# Integrated analysis on soils and ecosystem processes in southern and eastern Cameroon for establishing sustainable agriculture

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## *Facts and question on sustainable agriculture*

- Agricultural practices inevitably remove certain amounts of essential nutrients, such as N, P, K, Mg and Ca, from the agro-ecosystems by harvesting agricultural products and also through leaching/erosion losses.
- We have to minimize such losses and then compensate them in order to maintain agricultural productivity for long period of time.
- Then, what can we do?

## Objectives and outline of the study

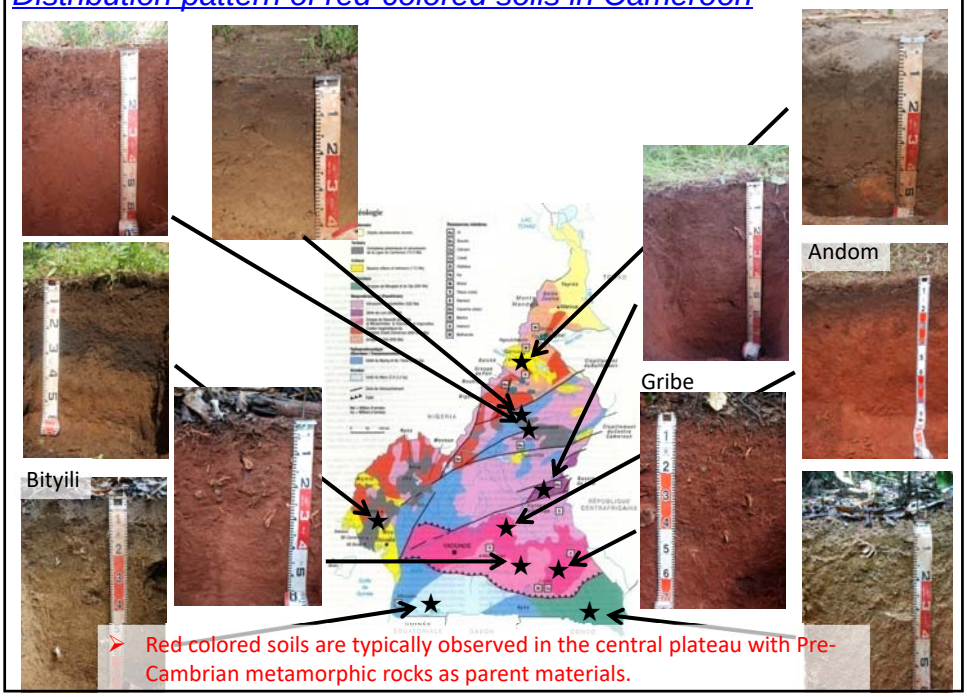
- This work intends to summarize the respective activities of soil ecological studies of the FOSAS project, in order to give basic recommendations for enabling sustainable agricultural development while maintaining the precious forest resources in the targeted regions of southern and eastern Cameroon.
- Agro-ecological conditions were evaluated from three different viewpoints, i.e., soil fertility status, risk of nutrient leaching loss, and risk of soil erosion, and overall recommendations are given for agricultural practices in the targeted regions.

  - ✓ Extensive soils survey in different regions of Cameroon
  - ✓ Intensive soil survey in Andom and neighboring areas
  - ✓ *In situ* soil ecological study at forest, savanna, and cropland in Andom (and in Gribe) to describe nutrient dynamics
  - ✓ Micro-scale monitoring of water budget and soil erosion in sloped land at Andom and Bityili

Soil fertility status | Risk of fertility loss | Risk of soil erosion

Overall recommendations are given for agricultural practices in the targeted regions.

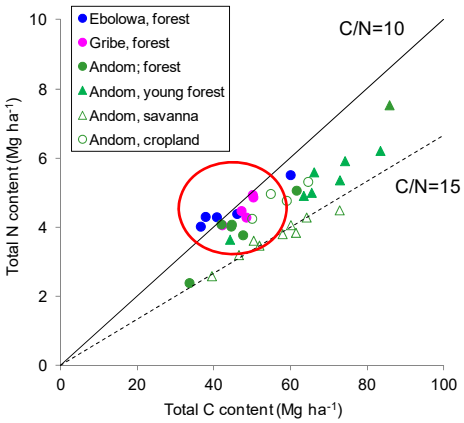
## Distribution pattern of red-colored soils in Cameroon



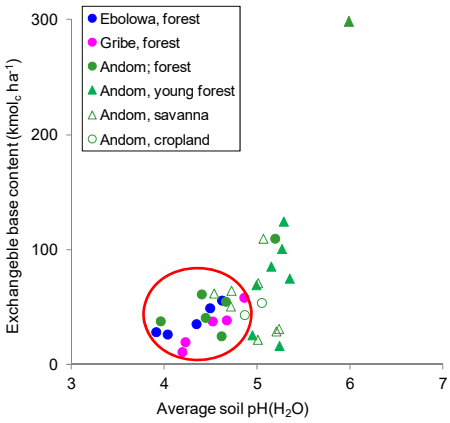

- Red colored soils are typically observed in the central plateau with Pre-Cambrian metamorphic rocks as parent materials.

## Chemical properties of surface soils distributed in three villages

a) Organic matter stock in the surface 30-cm layers of soil



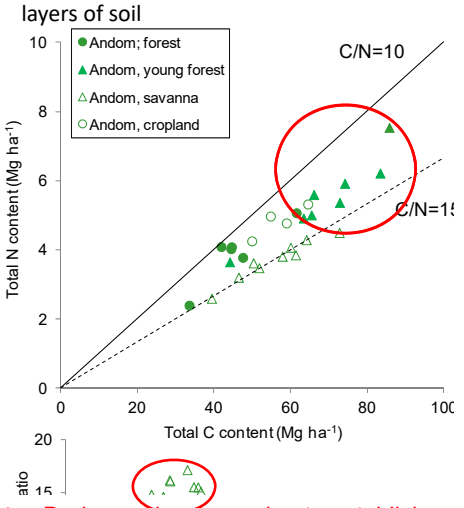

b) Soil pH and total stock of the exchangeable bases (Na, K, Ca and Mg) in the surface 30-cm layers of soil




- The amounts of organic C and N in surface soils were similar under matured forest in all the three villages.
- Overall acidity and the level of exchangeable bases were similar among matured forests in the three regions; characterized typically by low pH and low base status.

## Chemical properties of surface soils distributed in Andom

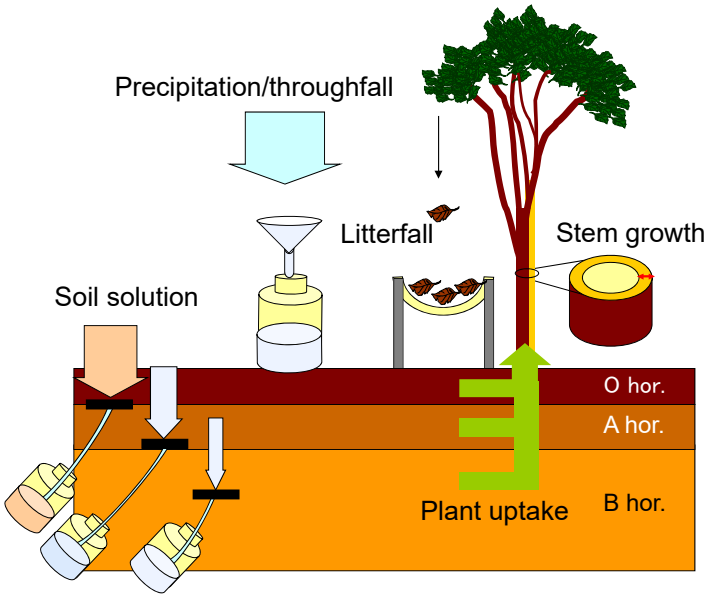
a) Organic matter stock in the surface 30-cm layers of soil



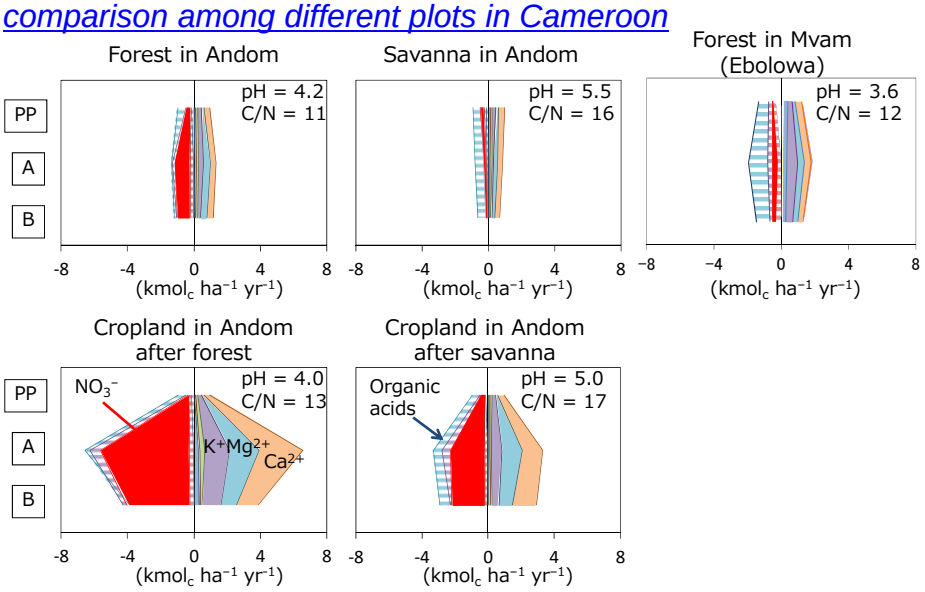

- In young fallow forest (8-30 years), organic matter level was higher than in the other stages, while C/N ratio there in the very surface horizon already reached at the same level of matured forest.
- The C/N ratio was higher at the very surface layers of soils in savanna.

- During early succession to establish young secondary forest, basic cations were accumulated and soil pH raised in the surface soils, presumably due to a pump-up effect of deep soil nutrients by root systems. The increased bases in the young forest were, however, gradually mitigated during further growth to matured forest presumably through intensive accumulation of basic cations into stems of big trees.

## Determination of fluxes of water and mineral nutrients

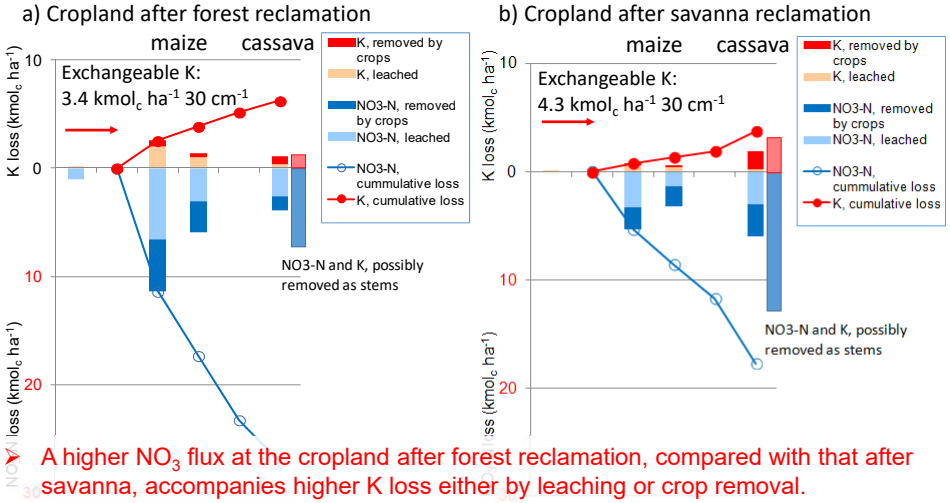



## Alteration of ion fluxes after forest reclamation: comparison among different plots in Cameroon



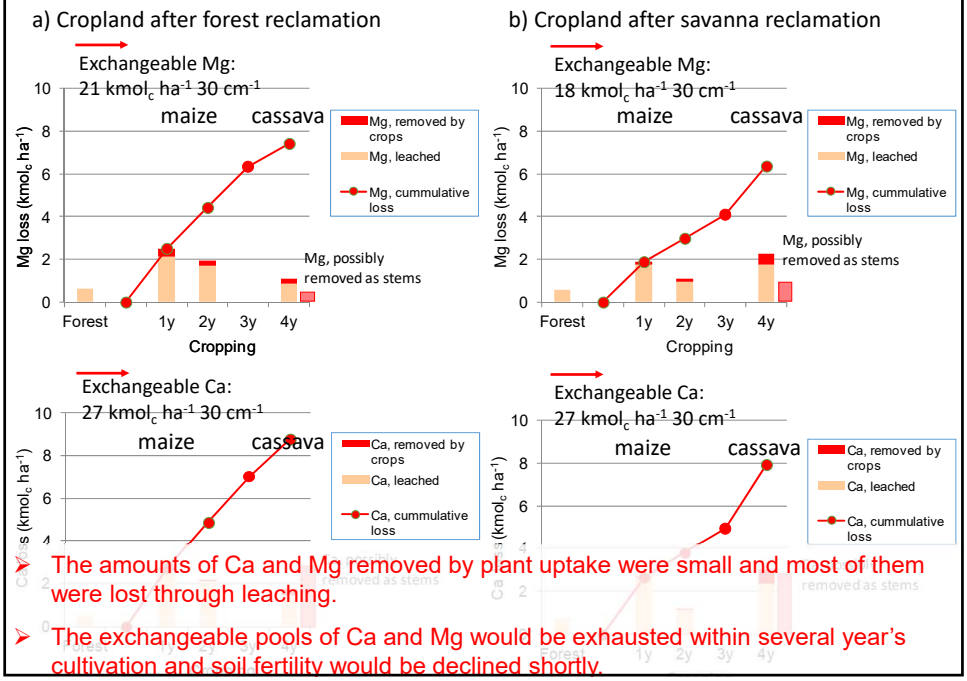

- The nitrification and the subsequent $NO_3$ flux are the driving forces to increase cation fluxes in croplands.

## Estimation of removal of N and K from the soils




- A higher $NO_3$ flux at the cropland after forest reclamation, compared with that after savanna, accompanies higher K loss either by leaching or crop removal.
- Exchangeable pool of K is not enough to compensate the K loss. Mineral weathering is an essential process for K nutrition even in Ferralsols.
- Note that cassava planting may result in huge loss of mineral nutrients through an intensive uptake by cassava plants and subsequently removal of most of their biomass.

## Estimation of removal of Mg and Ca from the soils




- The amounts of Ca and Mg removed by plant uptake were small and most of them were lost through leaching.
- The exchangeable pools of Ca and Mg would be exhausted within several year's cultivation and soil fertility would be declined shortly.

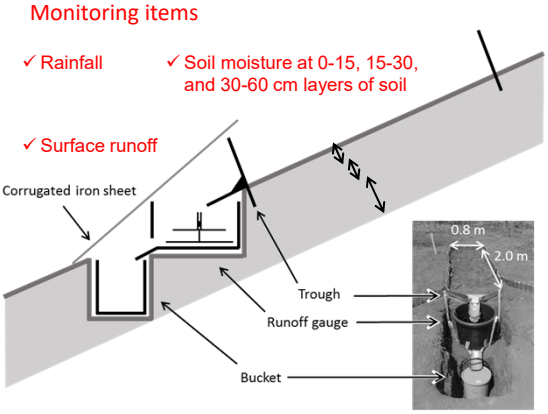
## *Determination of water budget and surface runoff generation in micro-scale (0.6 m * 2 m) erosion plot using datalogger system*

Monitoring items

✓ Rainfall

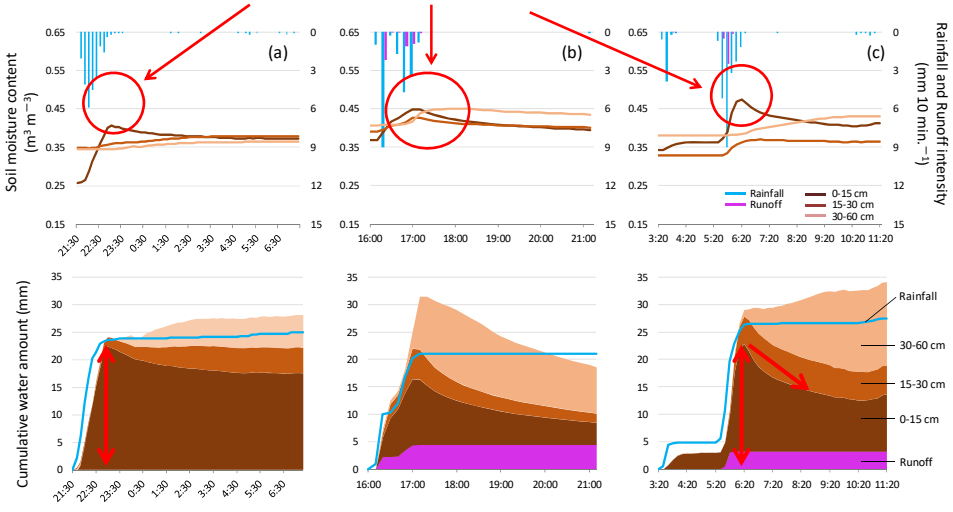
✓ Soil moisture at 0-15, 15-30, and 30-60 cm layers of soil

✓ Surface runoff




## *Water dynamics during rainfall events at sloped cropland in Andom*

Apparent saturation by water is between 0.4 to 0.45 $m^3$ $m^{-3}$.




Rainfall event 1; to dry surface

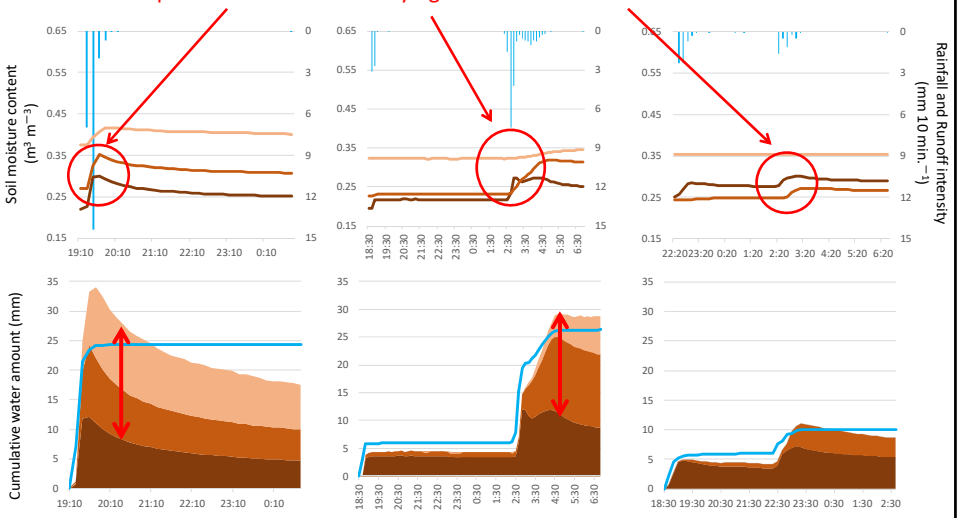
Rainfall event 2; to wet soils

Rainfall event 3; two steps sequentially, firstly to dry and secondly to moistened surface.

➢ Rapid invasion of water into the surface layers is observed, followed by sequential percolation into underlying horizons after saturation of the upper layers.

## *Water dynamics during rainfall events at sloped cropland in Bityili*

Water starts to percolate into the underlying horizons even at unsaturated level of 0.25 $m^3$ $m^{-3}$.




Rainfall event 1; heavy rainfall to the dry surface

Rainfall event 2; two steps sequentially, firstly to dry and secondly to moistened surface.

Rainfall event 3; heavy rainfall to the dry surface

- Rain water penetrates immediately to the subsoils, possibly due to bypass flow.

## *Overall evaluation of agro-ecological conditions at three villages*

- ✓ Extensive soils survey in different regions of Cameroon
- ✓ Intensive soil survey in Andom and neighboring areas
- ✓ *In situ* soil ecological study at forest, savanna, and cropland in Andom (and in Gribe) to describe nutrient dynamics
- ✓ Micro-scale monitoring of water budget and soil erosion in sloped land at Andom and Bityili

Soil fertility status | Risk of fertility loss | Risk of soil erosion

Overall recommendations are given for agricultural practices in the targeted regions.

## Overall evaluation of agro-ecological conditions at three villages

| | Chemical and mineralogical properties of soils | | | Nutrient supply and risk of leaching loss in cropland basrd on the solution study | |
|---|---|---|---|---|---|
| | Level of organic matter (30 cm layers of soils) (*a*) | CN ratio (A hor) (*b*) | pH and base status (30 cm layers of soils) (*c*) | Supply and leaxhing risk of N and K (*d*) | Supply and leaxhing risk of Ca and Mg (*e*) |
| Gribe | low (OC < 50 Mg ha$^{-1}$) | low (9-12) | low (pH 4-5) | high | moderately high |
| Bityili | low (< 50) | low (10-12) | low (3.5-5) | possibly low | possibly low |
| Andom forest | low (< 50) | low (10-12) | low (4-5) | high | moderately high |
| savanna | moderately high (40-80) | high (12-17) | intermediate (4.5-5.5) | moderately low | moderately low |
| East Kalimantan | low (< 50) | moderately low (10-15) | low (4-5) | low | low |
| Northern Thailand | high (> 80) | high (12-18) | high (5-7) | moderately high | high |

| | Parameter for erosion risk evaluation | | Evaluation from respective conditions | | |
|---|---|---|---|---|---|
| | Water permeability (*f*) | Topography (*g*) | Relative soil fertility status based on (*a*) to (*e*) | Risk of leaching loss based on (*d*) and (*e*) | Erosion risk based on (*f*) and (*g*) |
| Gribe | possibly high | gentle | moderately high (3/5) | high | low |
| Bityili | high | steep | low (1/5) | low | moderately high |
| Andom forest | possibly high | gentle | moderately high (3/5) | high | low |
| savanna | high | gentle | moderately low (2/5) | moderately low | low |
| East Kalimantan | possibly very low | steep | low (1/5) | low | high |
| Northern Thailand | possibly low | steep | high (4/5) | high | high |

## General recommendation for agricultural practices in three villages

| | Evaluation from respective conditions | | |
|---|---|---|---|
| | Relative soil fertility status | Risk of leaching loss | Erosion risk |
| Gribe | moderately high | high | low |
| Bityili | low | low | moderately high |
| Andom forest | moderately high | high | low |
| savanna | moderately low | moderately low | low |

1) At Gribe, combination of banana, cacao and agroforestry is recommended, to avoid leaching loss of nutrients and to utilize soils with relatively-high fertility for long period in future.
2) At Bityili, soil erosion might be a primary risk for sustainable agriculture due to the pre-dominance of sloped land. Combination of banana, cacao and agroforestry is recommended. Cassava and other annual field crops may be available on relatively gentle slope or flat land.
3) At Andom-forest, the agro-ecological conditions are similar to Gribe. Combination of banana, cacao and agroforestry is recommended as sustainable land use.
4) At Andom-savanna, soil fertility might not be so high. Cassava planting on flat land may be one of the feasible options to utilize such soils. However, it should be noted that cassava planting may result in huge loss of mineral nutrients through an intensive uptake by cassava plants and subsequently removal of their biomass.

## *Discussion for establishing sustainable agriculture*

Facts and question

- Agricultural practices inevitably remove certain amounts of essential nutrients, such as N, P, K, Mg and Ca, from the agro-ecosystems by harvesting agricultural products and also through leaching/erosion losses.
- We have to minimize such losses and then compensate them in order to maintain agricultural productivity.
- Then, what can we do?

Answers

- There are essentially two ways for such compensation of nutrient losses.
- One is input from outside, for example, by adding chemical fertilizers and/or manures; so called "spatial redistribution of resources."
- The other is to utilize *in situ* natural ecosystem processes; so called "ecosystem redistribution of resources."

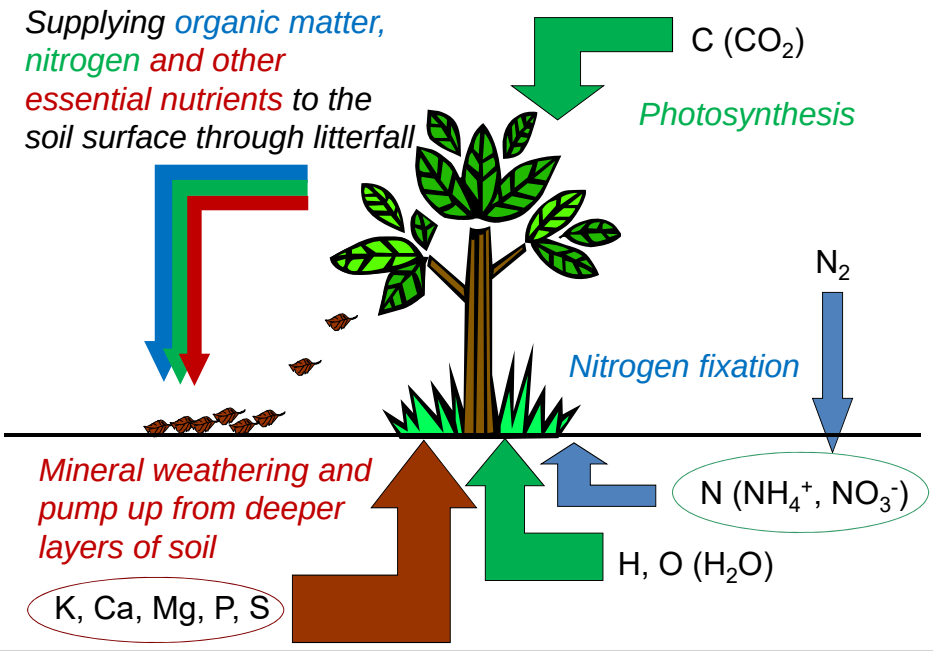
Example of "spatial redistribution of resources"
(1) Banana/coffee plantation by Haya ethnic group on Ferralsols in west of Lake Victoria, northwestern Tanzania

Example of “spatial redistribution of resources”
(2) Banana/coffee plantation by Chaga ethnic group on Andosols in Kilimanjaro region, northern Tanzania


Details of the second option, “ecosystem redistribution of resources”

- The essential source of N is the atmosphere. In order to recover soil N, we can utilize and enhance the biological nitrogen fixation.
- Most of mineral nutrients is originated from soils and lithosphere. The essential process to incorporate mineral nutrients to biological cycle is the liberation of nutritional ions from mineral crystals through mineral weathering. Plant root system, especially of trees, is excellent for this ability; it can extend its activity to deeper layers of soils where more amounts of mineral nutrients may present, it can promote mineral weathering by adding acid loads to soil, and it can return such nutrients once acquired to the soil surface through litter-fall.
- In this context, crop rotation systems including forest fallow, such as shifting cultivation, are rather simple approaches for utilizing the function of forest in a temporal sequence.
- Agro-forestry and/or mixed cropping of trees and annual crops similarly depend on the ability of tree root system for nutrient replenishment, but require more complicated processes for allocation of several plants.

## Nutrient replenishment of soil through the function of tree vegetation




Example of “temporal redistribution of resources”: a systematic shifting cultivation by Karen ethnic group on Acrisols in northern Thailand


Cutting fallow forest in late dry season


Burning


Landscape just after burning

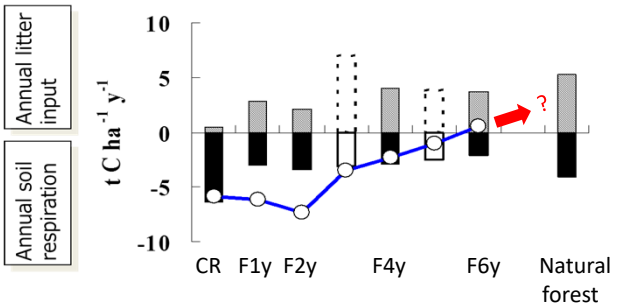

Upland rice planting during rainy season

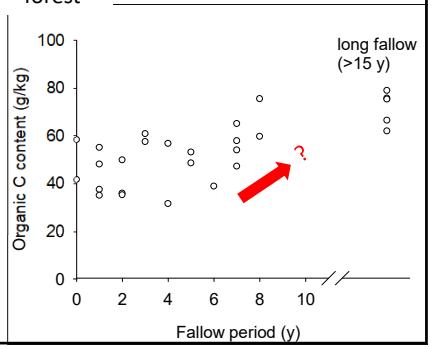
Landscape during fallow phase of shifting cultivation in northern Thailand





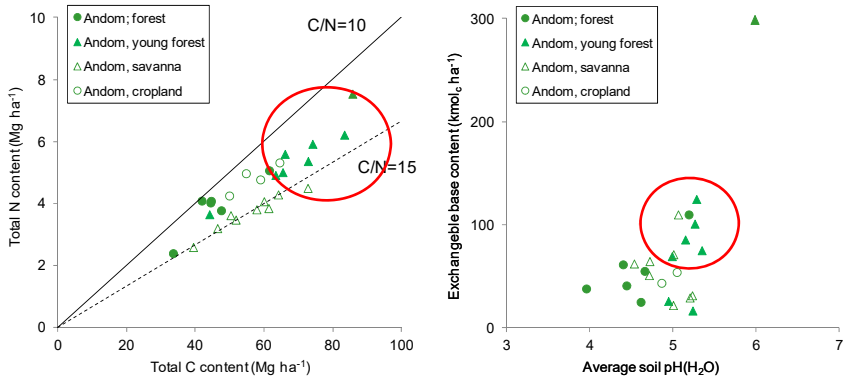
Annual input and output of organic matter of the soils with a cumulative budget under shifting cultivation in northern Thailand



*Specific recommendation for agricultural practices using short-fallow forest*

1) Continuous cassava planting may accelerate nutrient loss from soil through an intensive uptake of nutrients by cassava plants and subsequently removal of most of their biomass.
2) It could be noted that, at Andom village, soil fertility status, i.e., the amount of soil organic matter stock and its quality (C/N ratio), the level of exchangeable bases, and soil acidity, is often remarkably high in the soils under young fallow forest compared with that in the other land use stages, presumably due to an active supply of forest litter to surface soil as well as the pump-up effect of deep-soil nutrients by root systems of forest vegetation.
3) Therefore, an inclusion of forest-fallow, instead of savanna vegetation, into the land use systems may greatly contribute to improve the soil fertility and to maintain it for a long period of time.







Example of *Acacia* plantation combined with cassava cropping in central Vietnam

*Find sustainable agricultural management, which well adapts in this region!*