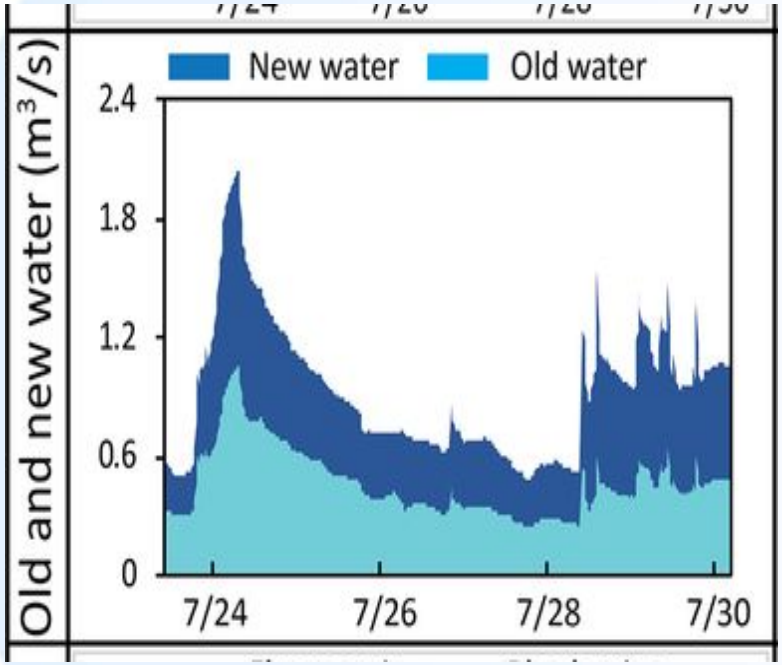
Xylem wate
-2‰

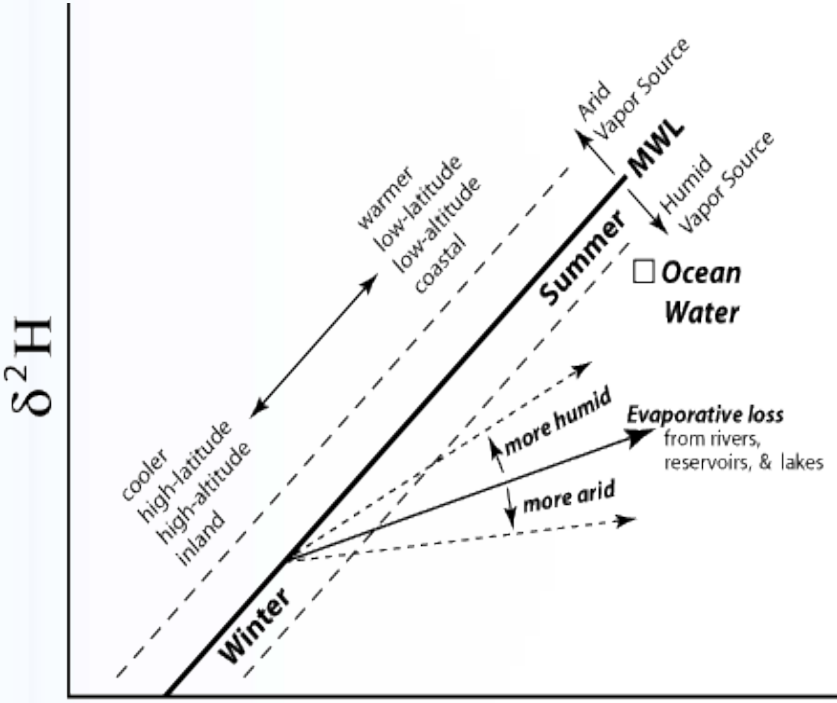
Soil evaporation water
-30‰

Soil water
Surface soil: +3‰
Deeper: -5‰

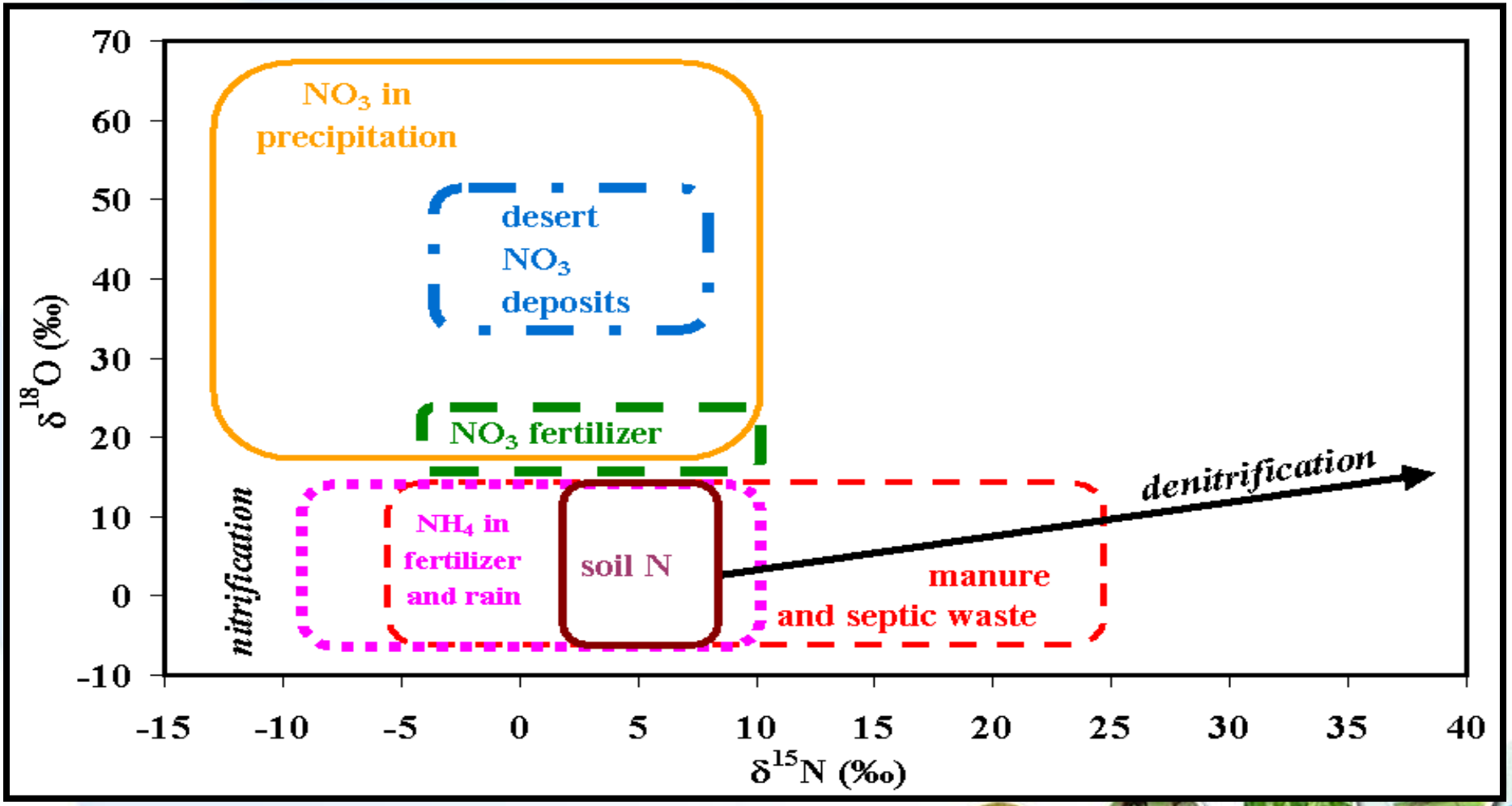
Nuclear Techniques for Assessing ET, Water Movement, Sources and Quality

- **Oxygen-18 / Deuterium**
  - **Origins & Sources of water**





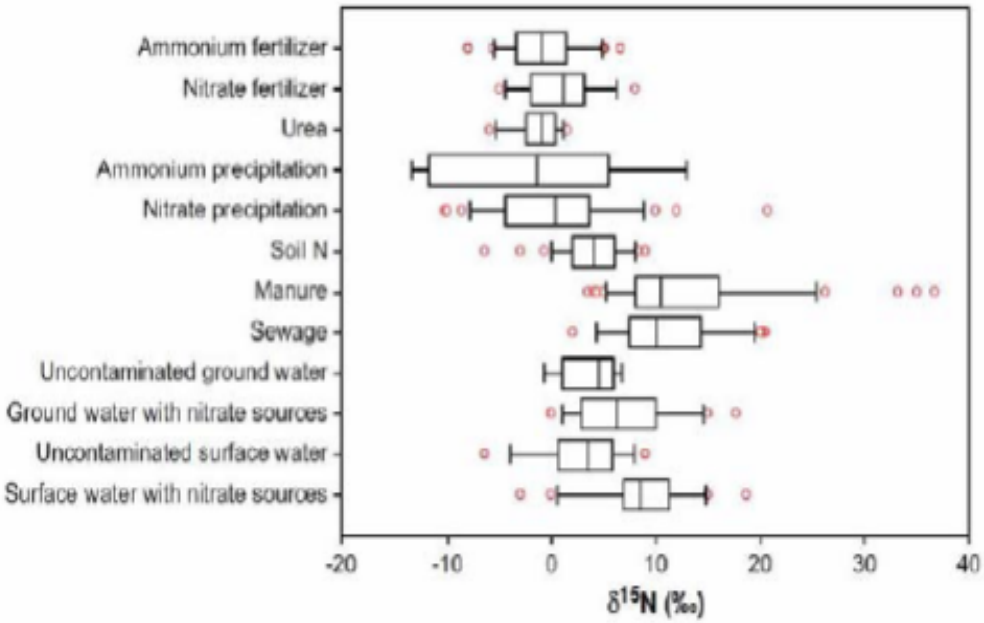
Determining sources of nitrate using isotopes of $\delta^{18}O$ & $\delta^{15}N$



A MULTI-ISOTOPE APPROACH

Kendall, 2004

Nitrate $\delta^{15}N$ & $\delta^{18}O$ from various sources, sinks and processes



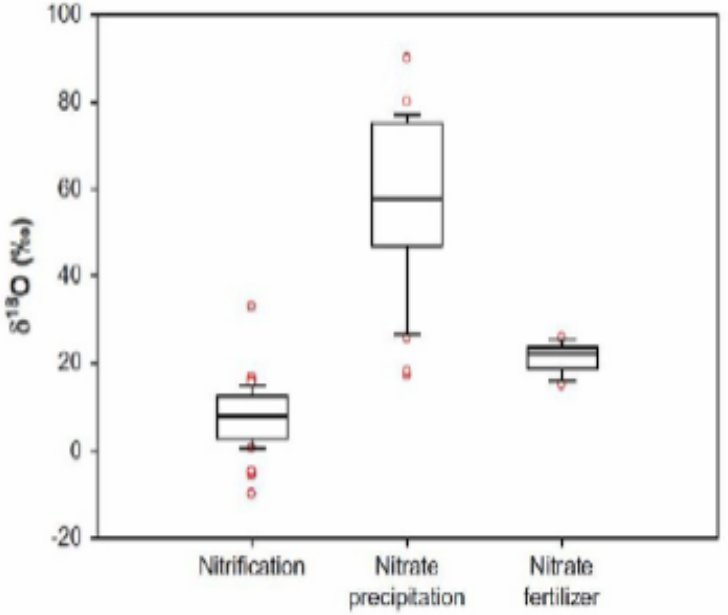
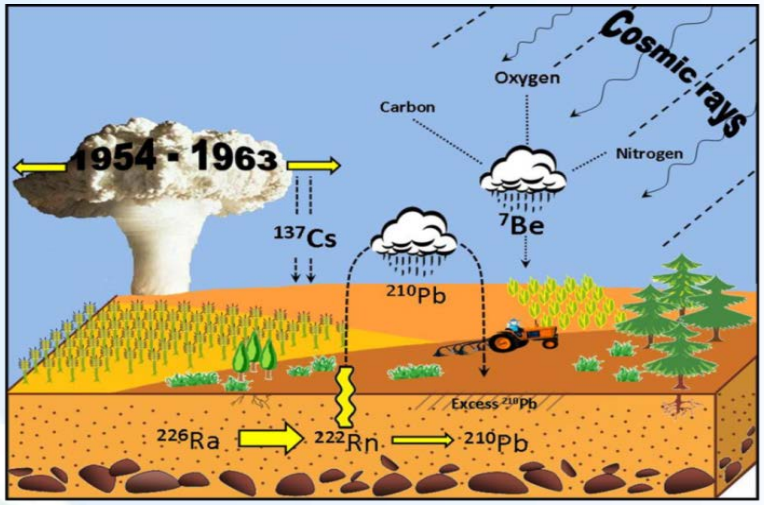


Figure 1: Box plots of $\delta^{15}N$ and $\delta^{18}O$ signatures of nitrate from various sources, sinks and processes. Data collected from literature. The box plots illustrate 25^{th}, 50^{th} and 75^{th} percentiles; the whiskers indicate the 10^{th} and 90^{th} percentiles; and the circles represent outliers. (Figures adapted from Xue et al., 2009, Water Research 43: 1159-1170)

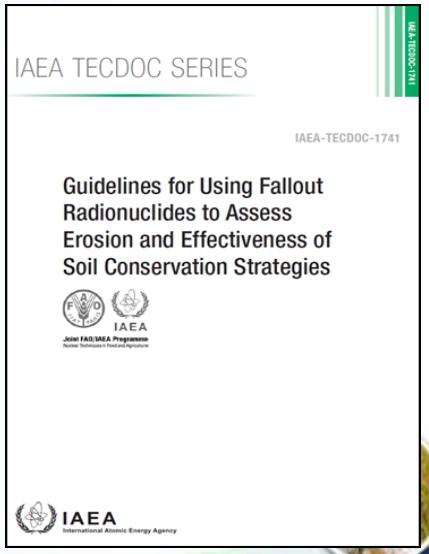
Nuclear Techniques for Assessing Soil Erosion

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

- **Fallout Radionuclides (FRNs) (Caesium-137; Lead-210; Beryllium-7)**
  - **Assessing soil erosion**
  - **Determining sediment in reservoir (sedimentation rates)**
  - **Developing soil conservation strategies at landscape level**
  - **Linking soil redistribution and soil quality (e.g. soil organic matter) in the landscape**

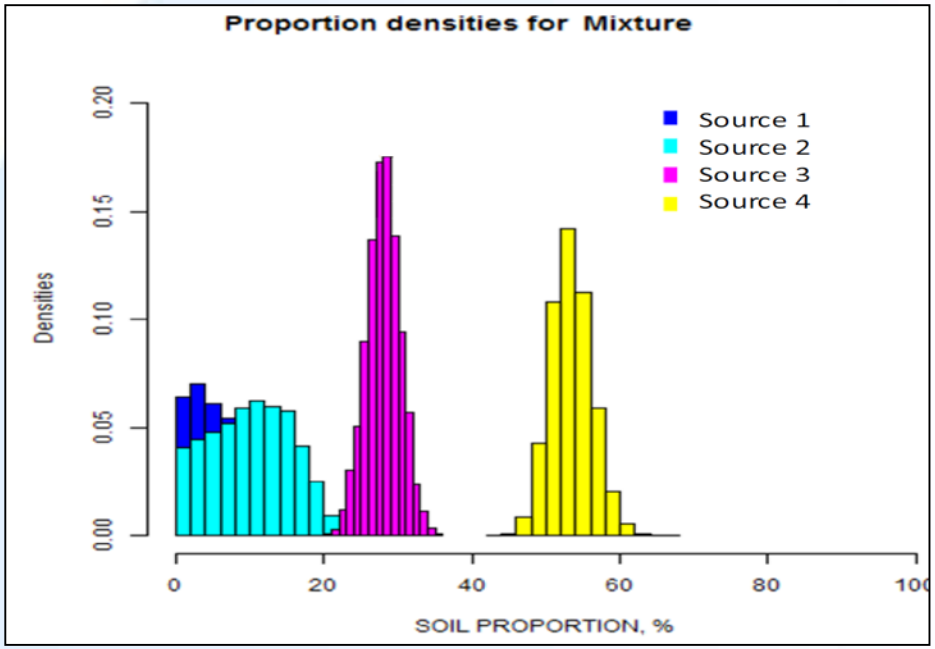


Adapted from : Zupanc, V., Mabit, L. (2010). Nuclear techniques support to assess erosion and sedimentation processes: preliminary results of the use of ^{137}Cs as soil tracer in Slovenia. *Dela*, 33, 21-36.



The FRNs Guidelines (i.e. IAEA TECDOC 1741)

CSSI (Compound Specific Stable Isotope)



Fingerprinting techniques for tracking and apportioning of soil/sediment sources

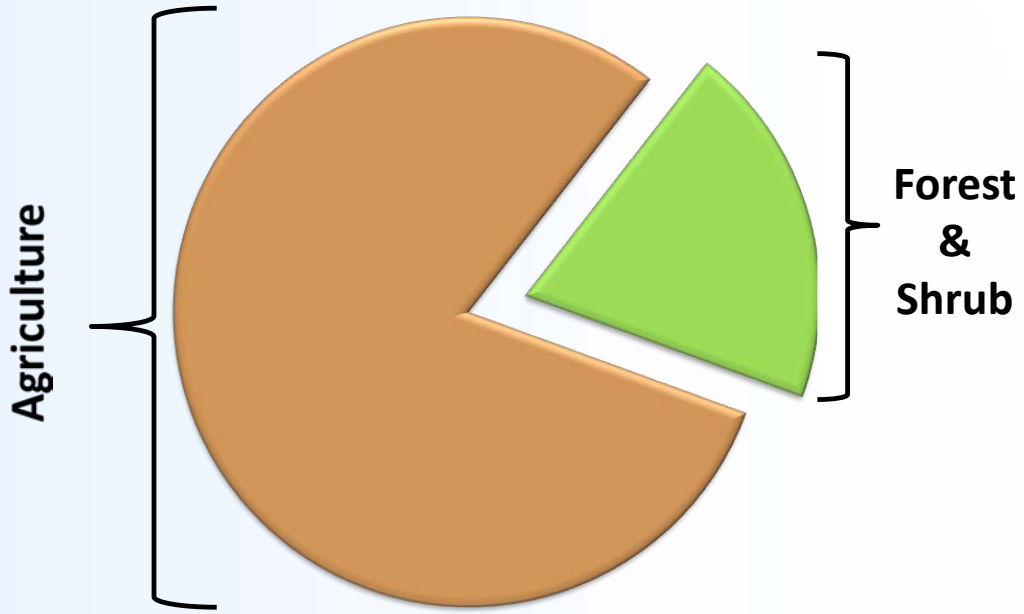
CSSI + FRN (^{210}Pb +^{137}Cs) combined for investigating historical land degradation and linking with land use history

Sedimentation & Water Quality Issues in Inle Lake

Inle Lake Watershed

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

We want to know the origin of the sediment deposited in the lake through $\delta^{13}C$ signatures in fatty acids – CSSI results



From CSSI: ??% of the sediment originates from agricultural fields

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Soil and Water Management & Crop Nutrition

The Soil and Water Management and Crop Nutrition (SWMCN) Section of the Joint FAO/IAEA Progr... and its associated SWMCN Laboratory assist FAO and ... development, validation and dissen... water and crop management techn... use of nuclear and nuclear-related ...

The aims are:
→ To enhance agricultural producti... of soil and water resources for sust... production systems and to improve farmers' livelihoods.
→ To improve soil quality and soil resilience against impacts of climate change and var...
→ To reduce greenhouse gas emissions and increase soil carbon sequestration in both ... lands.

To achieve these aims, we assist Member States through research and development (R... major emphasis on training the trainers, policy advice, technology transfer and technical support and assistance via

http://www-naweb.iaea.org/nafa/swmn/index.html

IAEA Myanmar & Asia-Pacific TC Projects

- Low N-tolerant rice varieties through the use of N-15 techniques (completed)
- Monitoring and Assessment of Watershed Management Practices on Water Quality and Sedimentation Rate of Inle Lake (Phase II) (National)
- **Climate Proofing Rice Production Systems: Nuclear Techniques for Climate Change Adaptation**
- **Assessing and improving soil and water quality to minimize land degradation and enhance crop productivity using nuclear techniques**
- **Reducing greenhouse gas emissions from agriculture and land use changes through climate smart agricultural practices**
- **Turning adversity into opportunity: Sustainable agricultural production and scaling-up on salt-degraded lands through integrated soil, water and crop management approaches - Phase II**

IAEA

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Thank you