Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Soil and Water Management & Crop Nutrition Section

Use of Nuclear Techniques in the Soil and Water Management & Crop Nutrition Sub-programme

The applications of nuclear-based techniques outlined below address issues of global concern in soil and water management and crop nutrition. However, the list is not exhaustive. Both stable (e.g. ^{10}B) and radioisotopes (e.g. ^{65}Zn) are used in the study of soil micronutrient disorders, which may be important on a local/regional scale. Additionally, there are applications of isotopes in the study of heavy metal pollution of soils (e.g. ^{115}Cd), and of nuclear-based techniques (tomography) in the study of soil fabric. Sterilization (gamma-irradiation) is another nuclear technique (process) with industrial or research applications (e.g. peat/sewage sludge/soils)

TREND / ISSUE	DESCRIPTION OF THE TECHNOLOGY	
	Nuclear technique	Advantages / disadvantages
1. Increasing competition for scarce water resources (irrigation) and deteriorating water quality (salinity)	• Soil Moisture Neutron Probe (SMNP)	Advantages: • Fast, economical, non-destructive, well adapted to field monitoring of sub-surface soil water cf. hand auger/gravimetric method • Provides instantaneous of volumetric soil water profile that is essential information to the soil water balance calculation • Allows irrigation scheduling according to crop needs or deficit irrigation strategy • Permits characterization of soil hydraulic properties Disadvantages: • Radiation protection and safety issues (sealed source): training, licensing, field storage/transport, disposal of old probes, personnel monitoring, etc. • Special probes need for surface-soil measurements
2. As above (urgent need to increase water use efficiency and to develop sustainable H_2O management systems)	• Variations in D, ^{18}O and ^{13}C natural abundance in soil and plant material	Advantages: • Permits selection of drought and salinity tolerant cultivars (^{13}C discrimination) • Allows sources of water transpired by plants to be identified (D, ^{18}O) • Identifies genetic diversity for hydraulic-lifted water in trees (D, ^{18}O) Disadvantages: • Precise analysis (D, $\delta^{13}C$, $\delta^{18}O$) requires skilled staff and an expensive isotope ratio mass spectrometer which is costly to maintain

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<tr><td rowspan="2">TREND / ISSUE</td><td colspan="2">DESCRIPTION OF THE TECHNOLOGY</td></tr>
<tr><td>Nuclear technique</td><td>Advantages / disadvantages</td></tr>
<tr><td>3. Widespread P deficiency especially, in acid soils of the tropics and sub-tropics</td><td>• ^{32}P- and ^{33}P-labelled materials
• Isotope dilution
• Isotopic exchange kinetics</td><td>Advantages:
• Direct measure of labelled P fertilizer recovery by crops. Assessment of P fertilizer management practices.
• Indirect assessment of the P supply from phosphate rock sources. Studies on ways/means to enhance phosphate rock sources.
• Complete characterization of available soil P and its dynamics by the isotope exchange method.
Disadvantages:
• Short half-life of ^{32}P (^{33}P marginally longer but more expensive) for crop uptake and residue decomposition studies (disposal advantage)
• Safety issues (open source), training, licensing, storage and disposal of contaminatyed wastes.
• Skilled staff and adequate laboratory facilities for handling and measuring radioisotopes.
• Limitations for widespread use in field experiments</td></tr>
<tr><td>4. Widespread N deficiency in cropped soils (low soil organic matter)</td><td>• ^{15}N labelled materials
• Isotope dilution techniques
• Variations in ^{15}N natural abundance</td><td>Advantages:
• Stable isotope (no health hazard)
• Direct estimate of fertilizer N uptake by crops (enriched or depleted sources), efficiency of fertilizer N practices and estimate of fertilizer loss by mass balance
• Direct and indirect estimates of the contribution of organic sources to crop N nutrition (enriched)
• Direct and indirect estimates of biological N fixation (enriched and natural abundance), N sparing and transfer of legume or biologically-fixed N to non-legume crops in sequence or intercropping
• Studies on nitrogen processes in the soil-plant system (nitrification, gross N mineralization and immobilization, nitrate reduction, denitrification) by isotope dilution and variations in ^{15}N natural abundance.

Disadvantages:
• Precise analysis of ^{15}N enriched samples requires trained staff and an expensive analyser (emission spectrometer with modern electronics), which is difficult to</td></tr>
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	Nuclear technique	Advantages / disadvantages
		maintain in agricultural institutes of developing countries. In the case for natural abundance analysis ($\delta^{15}N$) skilled staff and a more expensive isotope ratio mass spectrometer are needed. • Relatively high cost of ^{15}N-enriched materials, especially for small amounts or high enrichments
5. Increasing incidence of S deficiency (low soil organic matter and reduced anthropogenic inputs)	• ^{35}S or ^{34}S labelled materials • Variations in ^{34}S natural abundance	<u>Advantages:</u> • Stable isotope ^{34}S (no health hazard) • Sufficiently long half-life of ^{35}S for crop uptake and residue decomposition studies • Direct estimate of fertilizer S uptake by crops (^{34}S-enriched sources) and estimate of fertilizer loss by mass balance <u>Disadvantages:</u> • Precise analysis ($\delta^{34}S$) requires skilled staff and an expensive mass spectrometer which is costly to maintain • High cost of ^{34}S-enriched materials
6. Widespread and serious depletion of soil organic matter reserves (poor soil chemical and physical characteristics)	• ^{14}C or ^{13}C labelled materials • ^{14}C-dating of soil organic matter • Variations in ^{13}C natural abundance	<u>Advantages:</u> • Direct estimates of decomposition rates of labelled organic residues (residual labelled C or labelled CO_2 respired) • Estimate of Mean Residence Time of soil organic matter (^{14}C-dating) • Identify sources (C4 or C3) of organic matter breakdown and organic carbon sequestered in the soil profile on the basis of isotopic ratio ^{13}C / ^{12}C signature <u>Disadvantages:</u> • Safety issues (open source), training, licensing (^{14}C) • Disposal of ^{14}C-labelled materials and contamination of soil with ^{14}C • Prohibitive cost and sophistication of ^{14}C-dating
7. Accelerated rates of soil erosion, a major factor in soil degradation and loss of productivity	• ^{137}Cs inventory in soil • Other fallout radionuclides (^{210}Pb, ^{7}Be)	<u>Advantages:</u> • Retrospective medium-term estimates of soil erosion and sedimentation spatial patterns and rates at the landscape and watershed scale at different tropical soils. • Soil losses can be related to land use and management, topography and lithology. • Data can be used to validate predictive models and provide an economic analysis of erosion impact and conservation measures • Special structures (erosion plots) with long-term resource commitment are not

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		required Disadvantages: • Low activity of ^{137}Cs (especially in southern hemisphere soils) requires extended counting times (low sample throughput) and EQA services for low level γ-spectrometry • Dedicated gamma-counting equipment generally not available in developing countries • Need for multi-disciplinary (inter-institutional) research teams • Basic soil erosion research
8. Reclamation of saline soils (dryland and irrigated)	• SMNP • ^{36}Cl tracer • Variations in ^{13}C natural abundance	Advantages: • SMNP (refer to Item 1) • Percolation rates/salt movement (^{36}Cl) • Permits selection of transpiration efficient (arid) or inefficient (waterlogged) cultivars (^{13}C discrimination) Disadvantages: • As indicated previously for SMNP, radioisotopes, etc. • ^{13}C discrimination can be effectively used in C-3 plants
9. Continuing concern over soil-derived greenhouse gases and ozone-depleting substances	• ^{63}Ni or tritium electron capture detector (N_2O) • Flame ionization detector (CH_4) • ^{15}N- and ^{13}C-labelled fertilizers	Advantages: • Gas chromatographic methods are sensitive and rapid Disadvantages: • Need to use chambers (artificial environment) to collect gases • Emitted gases are entrapped in flooded soils • Need to use highly enriched fertilizers in denitrification studies with sophisticated mass spectrometric and data analyses by skilled staff