

Enhancing food security and mitigating greenhouse gas emission in smallholder farming systems in sub-Saharan Africa

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I want to share with you 4 questions and some thoughts on them.



Q I. Why smallholder farms are important in sub-Saharan Africa (SSA)?

less than 2ha of farm land

Importance of smallholder farms in SSA



Represent 80 % of all farms

Contribute 90 % of the agricultural production

Staatz and Dembele, 2007

Great concerns on food security in SSA



Underdeveloped agriculture



Degradation of agricultural soils

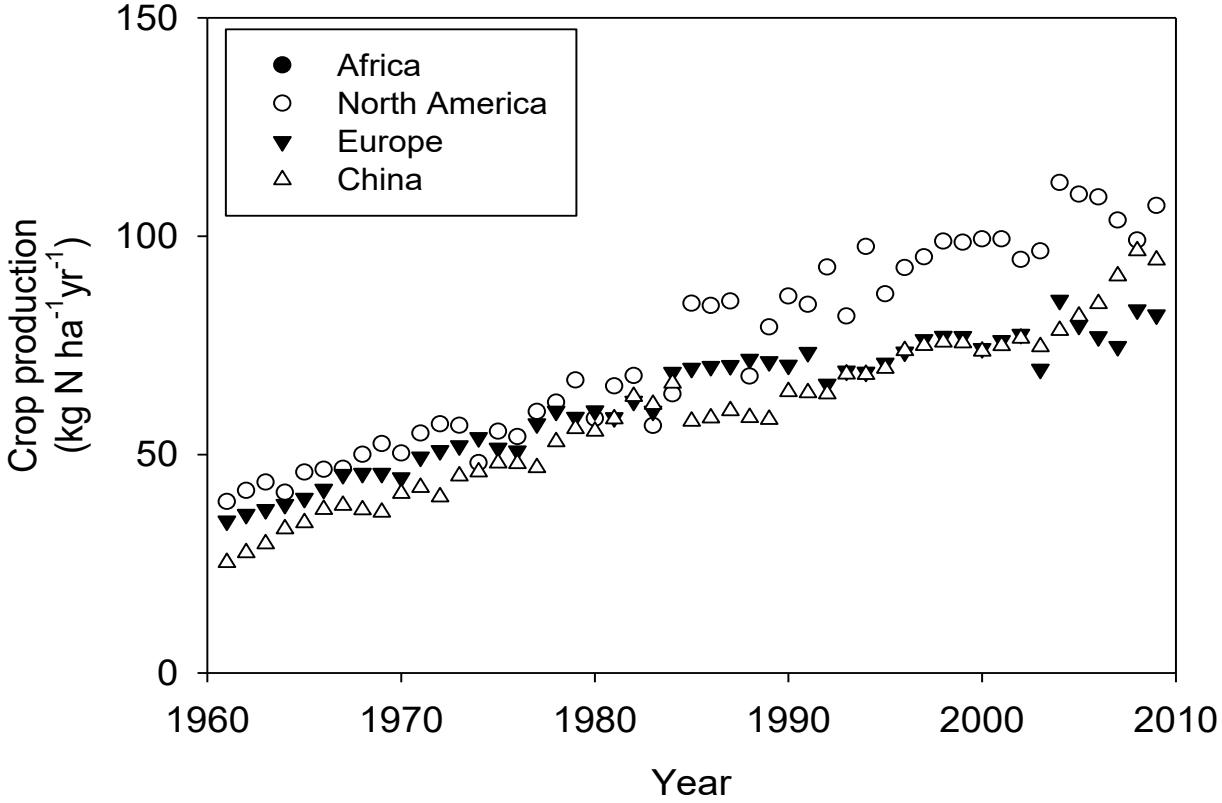


Drought affected water availability



Rapid population growth

Changes of crop productivity in 1961 to 2009



Data source: FAO STAT

Produced food crops only cover the food need for 20% of the households in SSA (Frelat et al., 2016).

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Breaking News: Nigeria's GDP grows in Q4 2018

Editorial

$35 billion food importation into Africa

By Editorial Board
21 August 2017 | 3:50 am





As important as food is to the family, nation and the African continent, how much commitment is there to its availability in sufficient quantities, and acceptable quality as well as at affordable prices? The recent experiences in Somalia and South Sudan where

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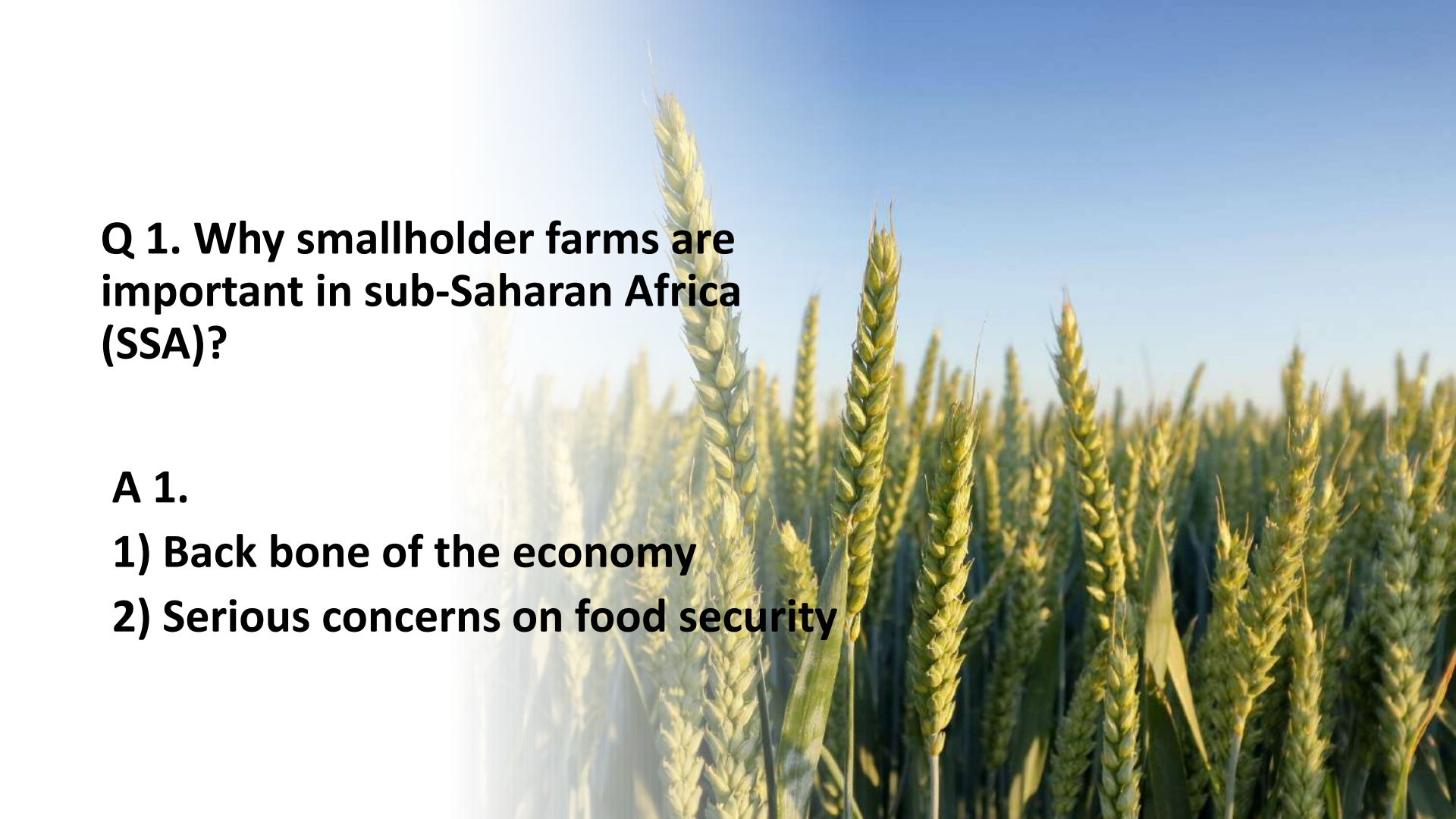
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Q 1. Why smallholder farms are important in sub-Saharan Africa (SSA)?

A 1.

1) Back bone of the economy

2) Serious concerns on food security



Q II. What smallholder farms are doing to enhance food security?

1. Expansion of agricultural lands

Average increase rates of
3.2 million ha per year in SSA (1993-2009) (FAOSTAT, 2014)

→ **1/3 of**  **(South Korea)**


Average deforestation rates of
3.4 million ha per year in SSA (1993-2009)
(FAOSTAT, 2014)
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However, many SSA countries have less than 6% of non-forested unutilized land

(Jayne et al., 2014).



✓**Further deforestation is predicted for expansion of agricultural lands.**

2. Development of rainwater harvesting & irrigation



Rainwater harvesting pond

Rainwater harvesting

- **Indigenous rainwater harvesting techniques** are more commonly used (Biazin et al., 2012).
- **Economic benefit & cost analyses** found significant profits of rainwater harvesting (Awulachew et al., 2008).
- **Rainwater harvesting potential** is estimated at over 10, 000 to 25, 000 m^3 $person^{-1}$ (Mati et al., 2006)

Irrigation

- Around **0.2 to 3.5%** of smallholder farms can access irrigation (Sheahan and Barrett, 2014)
- Irrigated agriculture accounts for **38% of the value** of all agricultural output (Svendsen et al., 2009)
- **Irrigable cropland** would be **20.5 to 48.6%** (Altchenko and Villholth, 2015)

3. Increase of cropping intensity & fertilizer use



Increase of cropping intensity

- **The number of crops grown per a year on the same field**

- **Increased 10.6 to 25.4%** in 1977 to 2007 (Headey and Jayne, 2014)



Low fertilizer application in SSA

16 kg N ha^{-1} in SSA



169.1 kg N ha^{-1} in the US

*Lassaletta et al., 2014





Recent findings-

- Inorganic fertilizer use is **far more widespread** than common assumptions about smallholder farming in SSA (Sheahan and Barrett, 2017).

- There is growing evidence that some farmers in SSA **apply excessive amount of fertilizer** (Liverpool-Tasie et al., 2017).



Q II. What smallholder farms are doing to enhance food security?

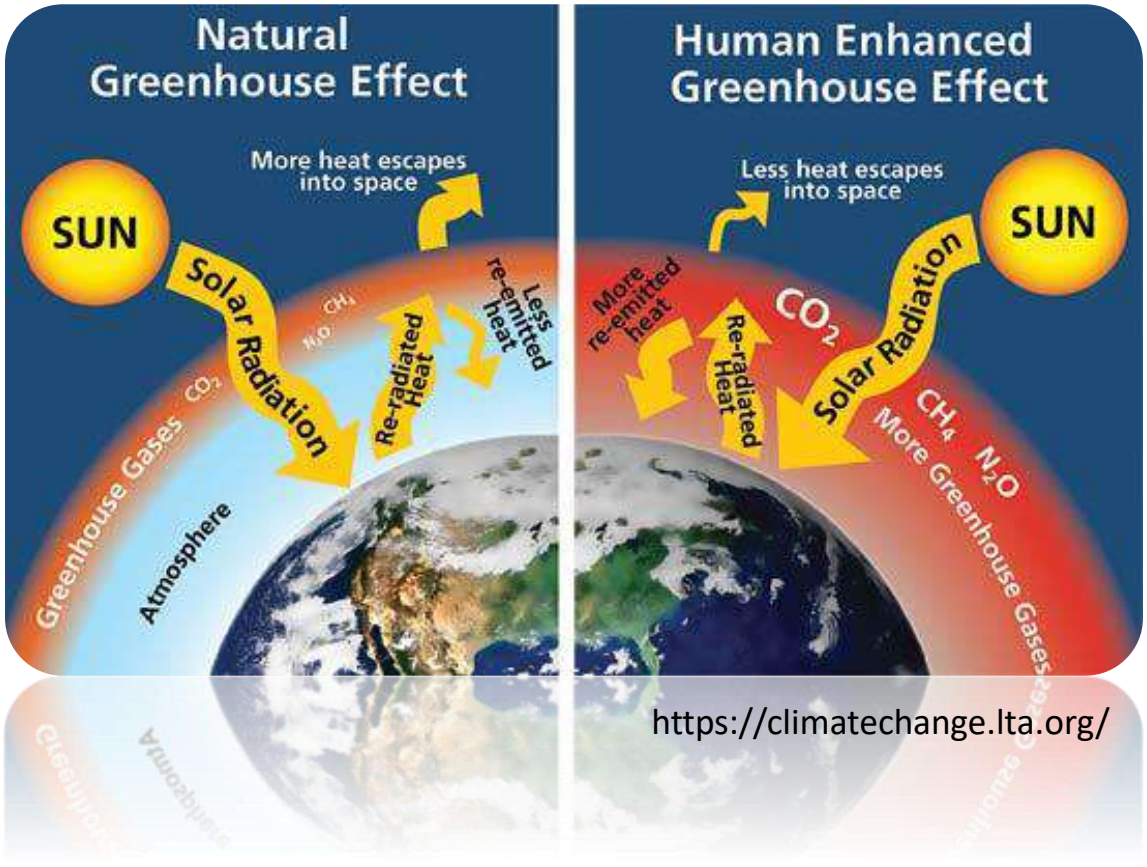
A II. Increasing –

1) agricultural lands,

2) water harvesting & irrigation,

3) cropping intensity & fertilizer use

Q III. How they affect greenhouse gas (GHG) emissions?



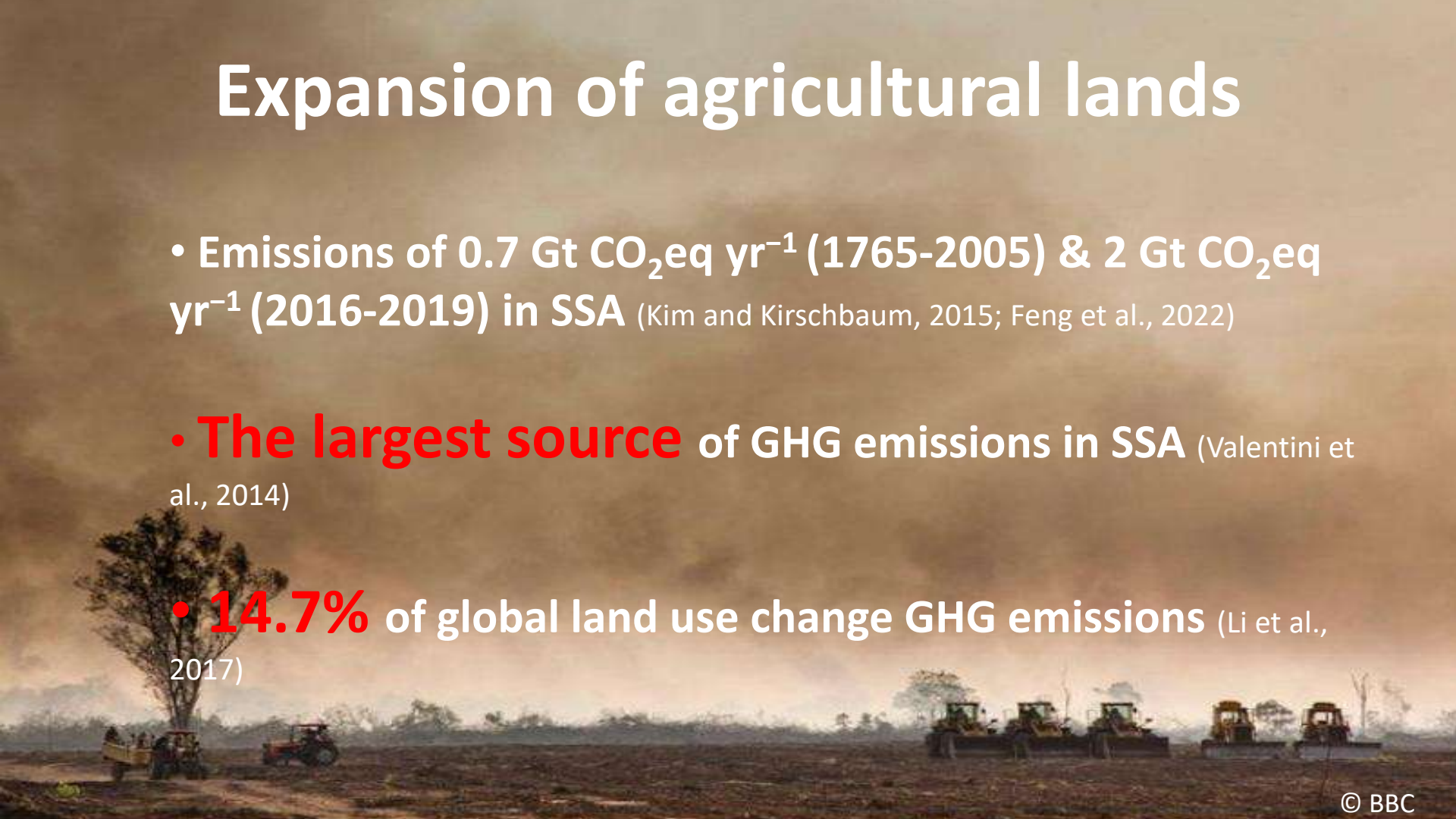
https://climatechange.lta.org/

Expansion of agricultural lands

- **Emissions of 0.7 Gt CO_2eq yr^{-1} (1765-2005) & 2 Gt CO_2eq yr^{-1} (2016-2019) in SSA** (Kim and Kirschbaum, 2015; Feng et al., 2022)

- **The largest source of GHG emissions in SSA** (Valentini et al., 2014)

- **14.7% of global land use change GHG emissions** (Li et al., 2017)



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Development of rainwater harvesting & irrigation





Increase of cropping intensity & fertilizer use

Increasing N fertilizer use can enhance

Soil organic carbon
(Han et al., 2016)

Greenhouse gas emissions

Increasing cropping intensity & Increasing N fertilizer use can **increase** (McLauchlan, 2006).

Annual increase rate of agricultural GHG emissions

1.1%
Global *

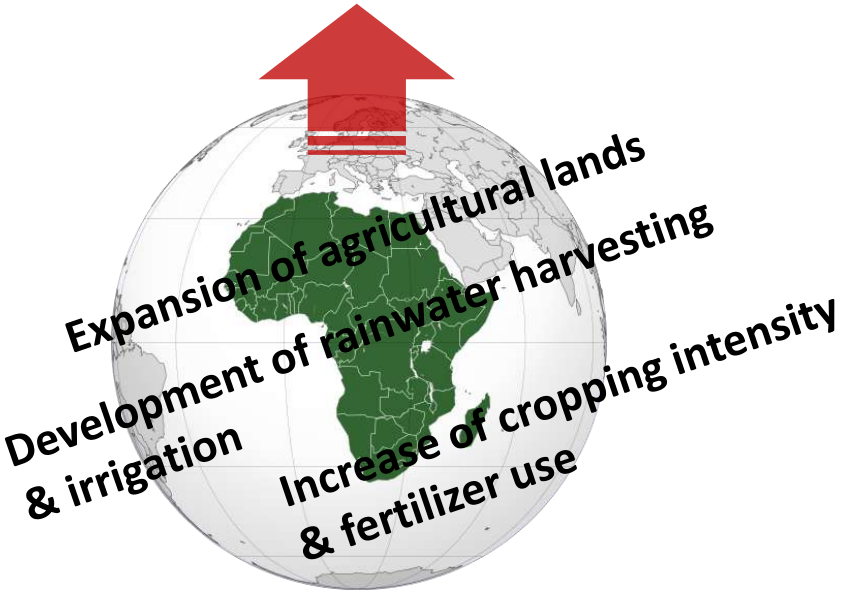
VS

1.2 - 4.7%
sub-Saharan Africa**

*2000 -2010 (Tubiello et al., 2013)

**1994 - 2014 (Tongwane and Moeletsi, 2018)

Q III. How they affect greenhouse gas (GHG) emissions?



Q IV. Is it possible to enhance food security & greenhouse gas mitigation in smallholder farms of SSA?





Land

Land: Improving and utilizing degraded land



Land: Improving and utilizing degraded land

494 M ha of human-induced degraded areas in SSA (Bai et al., 2008).

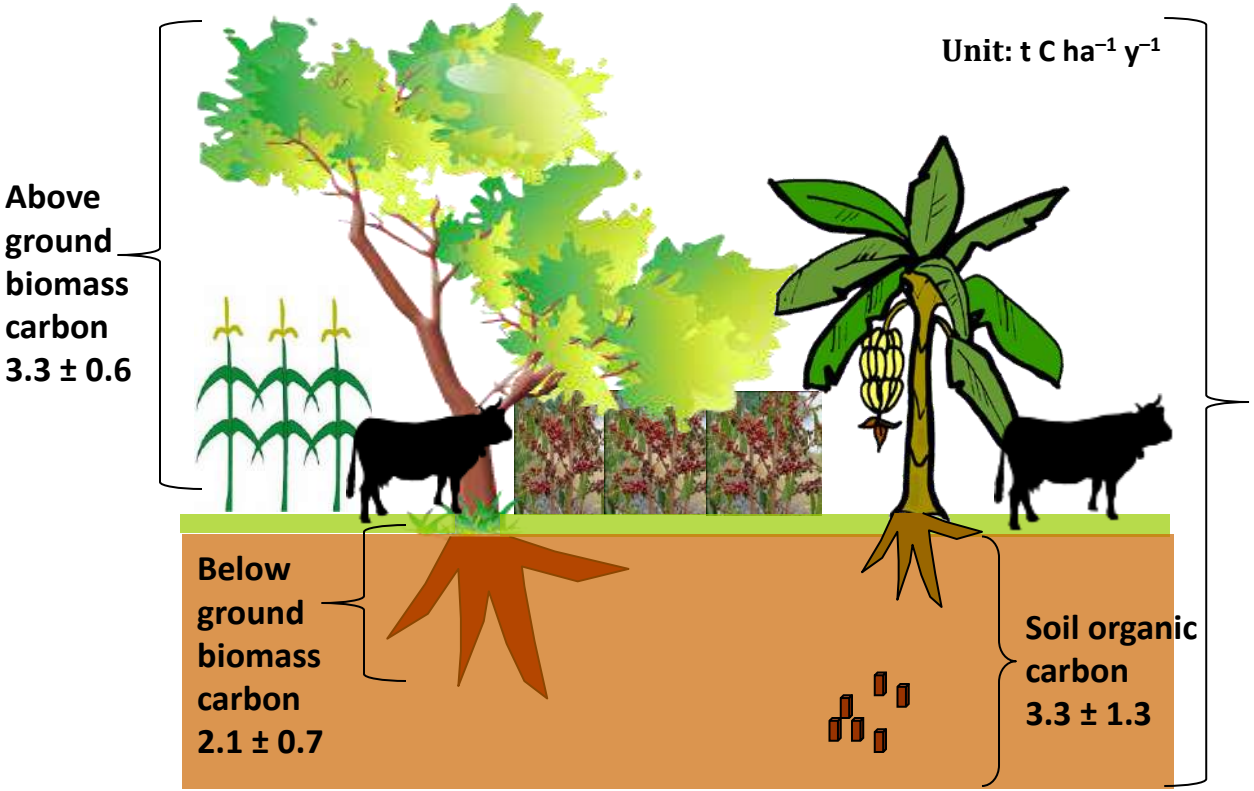
Annual costs of land degradation were **US$ 58 billion** (in 2007) **= 7 % of the region's GDP** (Nkonya et al., 2016).

Converting degraded lands to agroforestry

- **Increasing agricultural productivity 2 - 4 times** (Beedy et al., 2014)

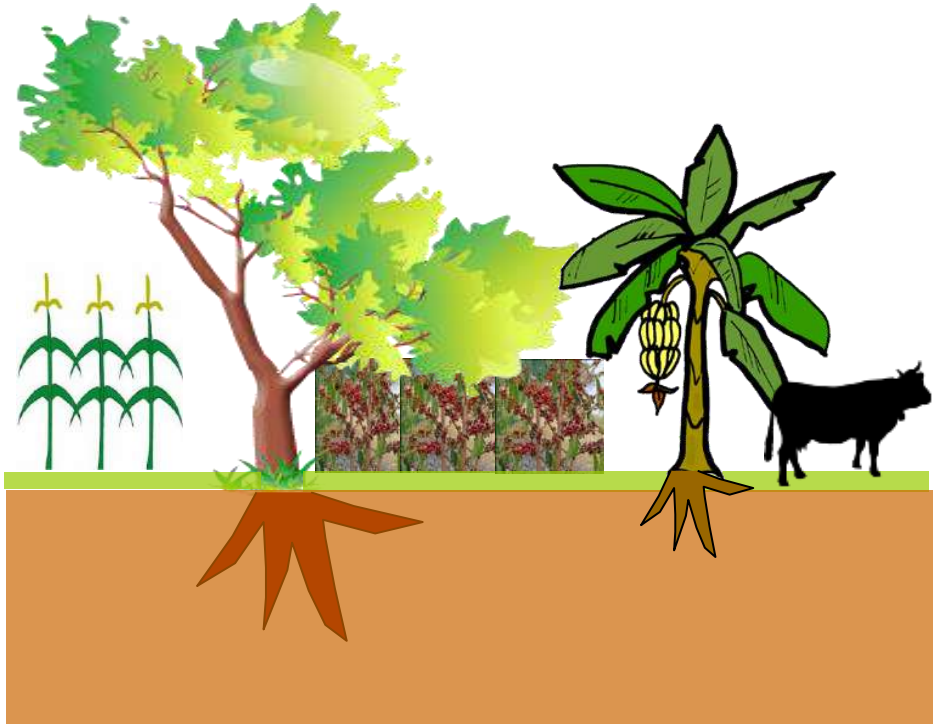
- **Greenhouse gas mitigation 27.2 t CO_2 eq ha^{-1} y^{-1}** (Kim et al., 2016)

Carbon sequestration in agroforestry



Data from 109 studies world wide (Kim et al. 2016)

Methane (CH_4) emissions in agroforestry ?

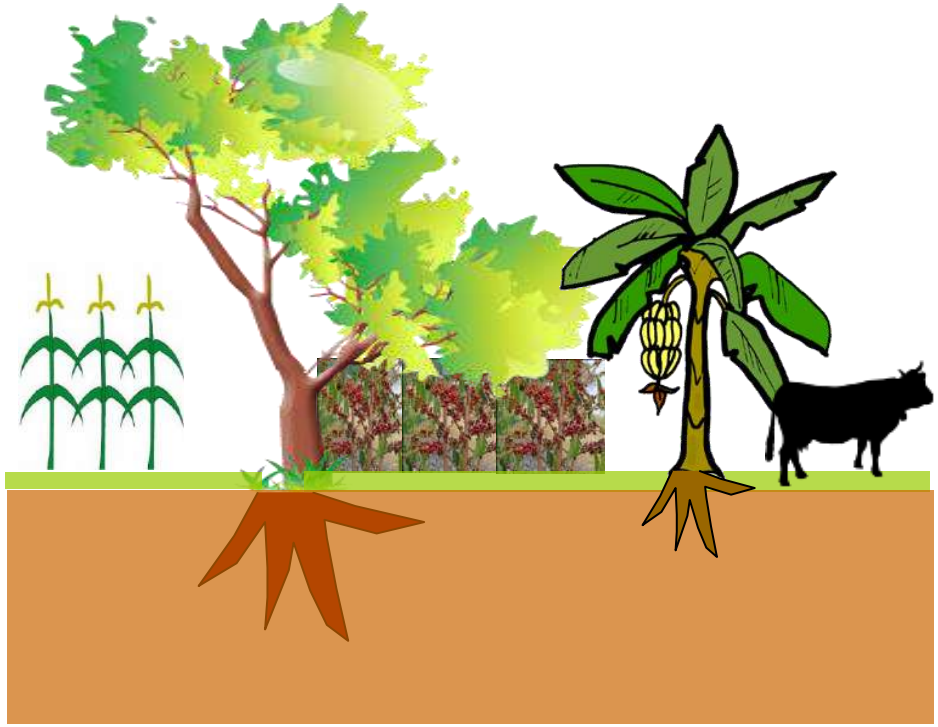


Data from 27 studies world wide (Kim et al. 2016)

Enhanced soil aeration
Improved microbial habitat

Methane (CH_4) uptake by soil
-1.6 ± 0.5 kg CH_4 ha^{-1} y^{-1}

Nitrous oxide (N_2O) emissions in agroforestry ?

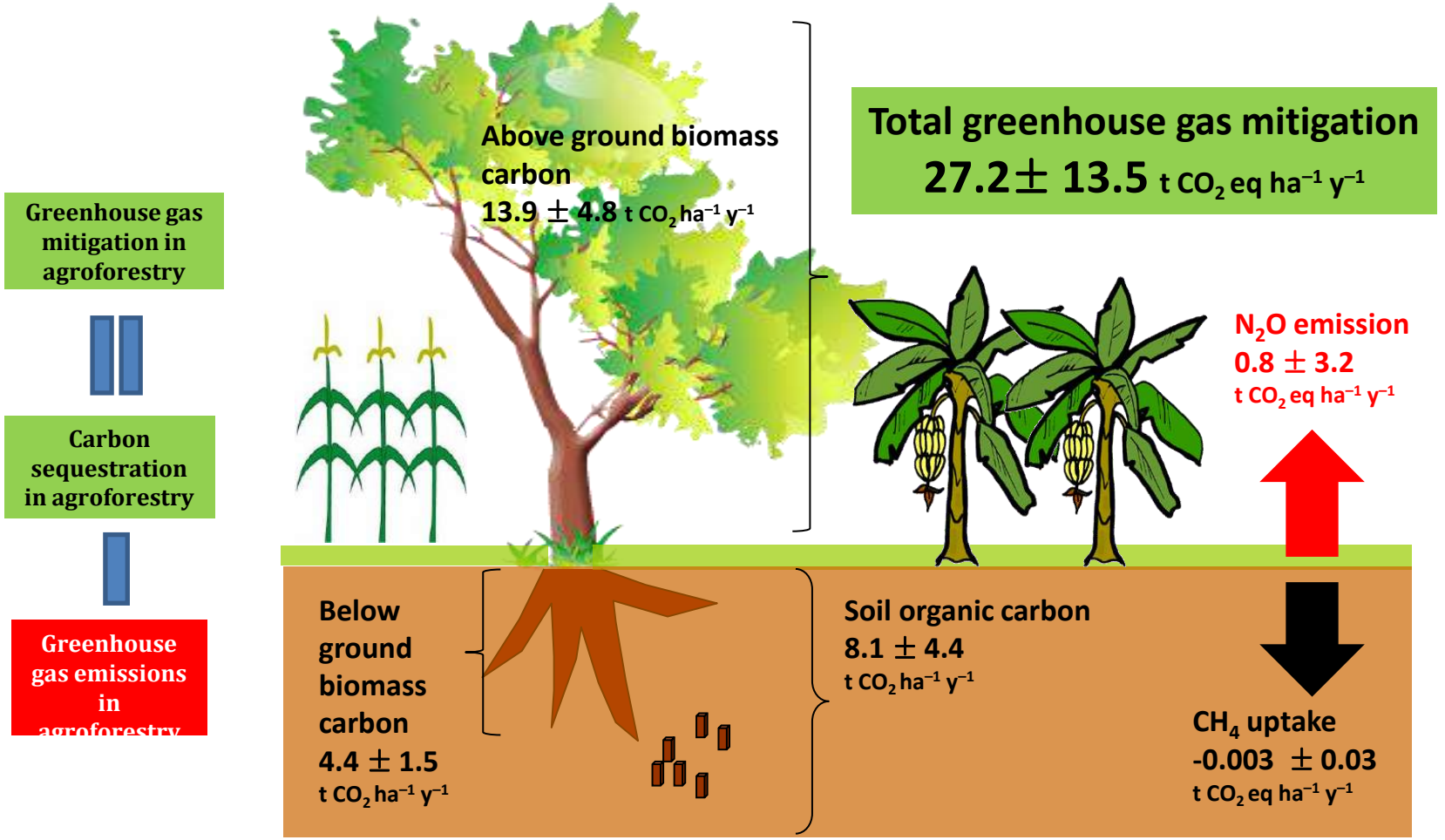


Nitrous oxide (N_2O) emission by soil

7.7 ± 1.7 kg N_2O ha^{-1} y^{-1}

Source of N_2O
N fixing trees, Crop residues, Litter fall, Manure, etc.

*Data from 27 studies world wide (Kim et al. 2016)



Kim et al. 2016

Land: Improving and utilizing degraded land

Assuming 20% of the degraded areas could be converted to agroforestry in SSA

Mitigation of 2.7×10^9 t $CO_{2\ eq}$ y^{-1}

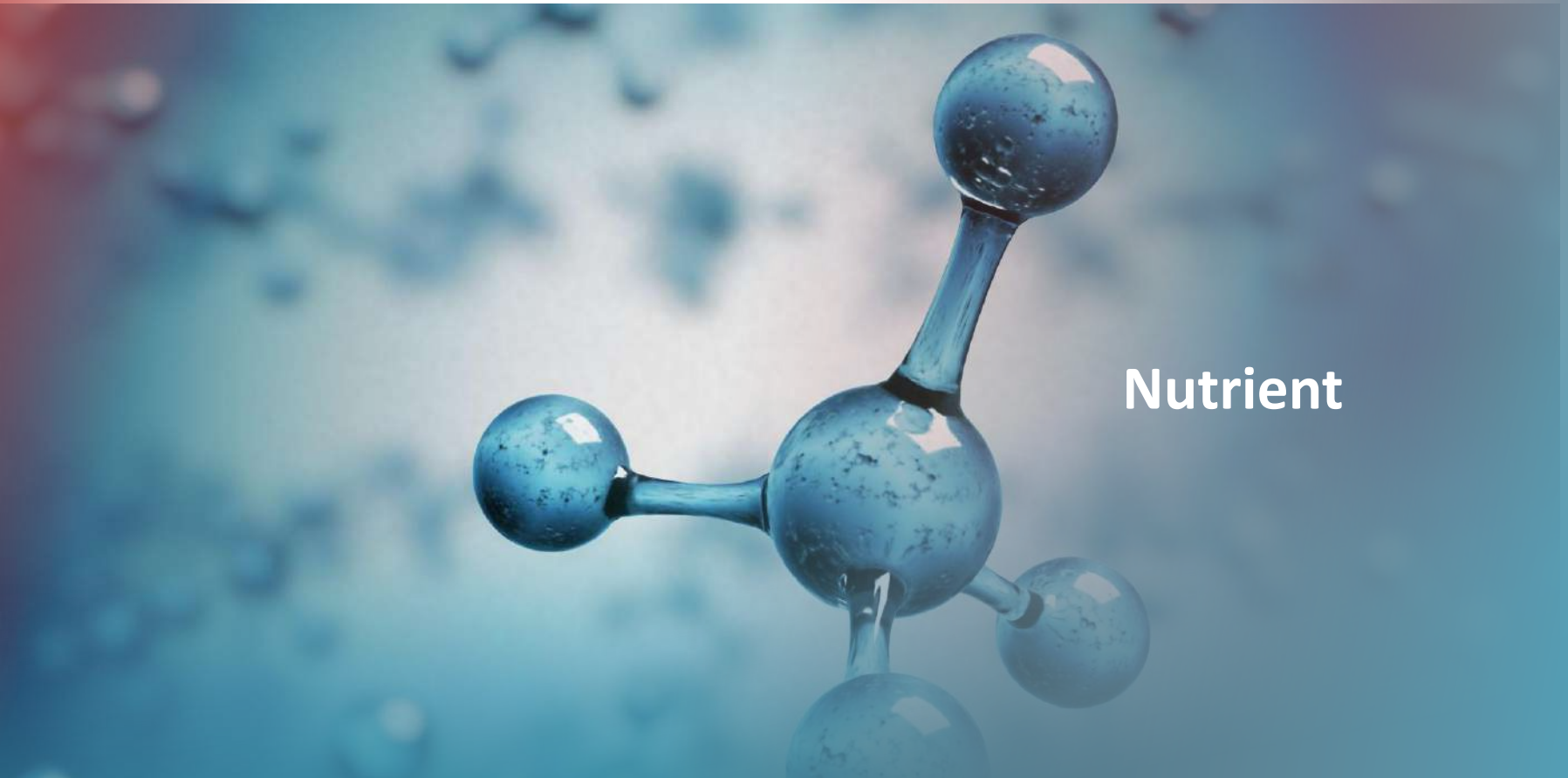
5.5 % of global GHG emissions

Water

Water: Appropriate rainwater harvesting & irrigation techniques and water management



Identifying and applying appropriate techniques and management can provide GHG mitigation potential (Sanz-Cobena et al., 2017).


Nutrient

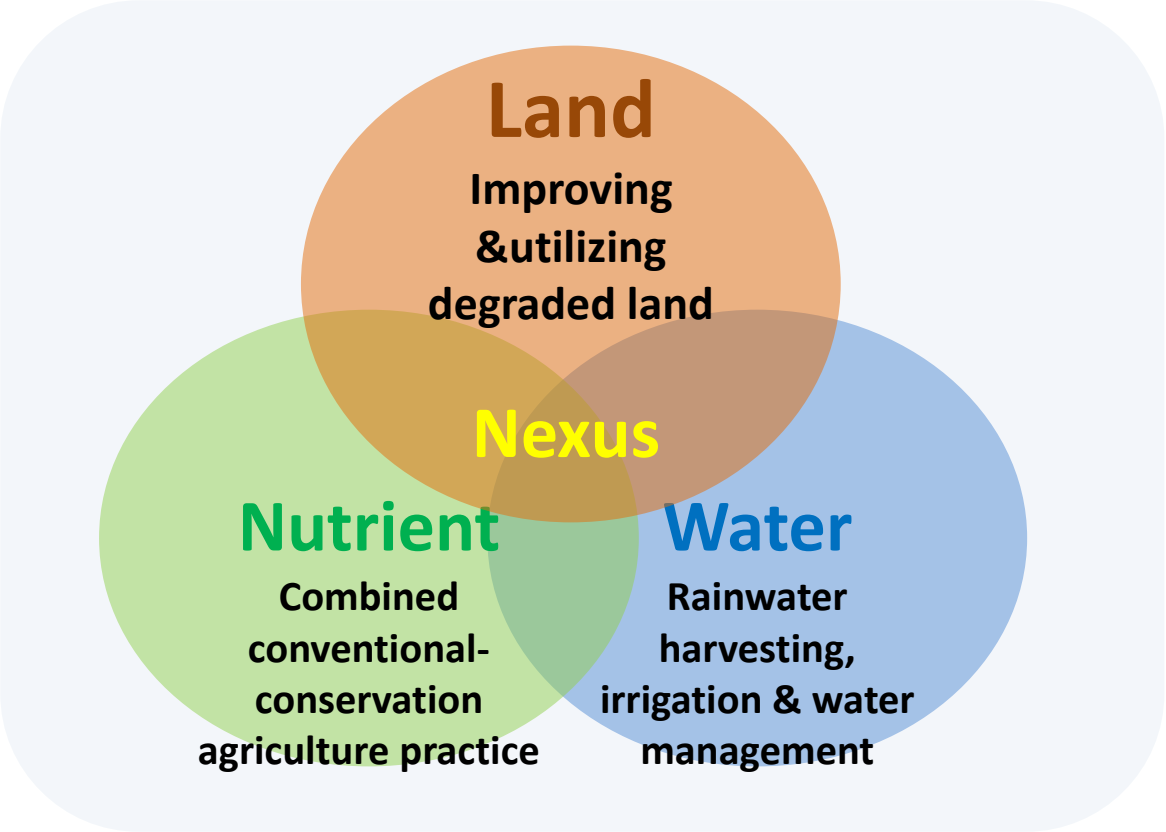
Nutrient : Combined Conventional-Conservation Agriculture (CCCA)

Inorganic fertilizers with reduced tillage, crop residues, or manure in SSA (e.g., Kurgat et al. 2017; Kimaro et al., 2016)

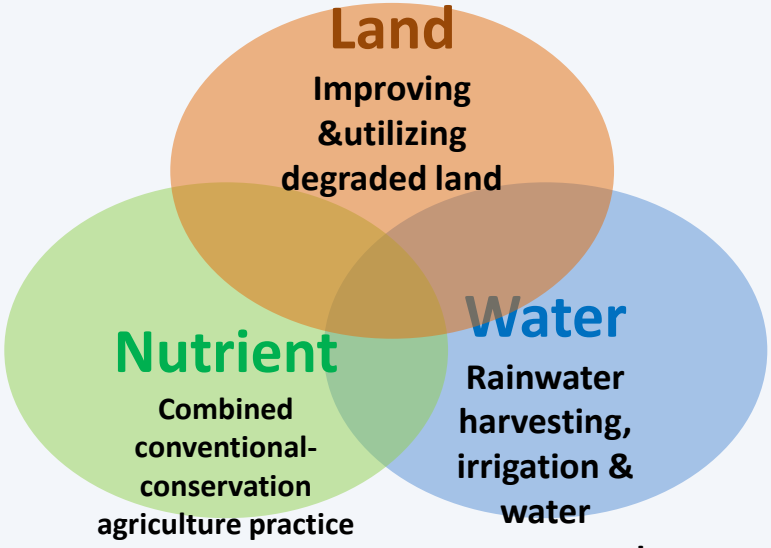
Increase yields & mitigate GHG emissions (e.g., Kurgat et al. 2017; Kimaro et al., 2016)

Reduce yield-scaled N_2O emission: 16 – 88 % (e.g., Kurgat et al. 2017; Kimaro et al., 2016)

Land–Water–Nutrient Nexus (LWNN)



Quantification of LWNN scheme



Yield-scaled GHG emission*

$$\frac{\text{GHG emissions}}{\text{Area}} \Rightarrow \frac{\text{GHG emissions}}{\text{Yield}}$$

*Kim and Giltrap, 2017; Linquist et al., 2012

How to analyze soil carbon content?



Element Analyzer

How to analyze soil carbon contents?

Journal of Arid Environments 153 (2018) 98–101

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Journal of Arid Environments

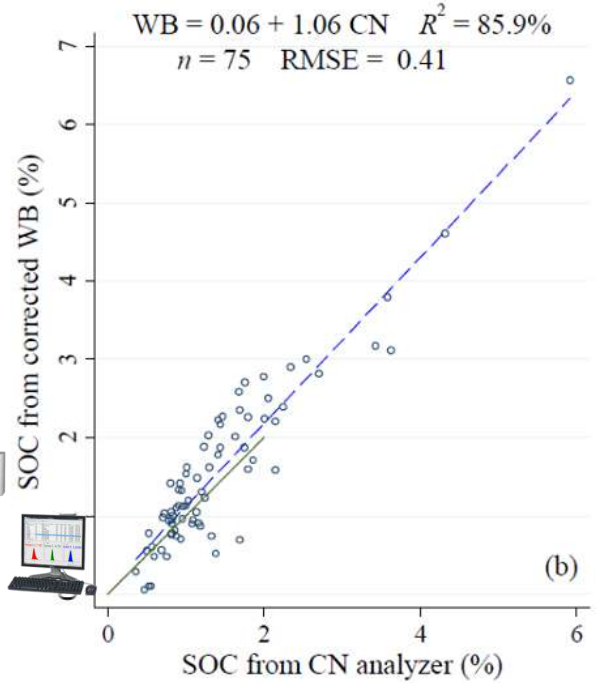
journal homepage: www.elsevier.com/locate/jaridenv

How reliable is the Walkley-Black method for analyzing carbon-poor, semi-arid soils in Ethiopia?

Tigist Araya Gessesse[a,b], Asia Khamzina[c,*]



Walkley-Black method (1934)



Apesteguia et al., 2018. Methods assessment for organic and inorganic carbon quantification in calcareous soils of the Mediterranean region. Geoderma Regional 12, 39-48.

De Vos et al., 2005. Capability of Loss‐on‐Ignition as a Predictor of Total Organic Carbon in Non-calcareous Forest Soils. Communications in Soil Science and Plant Analysis 36, 2899-2921.

Dieckow et al., 2007. Comparison of carbon and nitrogen determination methods for samples of a Paleudult subjected to no-till cropping systems. Sci. Agric. 64, 532–540.

Gessesse, T.A., Khamzina, A., 2018. How reliable is the Walkley-Black method for analyzing carbon-poor, semi-arid soils in Ethiopia? Journal of Arid Environments 153, 98-101.

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Nóbrega et al., 2015. Evaluation of methods for quantifying organic carbon in mangrove soils from semi-arid region. Journal of Soils and Sediments 15, 282-291.

Passos et al., 2016. Comparison of the quantitative determination of soil organic carbon in coastal wetlands containing reduced forms of Fe and S. Geo-Marine Letters 36, 223-233.

Sleutel et al., 2007. Quantification of Organic Carbon in Soils: A Comparison of Methodologies and Assessment of the Carbon Content of Organic Matter. Communications in Soil Science and Plant Analysis 38, 2647-2657.

Wang et al., 2013. Evaluating Loss-on-Ignition Method for Determinations of Soil Organic and Inorganic Carbon in Arid Soils of Northwestern China. Pedosphere 23, 593-599.

Wang et al., 2012. Comparisons of Three Methods for Organic and Inorganic Carbon in Calcareous Soils of Northwestern China. PloS one 7, e44334.

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Loss-on-Ignition Method



Element Analyzer



Walkley-Black method (1934)

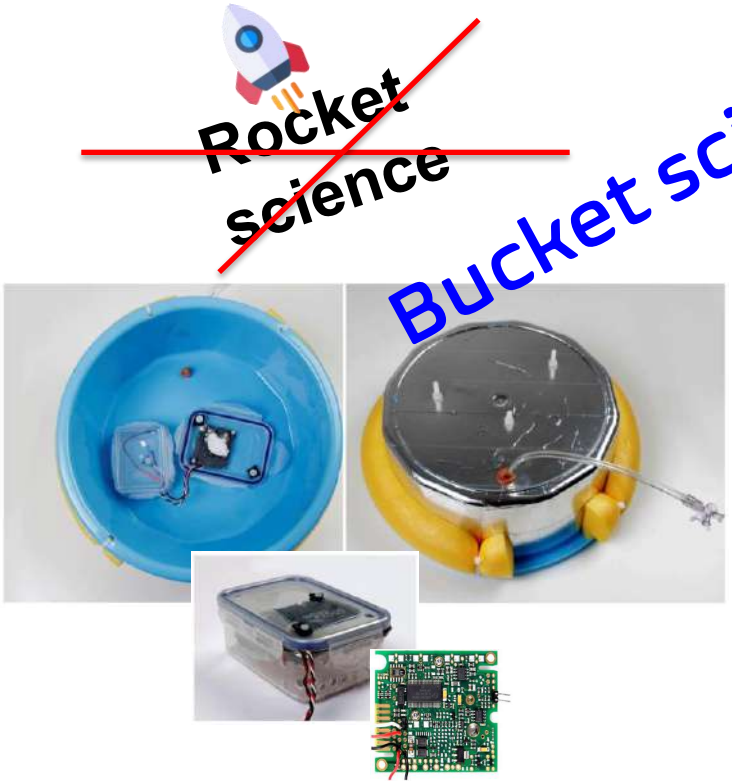
Greenhouse gas research?





Source: Oak Ridge National Laboratory

Greenhouse gas flux- chamber method



Biogeosciences, 12, 3849–3859, 2015
www.biogeosciences.net/12/3849/2015/
doi:10.5194/bg-12-3849-2015
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Biogeosciences Open Access

Technical Note: Cost-efficient approaches to measure carbon dioxide (CO_2) fluxes and concentrations in terrestrial and aquatic environments using mini loggers

D. Bastviken, I. Sundgren, S. Natchimuthu, H. Reyier, and M. Gålfalk

Low-cost sensors

Low-cost sensors for the measurement of atmospheric composition: overview of topic and future applications

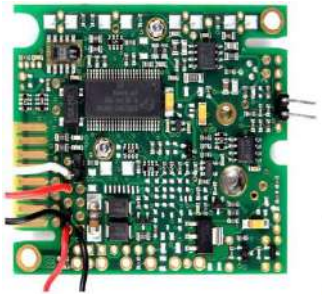
valid as of May 2018

Editors: Alastair C. Lewis, Erika von Schneidemesser and Richard E. Peltier

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Environment International 99 (2017) 293–302

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Environment International

journal homepage: www.elsevier.com/locate/envint

Full length article

Can commercial low-cost sensor platforms contribute to air quality monitoring and exposure estimates?

Nuria Castell [a,*], Franck R. Dauge [a], Philipp Schneider [a], Matthias Vogt [a], Uri Lerner [b], Barak Fishbain [b], David Broday [b], Alena Bartonova [a]

[a] NILU – Norwegian Institute for Air Research, Kjeller, Norway
[b] Faculty of Civil and Environmental Engineering, Technion - Israel Institute of Technology, Haifa, Israel

Environment International 116 (2018) 286–299

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Review article

Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone?

Lidia Morawska[a,b,*], Phong K. Thai[a,b], Xiaoting Liu[a,b], Akwasi Asumadu-Sakyi[a,b], Godwin Ayoko[a,b], Alena Bartonova[c], Andrea Bedini[d], Fahe Chai[e], Bryce Christensen[a,b],

NO, NO_2, CO, CO_2, CH_4, SO_2, O_3, PM, VOCs, etc.



Take home messages

- **Smallholder farms in SSA**
  - Back bone of the economy; concern on food security
- **Current land management practices**
  - Increasing agricultural lands, water harvesting & irrigation, cropping intensity & fertilizer use
- **Land–Water–Nutrient Nexus (LWNN)**

