UNIVERSITÀ POLITECNICA DELLE MARCHE



# Farming system and a possible presence of Terra Preta in Mozambique.

## How the system works and making it more sustainable.

*PhD student: Dominique Serrani*

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# Aim of the research

**The main research field is studying Mozambique soils and their fertility level, which is mainly affected by erosion, acidity and too intense leaching.**

# Research scheme



- Themes
  - Mozambique country
  - Mozambique soils
    FAO CLASSIFICATION
    - Is there Terra Preta?
  - Farming system
    - Slash and burn cultivation
      - Effect of fire on soil
    - Charcoal production

# Mozambique

## Know the country

# Mozambique Identity Card






Maputo



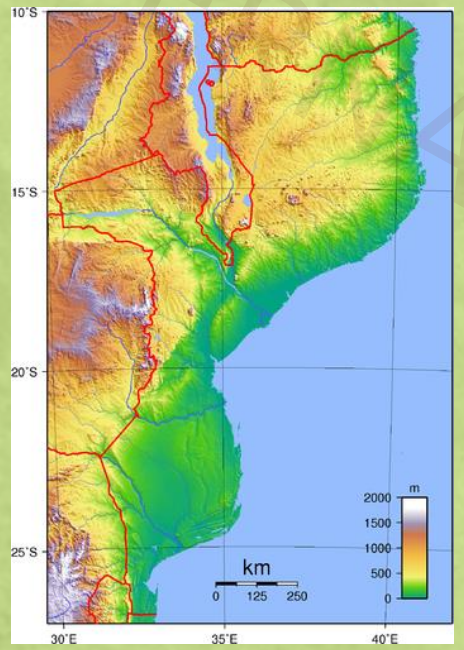
- **Extension:** 801 590 km²
- **Capital:** Maputo
- **Official language:** Portuguese
- **Government:** *Multi-party democracy*, current constitution was adapted in November 30th, 1990. The independence from Portugal was obtained in June 25th, 1975.
- **Population:** About 28 829 476 (The World Bank – 2016)
- **Fellowships:** Mozambique is a member of the *African Union*, the *Commonwealth of Nations*, the *Community of Portuguese Language Countries*, the *Latin Union*, the *Non-Aligned Movement*, and the *Southern African Development Community*.

# Geography and climate

Mozambique has two topographic regions, separated by Zambesi river.

- The northeast is an extended highland, with a coastal plain stripe originated from coral reef and in deeper Rift Valley mountain chain; typical vegetation is miombo woodlands.
- The southeast is an alluvial plain, covered by savannah and crossed from various rivers, the most important is Limpopo river.

(Portal do Governo de Moçambique)

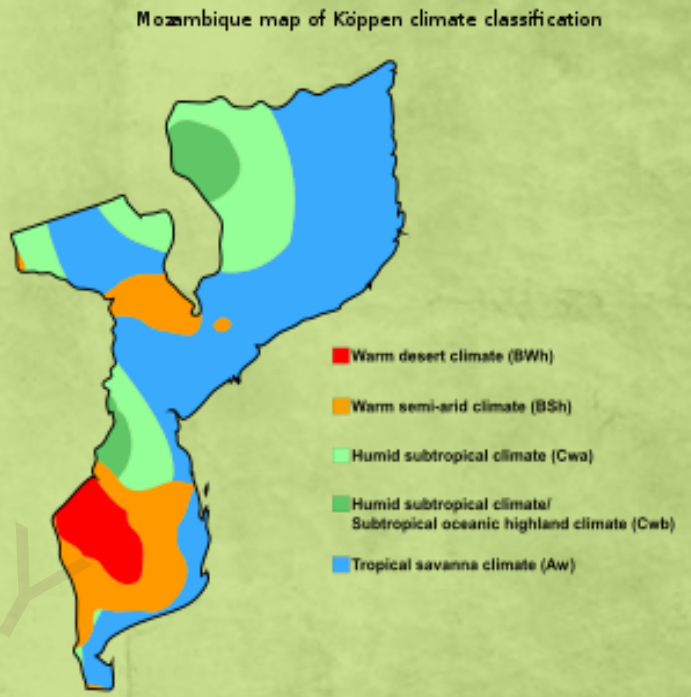



Mozambique has a tropical climate, with two seasons: a wet monsoon season from October to March, and a dry season from April to September.

However, climatic conditions are different along latitude: heavy rainfall in north highlands and coastal zone, and hotter conditions and lower rainfall in south lowlands.

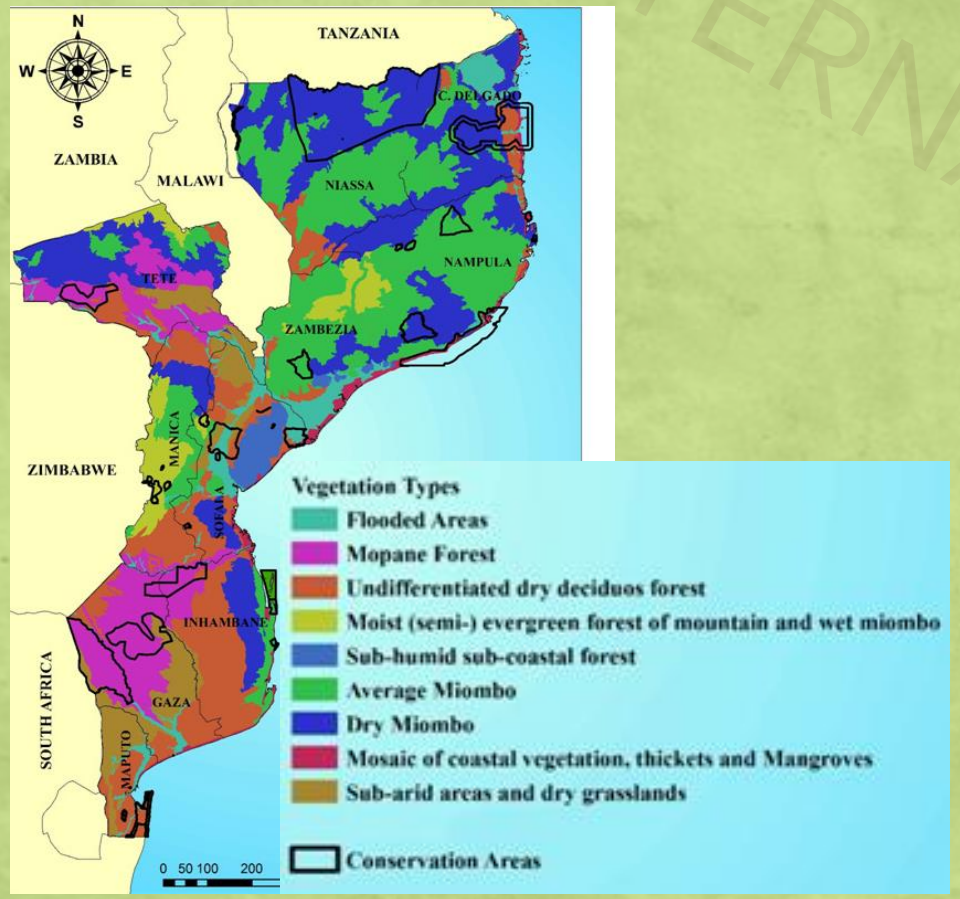
Cyclones and floods are common during the wet season in contrast to droughts during the dry season.

(Jones et al.,2013; Mafalacusser, J.M, 2013)



# Ecosystems

There are three main ecosystems in Mozambique:




## Miombo

The most common type of miombo has a structure of a "open forest" with two strata: the upper storey composed of woody vegetation of Brachystegia, Julbernardia, and Isoberlinia with others, and the lower storey composed of herbaceous species like Themeda triandra, Panicum, Hyparrhenia and Andropogon (Sitoe, 2004).

## Mopane

Open woodland comprised of an overstorey of *Colophospermum mopane* dominance and an understorey of grass and bushes (Veenendaal et al., 2004).

## Mangroves

Littoral plant formation adapted to live in extreme conditions of salinity, wind, tides, adverse temperature and muddy/sandy substrates.

The dominant species are *Avicennia marina* (Forssk.) Vierh., *Bruguiera gymnorrhiza* (L.) Lam., *Ceriops tagal* (Per.) C.B. Robinson, *Rhizophora mucronata* Lam. and *Sonneratia alba Smith.* (Barbosa et al., 2001).

# Mozambique economy

Slash and burn or itinerant system

Agriculture is one of the major economic sector, joined with agro-industry, mining industry, fishery and tourism.

| Country area | Land area | Agricultural area | Forest |
|---|---|---|---|
| 79938 (1000 ha) | 78638 (1000 ha) | 49950 (1000 ha) | 38146,4 (1000 ha) |

FAO estimate, 2014

**Recent updating**

In the last decades, demand for land has increased both in urban and rural areas. There has been a shift in land use from peasant smallholdings to real estate development and large commercial farms in some areas. In these cases, richer owners have the privilege to choose the best land and left the worst to poor people.

Lands are even more under pressure because of various changes, as population growth, urban expansion and internal migration (both economic and climate-related displacement).

Filipe and Norfolk, 2017.

# Farming System

Major Farming System
(Farming Systems and Poverty, FAO)


**Farming System**

6. Highland temperate mixed
7. Root crop
8. Cereal-root crop mixed
9. Maize mixed
14. Coastal artisanal fishing

- Cassava, maize/corn, millet, rice and beans are the most common.
- Cashew and mango trees can be found on many smallholdings.
- Cotton, tobacco, sugar and tea are grown in certain areas of the country.

Farmlands are divided for supplying family or tribes necessities; it's a low-input subsistence agriculture based on human work.

Agricultural system has different weaknesses:

- Scarce farmer knowledge
- Lack of storage facilities
- Poor transport links
- Climate extreme phenomena
- No favourable soil conditions
- Low use of fertilizer due to the high prices

# Mozambique

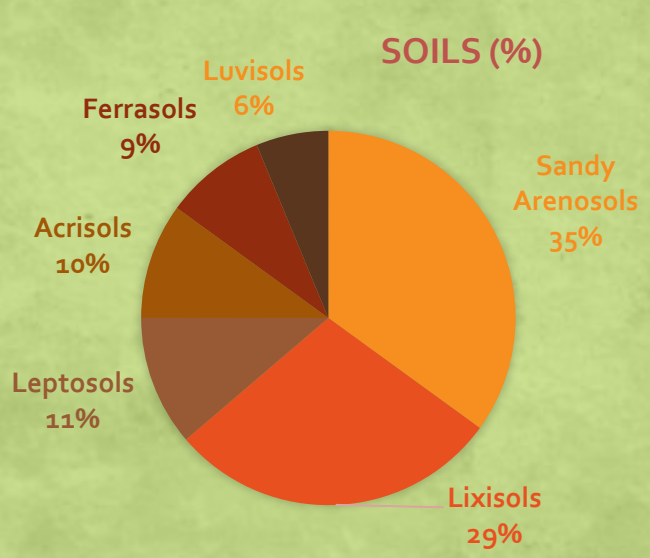
## Know the soils

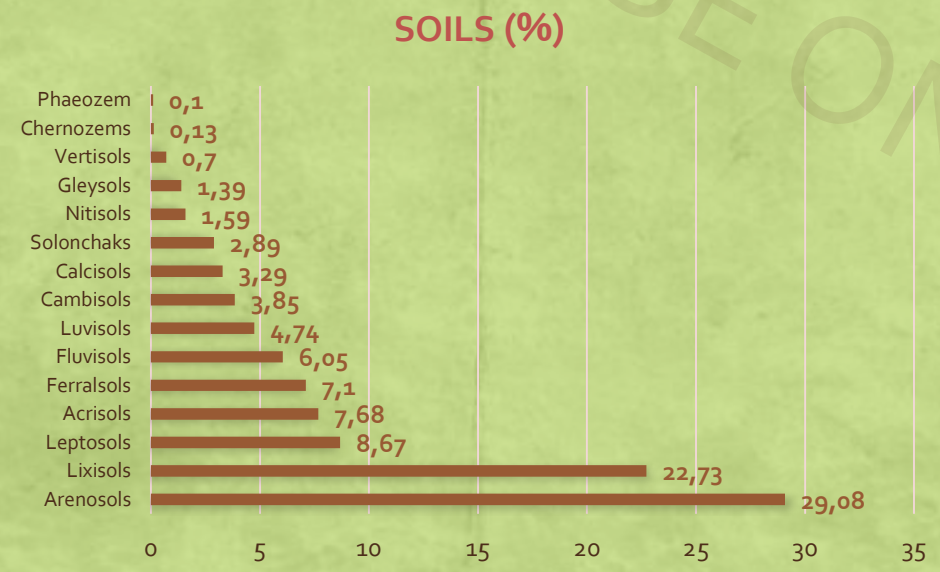
# Which soils are there in Mozambique?

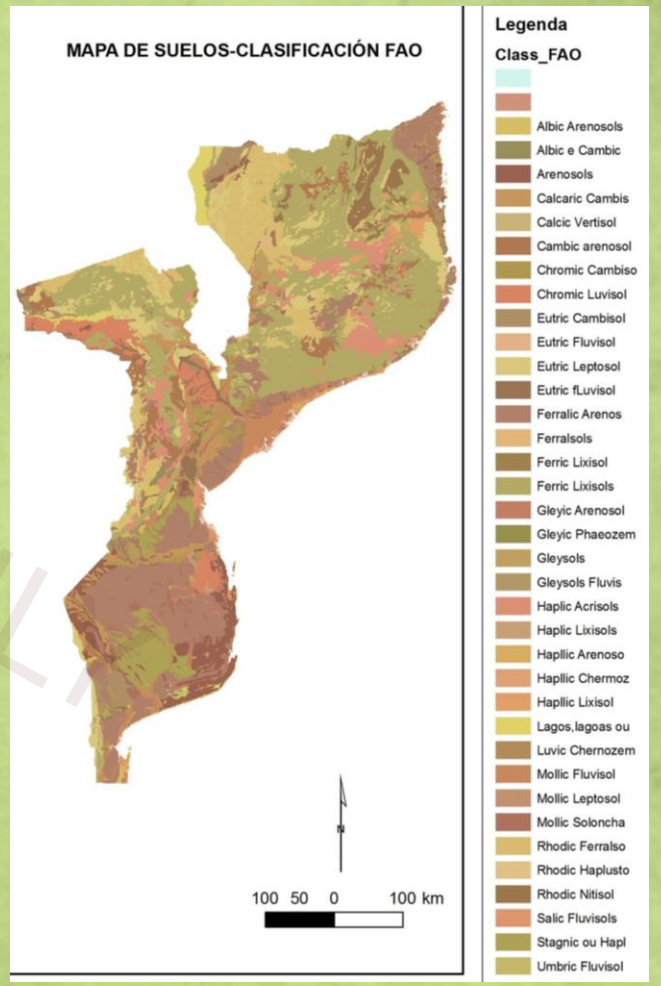
To understand the agronomic properties, Mozambique soils have been studied and identified especially with FAO classification.

In Soil Atlas of Africa the main soil types recognized are Arenosols, Lixisols, Solonchaks and Solonetz (Jones et al.,2013)

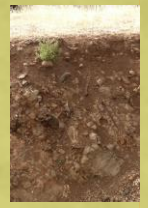
Maria et al. (2017) as well as Mafalacusser (2013) have reported similar results.



# Soils description

| Soil | | Description | Environment | Management and use |
|---|---|---|---|---|
| Arenosols |  | **Sandy soils** usually developed after in situ weathering of quartz-rich rock sediments or deposited sands. **Easily erodible** with **low water- and nutrient- holding capacity**. | From arid to humid and perihumid, and from extremely cold to extremely hot. | **Low coherence, nutrient storage capacity** and **sensitivity to erosion** are major limitations in dry zones. It offer ease of cultivation , rooting and harvesting of root and **tuber crops**. |
| Lixisols |  | **Slightly acid soil** with higher clay content in subsoil than in topsoil, due to a migration of clay. The **nutrition holding capacity is low** and they are susceptible to erosion after high-intensity rainfall. | Regions with tropical, subtropical or warm temperate climate with pronounced dry season. | **Perennial crops** are to be preferred to annual crops to preserve topsoil erosion and guarantee an amount of organic matter. The use of heavy machinery is advised against avoiding compaction. Lixisols needs recurrent input of fertilizer for continuous cultivation. |
| Leptosols |  | **Shallow soil** over hard rock, gravelly materials or highly calcareous deposits. | Mostly land at high or medium altitude. In mountainous and desert regions where hard rock is exposed or close to the surface and the physical disintegration of rocks due to freeze/thaw or heating/cooling cycles are the main soil-forming processes. | They have a resource potential for **wet-season grazing** and as **forest land**. Even if the excessive internal drainage and the shallow depth of many Leptosols can cause drought also in a humid environment. |
| Acrisols |  | **Strongly acid soils** with a **clay-enriched subsoil** and **low nutrient holding capacity**. | They originated especially from the weathering of acid rocks, in regions with a wet tropical/monsoonal, subtropical or warm temperate climate. | Forest is the natural vegetation type. **Shifting cultivation** is recommended if the period of restoration is long. **Agroforestry** and **rotation of annual crops** are good solutions to maintain the organic matter content without using expensive inputs. |

# Soils description

| Soil | | Description | Environment | Management and use |
|---|---|---|---|---|
| Ferralsols |  | **Strongly weathered soils** with **low nutrient capacity** and typical **red and yellow colour**. They have high quantities of aluminium oxides, iron oxides and kaolinite and low quantities of calcium and magnesium. | Common in undulating land of Pleistocene age or older; less frequent in younger and easily weathering rocks. | They have **good physical properties** but **unfavourable chemical properties**. To maintain soil fertility manuring, mulching and/or adequate fallow period or agroforestry practices are helpful managements. |
| Fluvisols |  | **Young soils** in floodplains, lakes, deltas or marine deposits constituted by different layers of **sediments**. In general they are **fertile**; it depends on the type of sedimentary materials. | River plains and fans, valleys, lake depressions and tidal marshes on all continents and climate zone. Many Fluvisols under natural conditions are flooded periodically. | Fluvisols are **naturally fertile** and wetland crops as well as dryland crops are grown on it. |
| Luvisols |  | **Slightly acid soils** with a clay-enriched subsoil layer and **high nutrient-holding capacity**. They have a well developed structure that contributes to a good water-holding capacity. | Cold and warm regions with distinct dry and wet seasons, commonly in flat or gently sloping land. | Most Luvisols are **fertile soils** and suitable for a wide range of agricultural uses. Generally in warmer regions the lower slopes are widely sown with **wheat** and/or **sugar beet** while the often eroded upper slopes are used for **extensive grazing** or planted with **tree crops**. |

(IUSS Working Group WRB, 2015; Jones et al., 2013)

**Mozambique soils are acidic with low nutrient capacity and high weathering rate, it means that fertility is seriously compromised.**

# Soil remediation

- Increase soil pH
- Increase soil structure
- Reduce Al toxicity
- Increase nutrients
- Reduce erosion

Burning plant residues and amending with ashes: source of K, Ca, Mg, $CO_3$'s.

Liming materials, pure calcium carbonate or dolomitic lime to increase pH.

Gypsum is calcium sulfate, only improves structure in soils that have extremely high sodium contents.

Addition of biochar, compost, manure, green manure improve the formation of soil organic matter.

Mulching, it helps to protect soil from the impact of direct rainfall.

Application of urea and chemical fertilizer, to provide N, P and K.

# Terra Preta

To know characteristics to understand if it may be present in Mozambique

# Terra Preta *de Índio*

Ferralsols Terra Preta

**Anthropogenic Dark Earths** (**ADE**) or *Terra Preta (de Índio)* was roughly defined from Glaser and Birk (2012) as a soil characterized by a topsoil horizon with high levels of stable soil organic matter - SOM (Glaser, 2007; Glaser et al., 2001), biochar, and nutrients (especially phosphorus) and which contains archaeological artefacts of pre-Columbian origin.

Terra Preta contains biochar, bones, artefacts, etc.

*Terra Preta* is extensively developed on Amazonian soils such as Ferralsols, Acrisols, Arenosols and other types as Plinthosols, Cambisols, etc. (Kämpf et al., 2003). Due to similar composition of *Terra Preta* to adjacent soils it seems reasonable presume that it formed *in situ*, by addition of biochar and nutrient-rich waste material (Glaser and Birk, 2012).

# Terra preta characteristics

Terra preta contains >200 mg $kg^{-1}$ of plant-available P, in contrast to surrounding soils which contain about 5 mg $kg^{-1}$ (Falcão et al., 2009). Ca is strongly enriched in relation to surrounding soils, while K, Mg, Fe, and N are not necessarily higher (Lehmann et al., 2003).

Nutrients

Mineralization of labile SOM contributes to the high amounts of plant-available nutrients in terra preta (Glaser, 1999).
Also ashes, organic matter from floodplains, organic wastes are responsible for the high levels of nutrients.

pH

Terra preta is less acidic, pH values ranging from 5.2 to 6.4. Therefore, plants normally do not have Al toxicity problems, and this could be one reason for their high productivity (Falcão et al., 2009).

SOM stable fraction of humic acids contain more condensed aromatic structure that are recalcitrant to mineralisation and contribute to physical and organo-mineral stabilisation (Glaser et al., 2003). Condensed aromatic structure is considered an end product of biochar oxidation (Glaser et al., 1998, 2001).

SOM

SOM - Soil Organic Matter - is greater in quantity and quality in terra preta than in surrounding soils.

CEC

CEC – Cations Exchange Capacity - in terra preta is approximately 13–25 $cmol_c kg^{-1}$ instead of being lower than 12 $cmol_c kg^{-1}$.
(Sombroek, 1966; Zech et al., 1990; Glaser et al., 2001; Glaser et al., 2003; Lehmann et al., 2003; Glaser, 2007; Falcão et al., 2009)

Higher amounts of carboxylic groups and phenolic groups compared to surrounding soils, for these reasons, SOM in terra preta has higher CEC than SOM in naturally occurring soils (Sombroek, 1966; Liang et al., 2006).

# Slash and burn

To know the system and its effect on soils

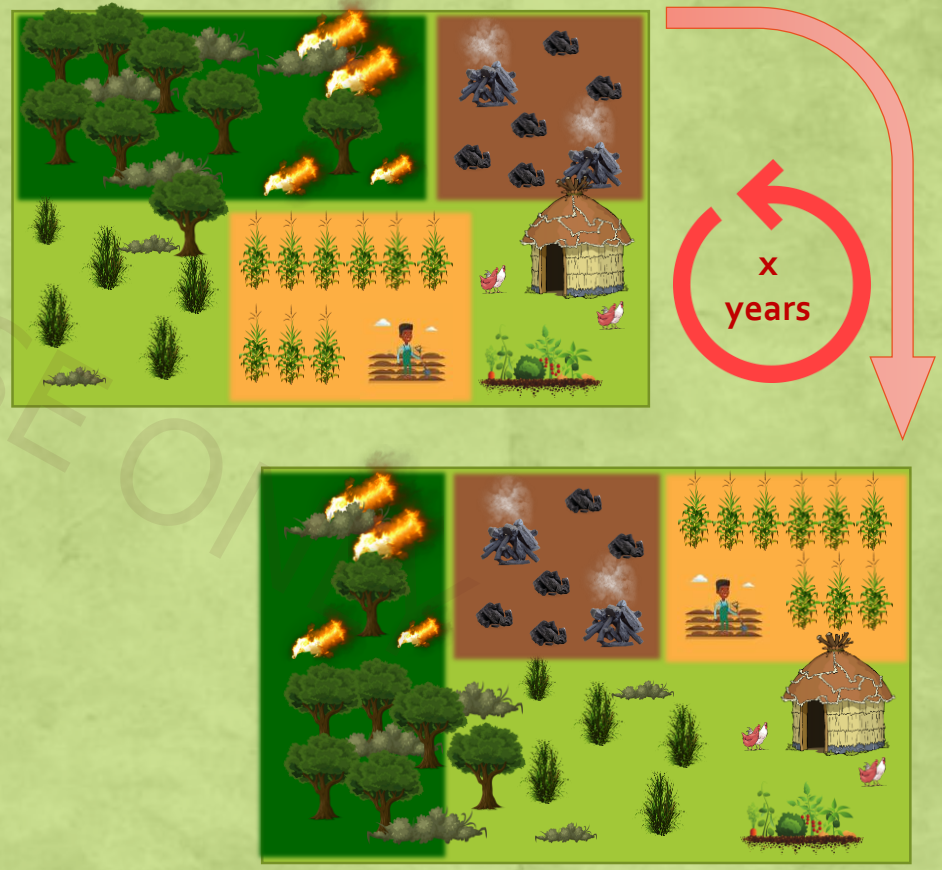
# What kind of agricultural techniques?

- Slash and burn/shifting/swiddening cultivation

It is an ancient agricultural practice (Mertz et al., 2009a, 2009b; Dressler et al., 2015), largely spread especially in tropical area: Asia, Africa and Latin America (e.g. Brady N.C., 1996; van Vliet et al., 2012; Mukul and Herbohn, 2016).

The main characteristic is that the land users work a piece of land, shifting from one place to another, slashing and burning vegetation, in order to convert it into a cultivable area. Often, they use ashes and/or compost to fertilize soil (Gay-des-Combes, 2017), they cut branches for selling and produce charcoal.

14–34 million people of tropical Asia depend on shifting cultivation (Mertz et al., 2009b).



# Effects of fire on soil

**The effect of fire on soil depends on various factors:**

- The type and intensity of fire
- The soil characteristics, for example: texture, moisture, porosity
- The nature of burned materials
- Climate condition
- Topography

(e.g. García-Oliva et al., 1999; Ketterings et al., 2000; Bird et al., 2000; Gonzáles-Pérez et al., 2004; Edivaldo Lopes Thomaz, 2013)

**Fire causes different soil variations:**

- Loss of protective canopy and destruction of litter layer
- Hydrophobic effect in certain soils with a litter riches of lipids, waxes, fats and resins
- Reduce infiltration and enhance runoff
- In coarser soils, reduction of aggregate stability
- In tropical soils, with high contents of clay and iron and aluminium oxides, creation of more stable aggregates
- With high temperature mineralogical alteration, more magnetic susceptibility
- Production of black carbon
- Alkalinisation effect by ashes
- Increase of the humin fraction, the most stable and persistent

# Biochar and black carbon

**Biochar** is a pyrogenic material originated from the incomplete combustion of biomass (Glaser et al., 2001).

Its structure is really complex, constituted by polyaromatic chains, strictly depends on originally charred material.

Biochar contains **black carbon.** It consists principally in randomly oriented graphitic layers, but also alkyl domain and a considerable oxygen content.

(González-Pérez et al., 2004; Gay-des-Combes et al., 2017b)

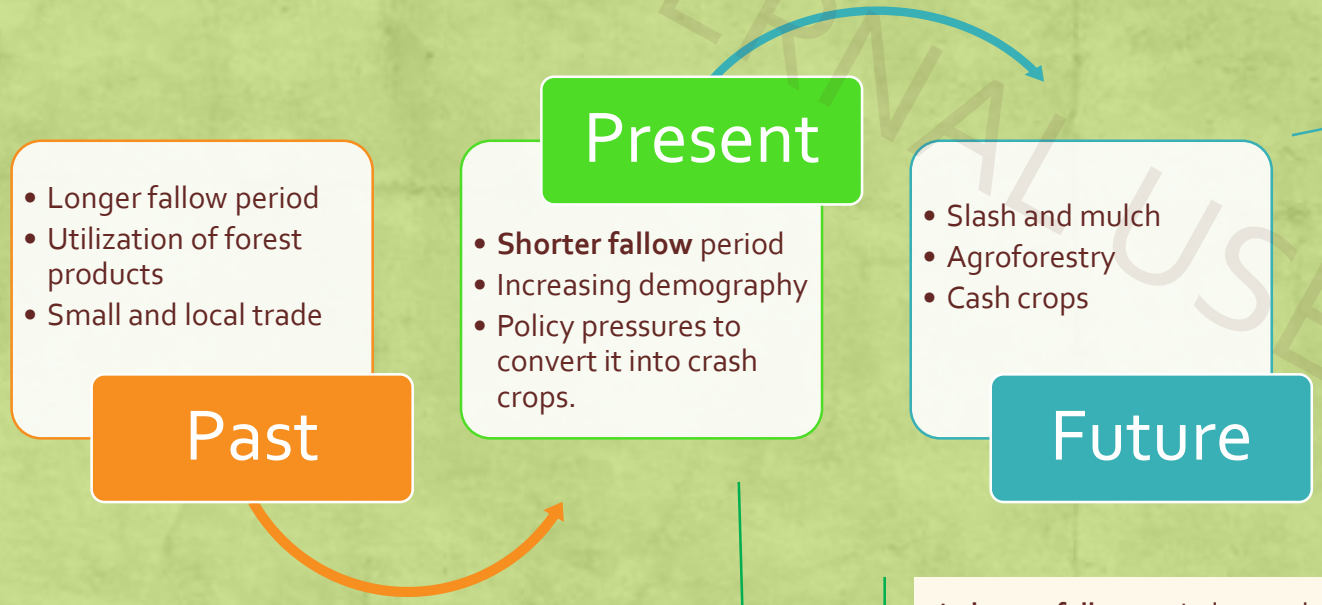
Black carbon is an important source of carbon stored and locked in soil.

Black carbon represents:
1-6% in the total soil organic carbon
35% in Terra Preta Oxisols
60% in Chernozen from Canada

- Forest fires
- Low heat
- Smouldering fires for food and pottery preparation
- Spiritual reasons
- Biochar amendments on home garden

# Slash and burn through the years

There's a point of view shared from scientific community, organizations etc., is that swiddening agriculture is no more sustainable (e.g. Kleinman et al., 1995; Davidson et al., 2009; Nath et al., 2016; Gay-des-Combes et al., 2017b).




Slash and mulch how explained by Félix (2015) and Kearney (in press), along with agroforestry (Nath et al., 2016) could be a valuable alternative to present slash and burn.
Another option promoted from Governments is the conversion to cash crops (e.g. Vongvisouk et al., 2014).

A **shorter fallow** period caused several problems:

- Gradual decrease in crop yield (Jakovac et al., 2016)
- Soil fertility depletion (Gay-des-Combes et al., 2017; Runyan et al.,2012)
- Ongoing deforestation (Mukul and Herbohn, 2016)
- Less carbon sequestration (Kotto-Same et al., 1997)
- Reduction of forest products: charcoal, medicines, fruits, nuts, artisanal material (Junsongduang et al., 2013)
- Loss of habitats (Styger et al., 2007)

# Final considerations

- Know as more as possible about Mozambique helps to find solutions in respect of their culture and way to live.
- It's useful comprehend and localized Terra Preta for is important role in climate change.
- Slash and burn is an ancient practice and farmers are really tied to that, we may try to understand and improve it.
- Understand fire effects on soil and organic matter processes helps to prevent soil diseases.


Thanks for the attention

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