Compound-specific stable isotope analysis for improving precision soil conservation strategies: An overview of the lessons learnt in a FAO/IAEA Coordinated Research Project

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IAEA
Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Atoms for Food and Agriculture: Meeting the Challenge

Need for new tools for more efficient land conservation at landscape level

- From erosion budget (FRN) to identification of critical areas of land degradation
- Information on source is a key requirement for targeting sediment control measures *(Walling et al., 2008)*
- Focus efforts and limited funds available for soil conservation.

Photo by Petra Schmitter,
University of Hohenheim, Germany

Coordinated Research Project D1.20.11

Title: **„Integrated Isotopic Approaches for an Area-wide Precision Conservation to Control the Impacts of Agricultural Practices on Land Degradation and Soil Erosion (2009-2013)“**

Objective:

- ✓ To develop the integrated use of both fallout radionuclides (FRN) and compound-specific isotopic analysis (CSIA)
  - To establish comprehensive soil redistribution patterns and
  - to identify hot spots of critical land degradation in agricultural landscapes for cost-effective implementation of precision conservation measures.

Duration: 2009 - 2013, 17 participants

Where are those hot spots of critical land degradation?

Source 5 – Bamboo forest

Source 4 – Timber wood plantation

Source 1 – Homesteads?

Source 2 - Maize

Which land use in the uplands is causing this damage to rice paddies in the lowlands?

Source 3 - Cassava

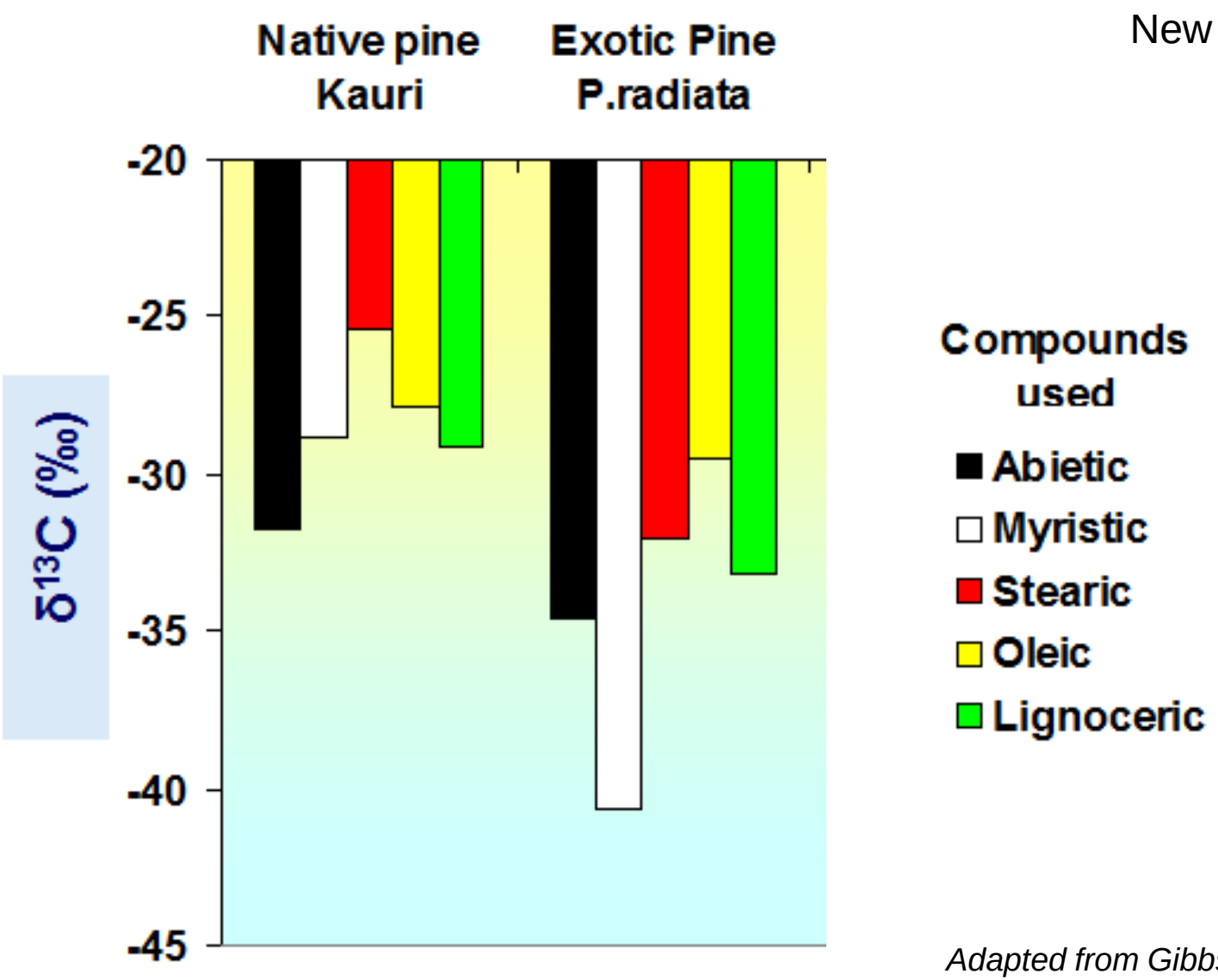
Concept of the use of Compound-Specific Isotope analysis (CSIA)

- … The concept behind the CSIA method is that **“land use”** is usually defined by the **plants growing** on that land.

- All plants produce a **range of organic compounds** that “leak” from the roots or leach from leaves into the soil
    - Soluble in water
    - Bind to soil particles
    - “**fingerprint**” to identify the source by its spectrum

- Different plants produce a similar range of organic compounds but with **different isotopic $\delta^{13}C$ values**

CSIA of fatty acids for different plant species



New Zealand

Adapted from Gibbs et al., 2008

Compound-Specific Isotope Analysis

Sample collection + preparation

Separation of fatty acids
Extraction with CH_2Cl_2-MeOH

Derivatisation
Conversion of fatty acids to their methyl esters

Compound-Specific Isotope Analysis
GC-c-IRMS

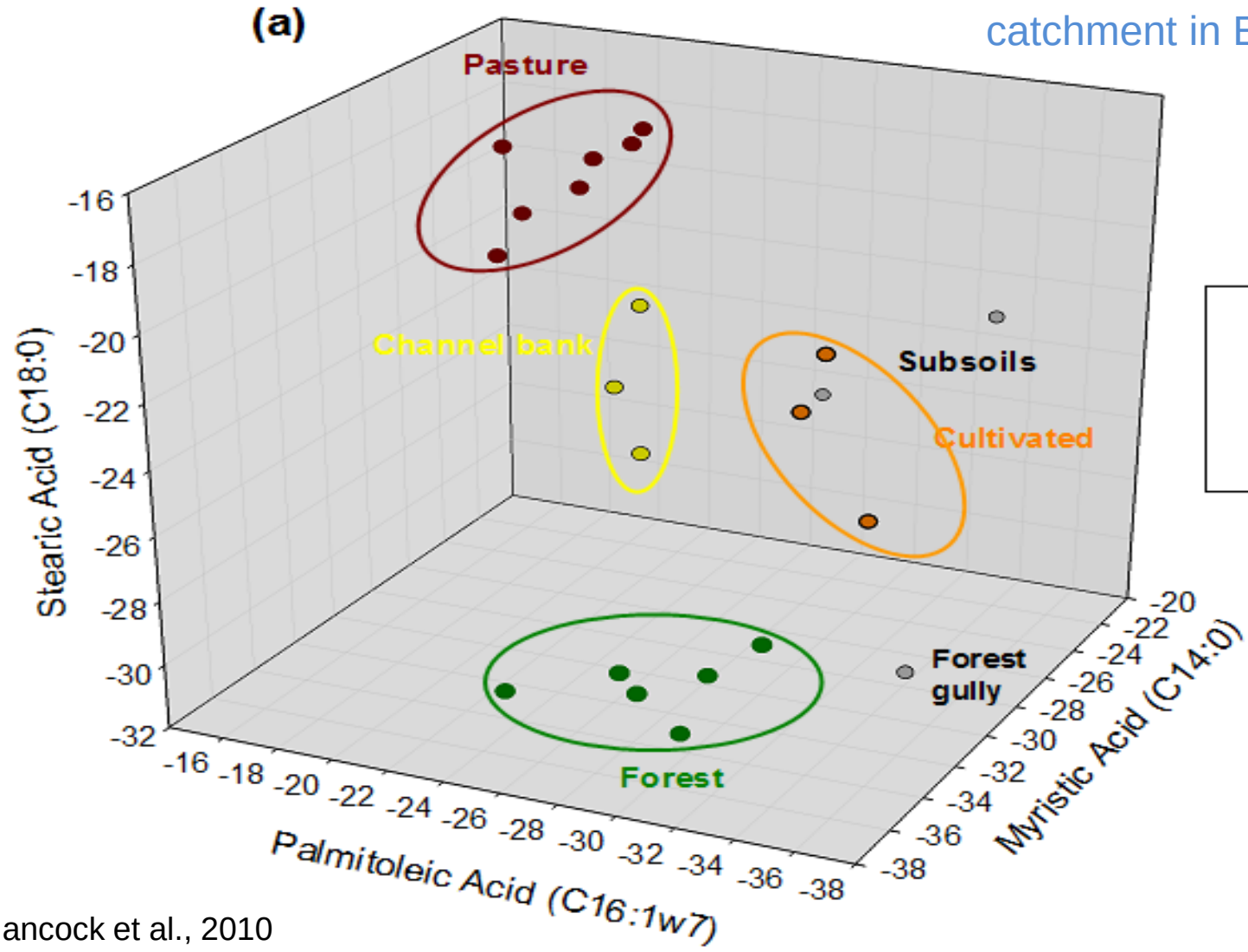
Specific instruments and skills

- Bulk ^{13}C signatures of sediment can provide general information about sediment sources → More precise detailed information by CSIA

- CSIA requires specific instruments and skilled operators (*Linking gas-chromatography via an on-line combustion interface to isotope ratio mass spectrometry*).
  - Current analysis costs are high
  - Cost of the analysis is expected to drop dramatically in the coming years, reducing to as little as 65 US$ per sample.

CSIA of fatty acids for different land uses

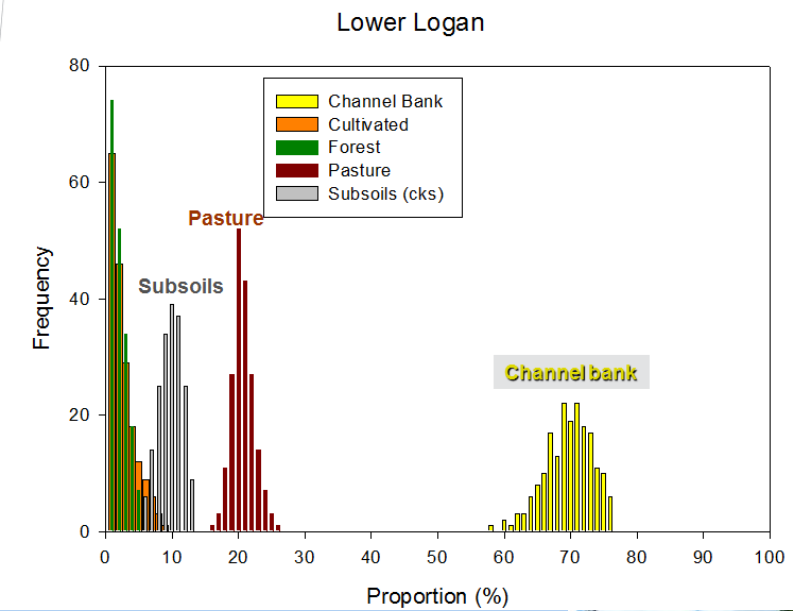
Rural coastal Australian catchment in East Australia



Hancock et al., 2010

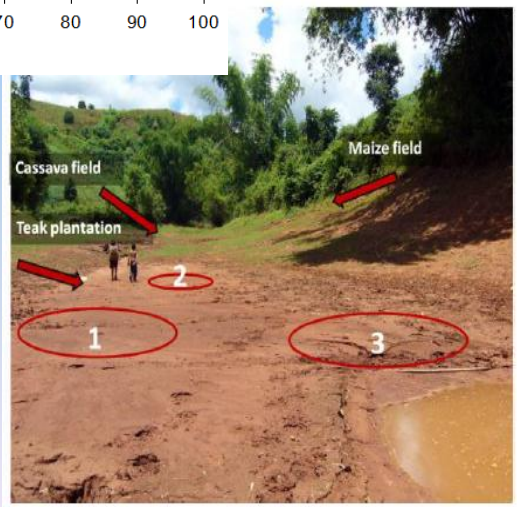
National Research FLAGSHIPS Water for a Healthy Country CSIRO

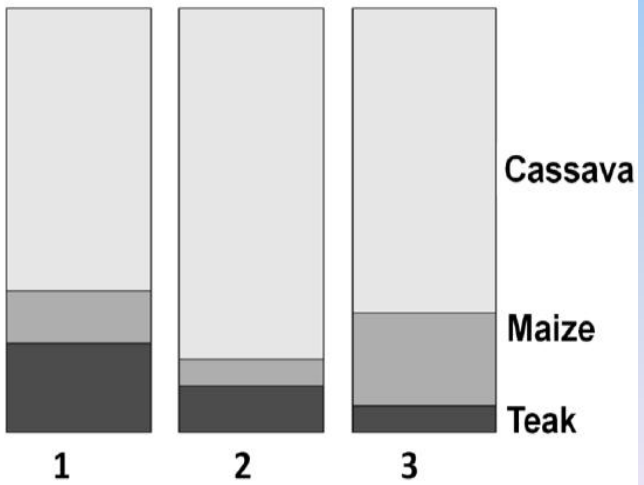
Critical hot spots of land degradation?



East Australia
(Hancock et al., 2010)

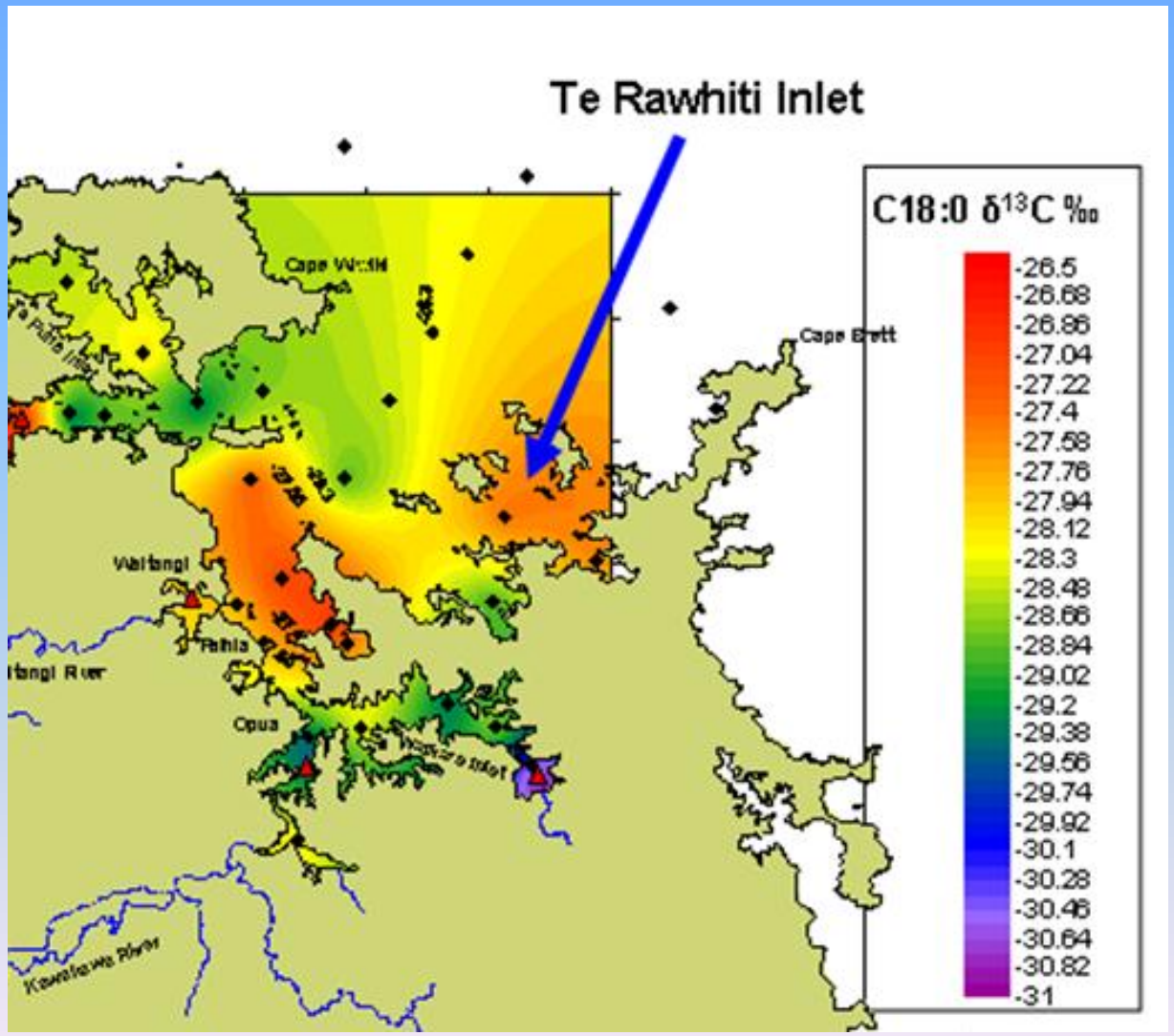
Mixed Modelling Approaches





North West Vietnam
(Brandt et al., 2011)

Spatial variability of sediment deposition



Adapted from Gibbs, 2010

Summary of suitable specific organic compounds to identify and apportion areas sensitive to erosion through CSIA

Type	Origin	Applications	Advantages	Limitations
Fatty acids (^{13}C)	Root exudates; Plant materials; Animals	Land-use soil source identification, to the root depth	✓ Isotopic signature conservative. ✓ Polar, move deep into the soil with water ✓ Tightly bound to clays.	✓ Concentrations low in older or sandy soils (larger sample) ✓ Mixed land-use history difficult to resolve?
Alkanes (^{13}C)	Leaf waxes	Surface soil discrimination by land-use. Top layer only	✓ Isotopic signature conservative. ✓ Non polar, do not move by water, and waxes adsorbed onto surface soil layers only.	✓ Surface layer eroded first so signature rapidly removed from source. ✓ Need for different GC column to separate.
Resin acids (^{13}C)	Pine trees	Identifying pine harvest as soil source	✓ Specific to pine trees. ✓ Specific resin acid half life gives time since deposition.	✓ Rapid decay of abietic acid in sunlight within a month
Amino sugars (^{13}C)	Soil fungi bacteria	Tillage vs no tillage	✓ Discriminates land management, e.g. conservation agriculture.	✓ Many unknowns to be investigated
Fatty acids (Deuterium)	Root exudates; Plant materials; Animals	Altitude in a single land use	✓ Adds new dimension	✓ Extra cost for analysis

Harmonized Protocol

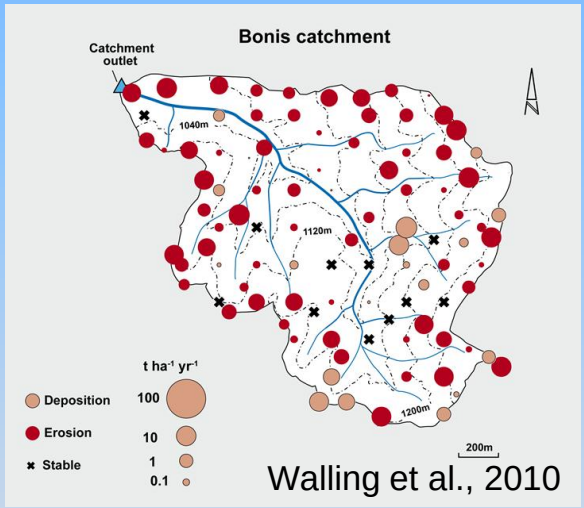
A harmonized protocol for the application of CSIA to identify critical sediment source areas and erosion hotspots at the catchment scale (focus mainly on the use of fatty acids) → Data exchange and comparison

- Tested in Australia, Austria, Belgium, Canada, Ethiopia, Germany, New Zealand, United Kingdom and Vietnam
- To be tested 2012-2013 in Chile, China (2), Morocco, Poland, Russia and Syria

Boeckx et al., 2010

Integration of CSIA with fallout radionuclides (FRNs) based techniques

- ✓ FRNs are powerful tools for assessing landscape-wide soil redistribution and identifying erosion processes



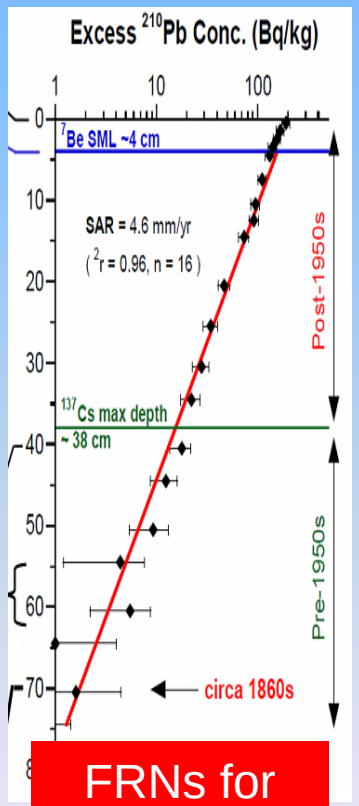
Walling et al., 2010

- ✓ Use of ^{7}Be (short half-life of 53 days) for identification of recent sediment deposits, which can then be sampled for CSIA so that hotspots of recent land degradation can be identified

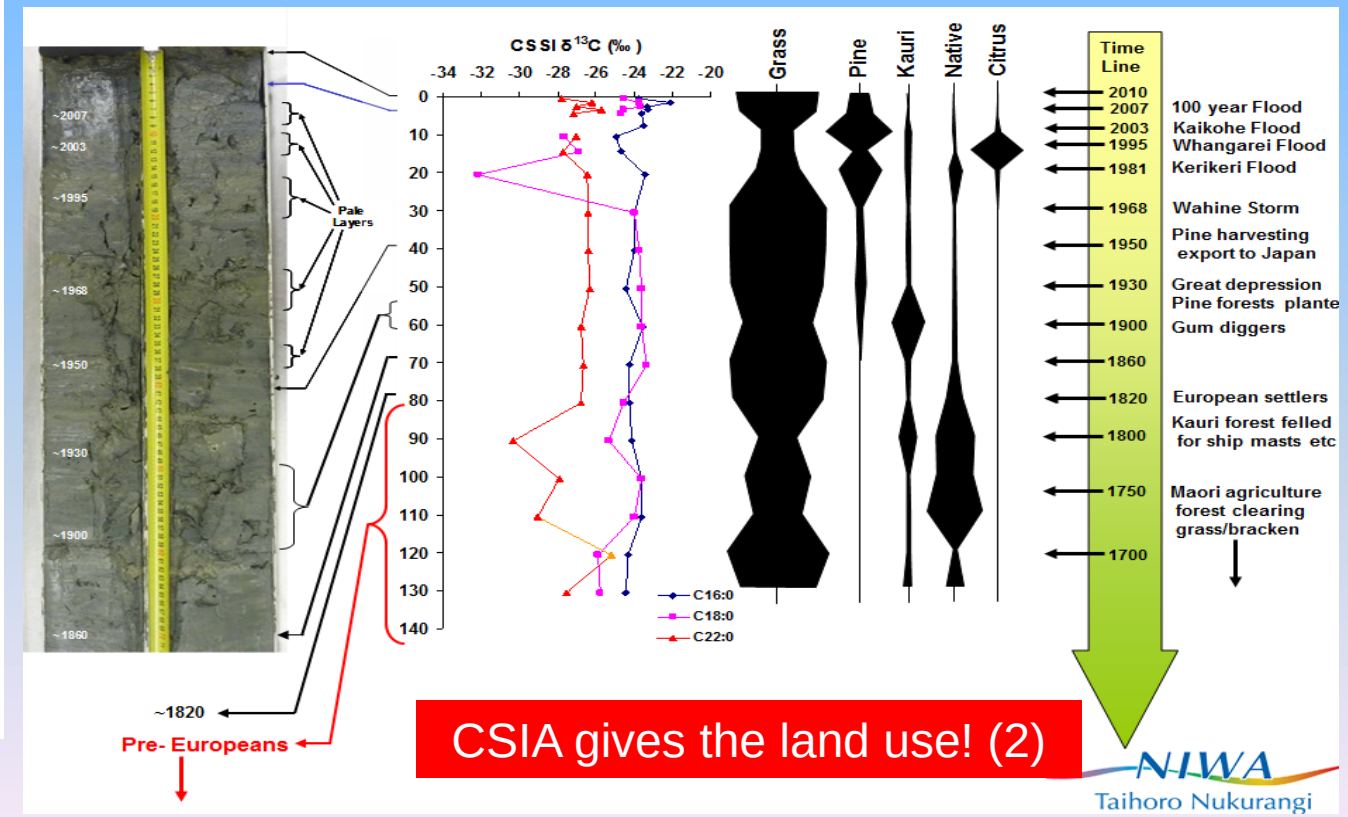
Integration of CSIA with fallout radionuclides (FRNs) based techniques (2)

Linking of FRNs (^{137}Cs and ^{210}Pb) with CSIA →

Past land degradation and its linkage with land use history.



FRNs for dating (1)



CSIA gives the land use! (2)

Cs-137

Pb-210

Many thanks for your attention!

CRP D1.20.11 team