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Research Institute of Organic Agriculture
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CHALLENGES FOR ORGANIC AGRICULTURE RESEARCH IN TROPICAL ZONES

Soil Fertility and Waste Management in the Tropics

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The Soil

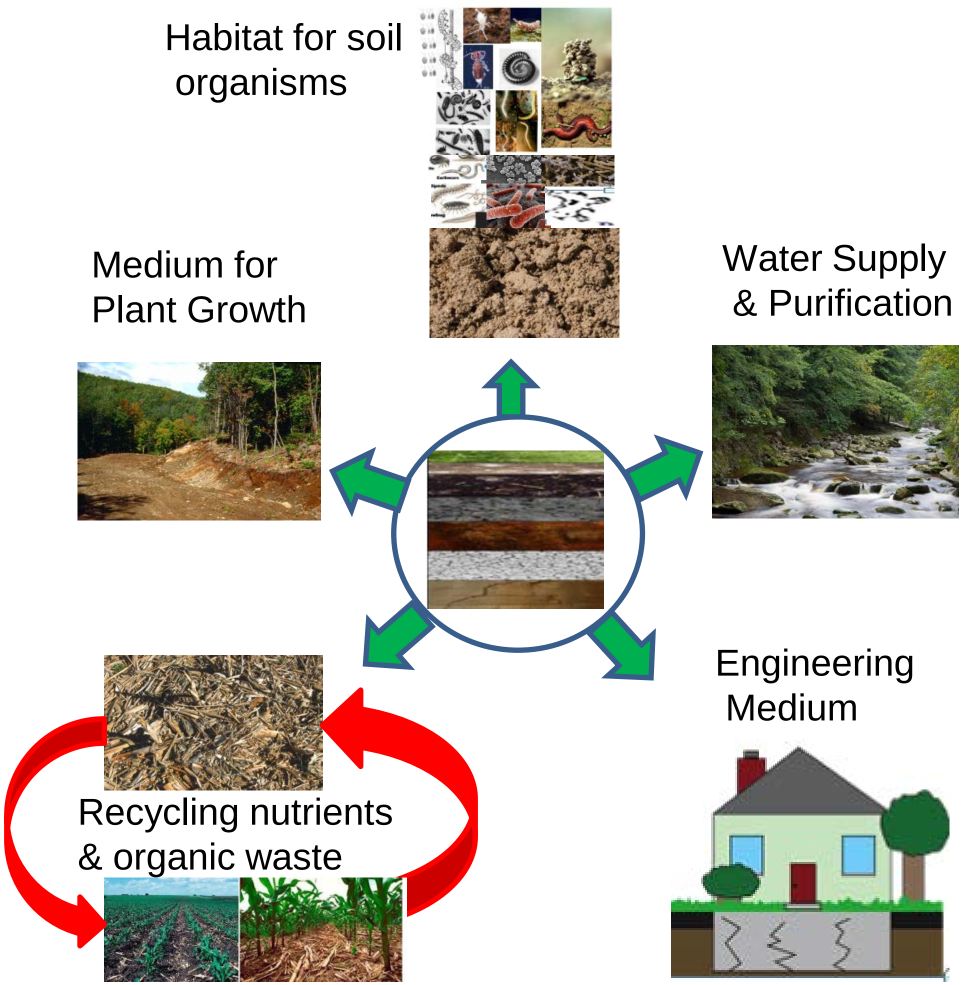


Fig. 1: Functions of Soils in the Ecosystem

A. Soil, one of the most important natural resources.

B. Consist of the following components:

Mineral	= 45%
Water	= 20-30%
Air	= 20-30%
Organic matter	= 5%

C. Soil provides multiple ecosystem services.

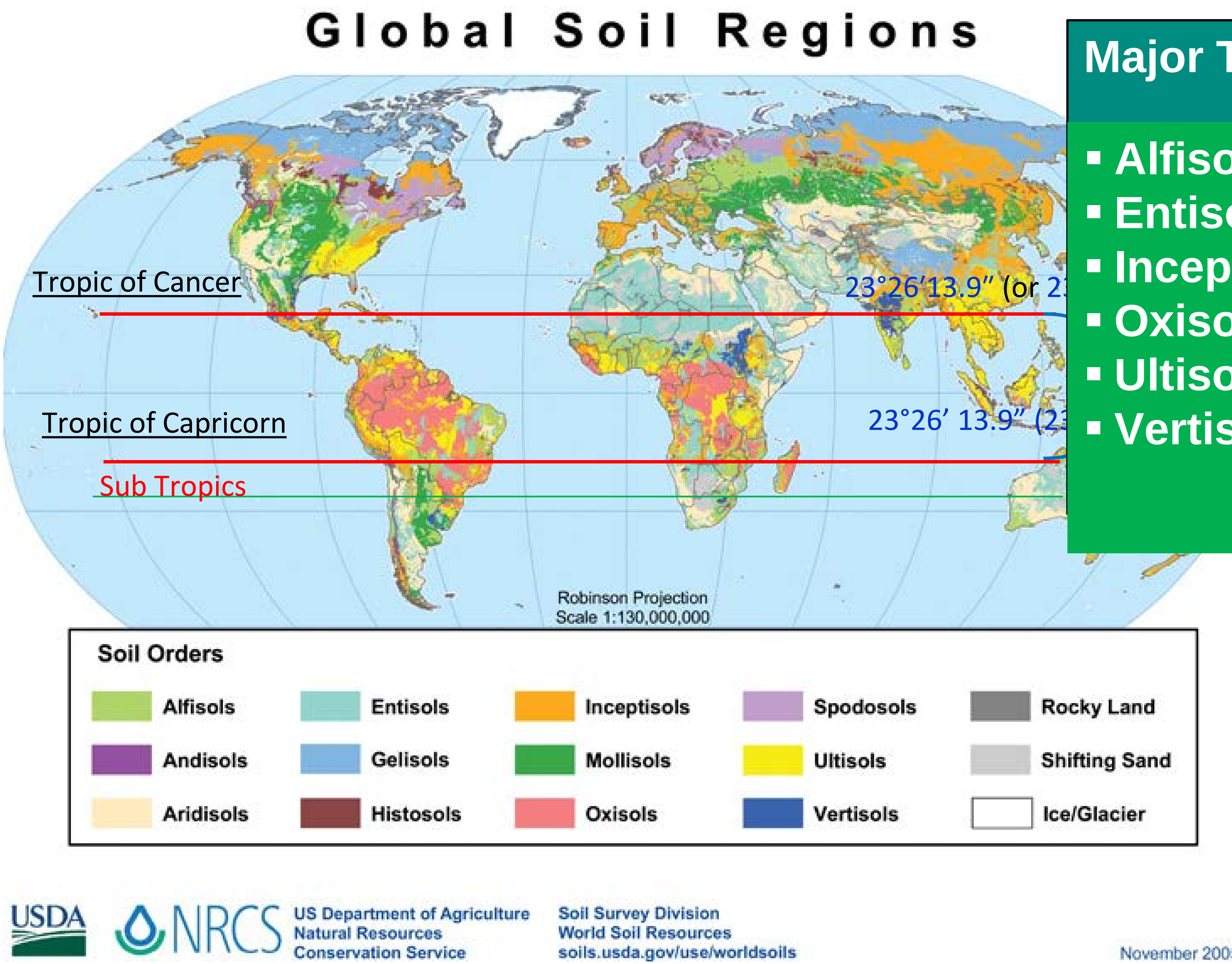
D. Soil is a living organism, needs

- ❖ nourishment,
- ❖ need care, and
- ❖ protection

Definition of soil fertility

Soil fertility is defined as ‘‘the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops’’[SSSA 1997]

Geographical Distribution of Soils



Major Tropical Soils

- Alfisols
- Entisols (Psamments)
- Inceptisols (tropets)
- Oxisols
- Ultisols
- Vertisols

Fig. 2: Global soil regions

Why Soil Fertility Management

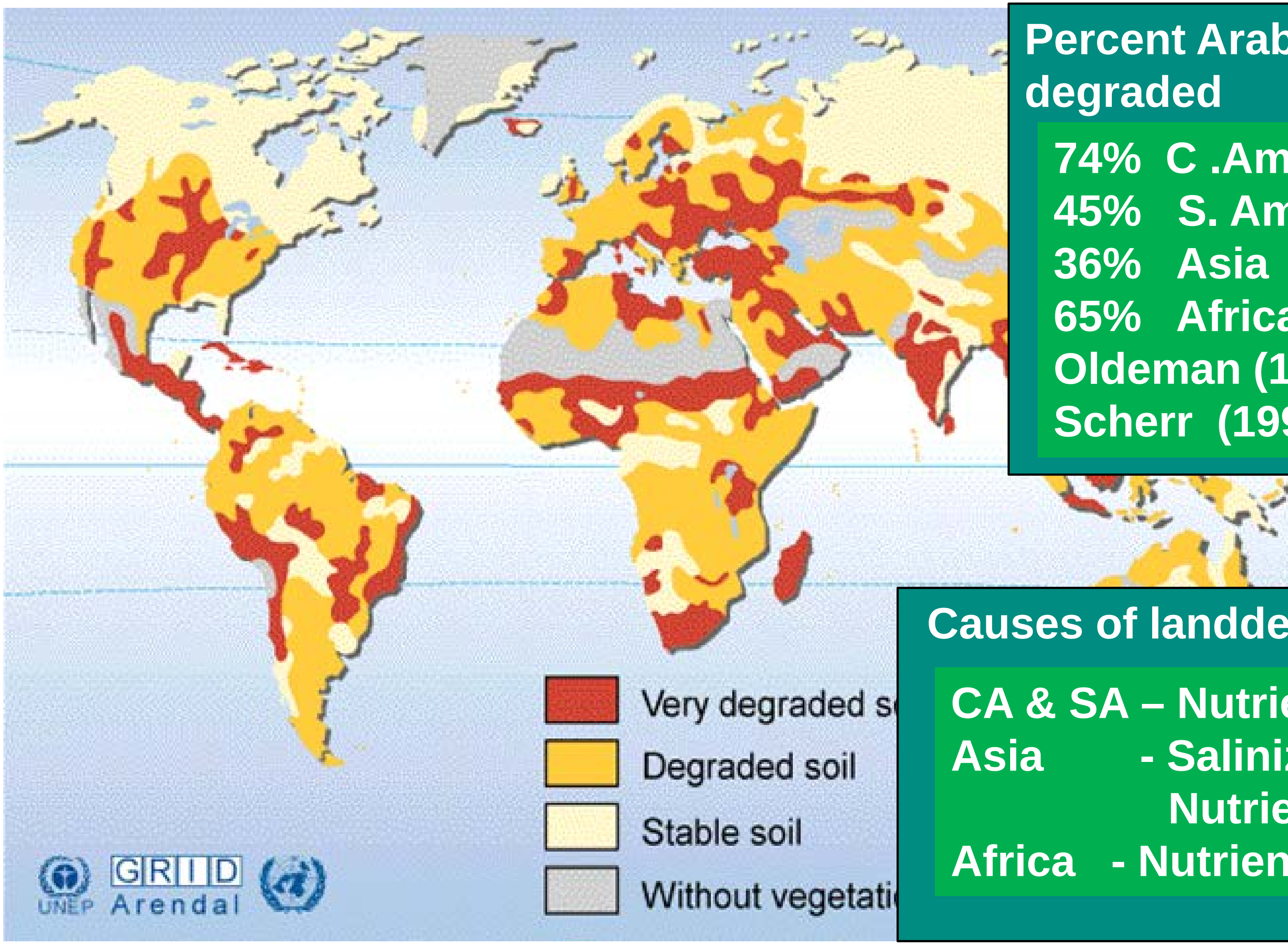
Table 1 Major Tropical Soils

USDA Soil Taxonomy	**FAO Soil Taxonomy**	**Description**
Alfisols	Luvisols, Eutric, Nitosols, & Lixisols	Gray to brown s… base nutrients a…
Entisols	Various	Soils with poorly… deposit
Psammets	Arenosols & Regosols	Sandy, **acid, inf…**
Tropepts	Cambisols	Well drained inc… **infertile**; Eutrop…
Oxisols	Ferrasols & Plinthisols	Deep, **highly w… status soils**, ex… drainage
Utisols	Acrisols, Dystric, Nitosols & Alisols	Similar to **Oxiso…** with depth. Texture from sandy to clayey
Vertisols	Vertisols	Dark heavy clay soils that shrink and crack when dry. Moderately high base status

Inherent low soil fertility

- Dominance of low activity clays in the clay fraction.
- Low CEC
- Low organic matter
- Low capacity to retain & supply nutrients
- High P fixation
- Low base cations
- Acidic, pH < 5
- Low micronutrients

Why Soil Fertility Management...



Percent Arable land degraded

74% C .America
45%   S. America
36%   Asia
65%   Africa
Oldeman (1999);
Scherr (1999)

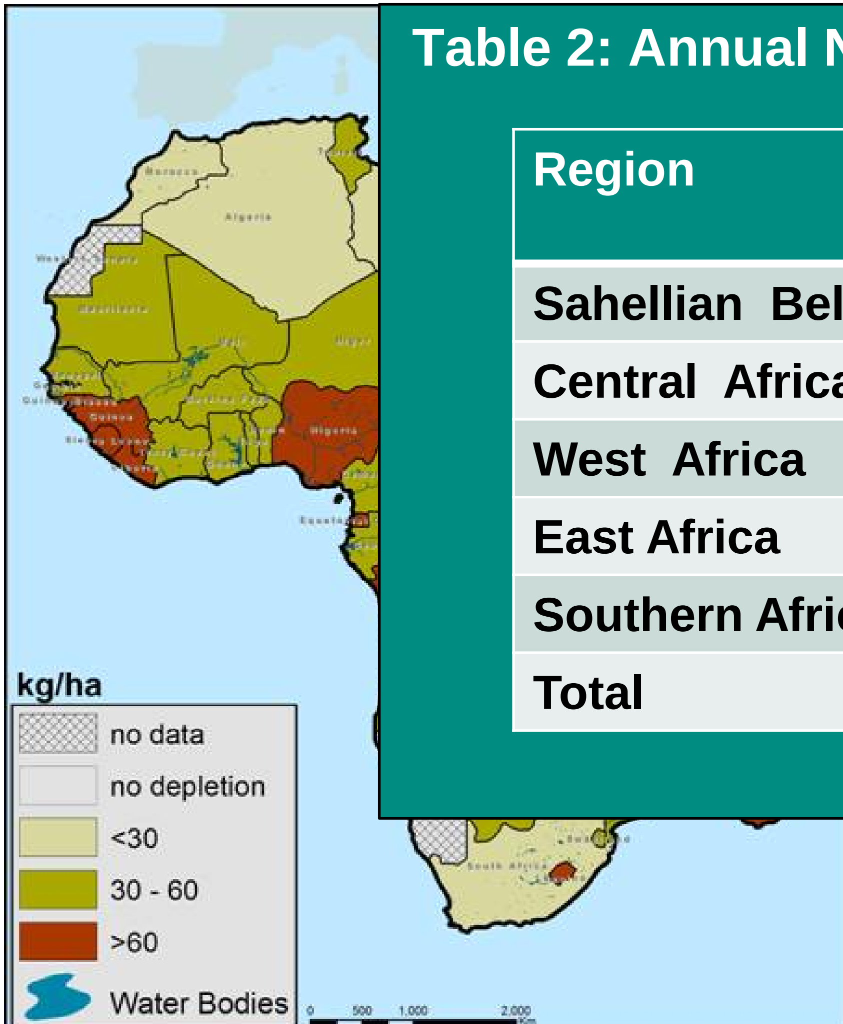
Causes of landdegradation

CA & SA – Nutrient loss
Asia - Salinization & Nutrient loss
Africa - Nutrient mining

Fig. 3: Soil degradation

Evidence of Accelerated Soil degradation in SSA

1995-1997 **2002-2004**



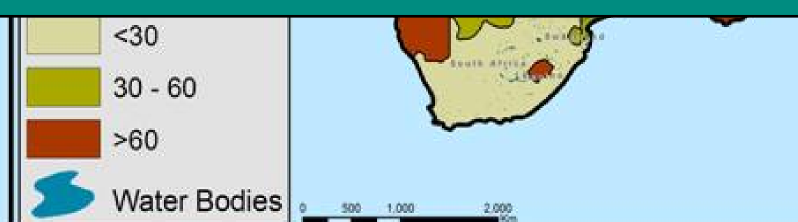


Table 2: Annual Nutrient Balance in Africa 1993-1995

Region	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Sahellian Belt	-233	-81	-206
Central Africa	-93	-43	-83
West Africa	-347	-104	-279
East Africa	-290	-98	-300
Southern Africa	-157	-19	-214
Total	-1121	-346	-1081

Fig 4: Nutrient mining of agricultural land in Africa kg/ha/year

Source: Hanao & Baanante, 2006; IFDC 2006

Soil Erosion & Leaching

Bush burning

Uncontrolled Timber logging

Harvest and removal of crop Residues to urban markets

Soil Erosion

- **Most African countries (especially W.A and C.A) lose about 50 tons of soil per hactare per year.**
- **Equivalent to 20 billion tons of N, 2 billion tons of Phoshorous & 41 billion tons of potassium per year**

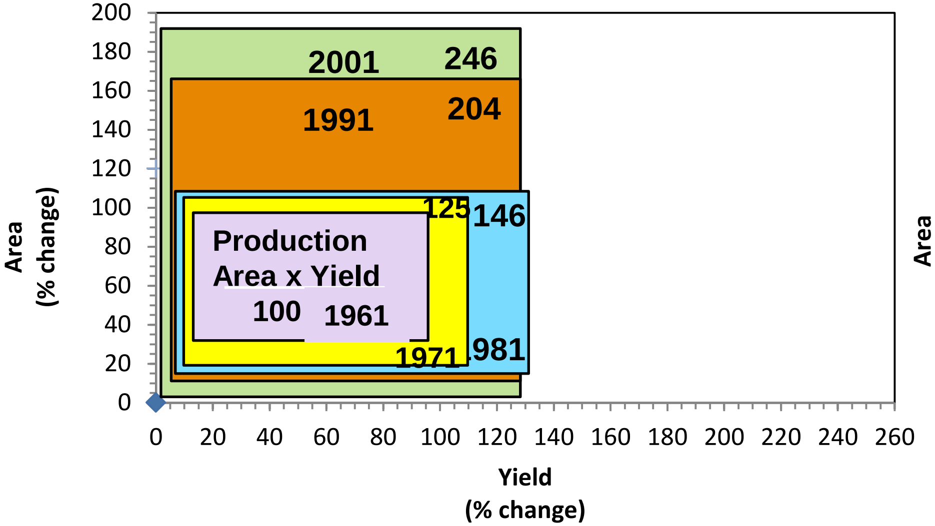
Source: FAO

Negative Impact of land degradation

A. Per Capital Food Production in Africa and Asia

B. Ecological imbalance

C. Increasing level of poverty 40% SSA population living below the poverty line



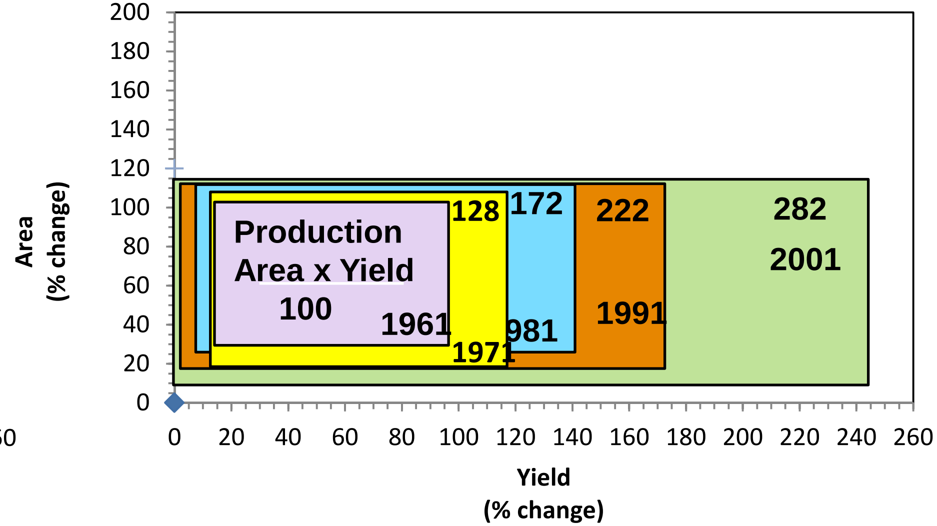


Fig. 5: Changes in Cereal Production in Sub-Saharan Africa Due to Changes in Area and Yield (1961 = 100)

Fig.6: Change in Cereal Production in Asia Due to Changes in Area and Yield (1961 = 100)

Source: IFDC, 2006; UNEP, 2002

Paradigm shift of management of soil fertility in Africa

Table 3

Year	Soil fertility management approaches	Factors that discourage the practice/ Remarks
Up to 1960	Traditional bush fallow method (10 or more years)	▪ Population growth
From 1960s-1970s	External inputs (mineral fertilizer, lime, irrigation water & improved cereal germplasm)	
1980s	Low external inputs sustainable agriculture (LEISA)	
1980s-1990s	Integrated Natural Resource Management (INRM) & Integrated soil fertility management (ISFM)-AGRA ?	

Critical Lesson Learned

A highly context-specific approach is required which takes into account:

- **The status of soil fertility.**
- **The avaialability of organic**
- **inputs.**
- **Ability to acess & pay for mineral fertilizers**

Source: Bationo ,2009

Technologies developed to improve agricultural production & soil fertility in SSA

Benefits

- Favourable microclimate,
- Permanent cover,
- Improved SOM and biological activities,
- Improved soil structure,
- Increased infiltration of water,
- Improved nutrient cycling and soil fertility

Constraints

- Areas lost for crop production,
- Recommended trees did not meet the immediate and long term needs or expectation of farmers
- Lack of planting materials (seed and seedlings)

Source: Kwesiga et al. (2003) ; Minae et al. (1989); Jalloh et al. (2011); Ngwira et al. (2014)

Agroforestry

Alley cropping

Vegetative strip

Improved fallow

Constraints...

- Competition with crops for space and natural resources (water, nutrients, sunlight etc).
- Land tenure system
- Farm size- area of land & duration
- Problems with residue management

Technologies developed to improve agricultural production & soil fertility in SSA

Green manure and cover crop

Crotalaria juncea

Pueraria phaseoloides

Sesbania rostrata

Mucuna bracteata

Cowpea

Source: Nederlof & Dangbégnon (2007); Gachene et al. (1999); Pessarrakli (1999)

Benefits

Cover crops

- Provide soil cover
- Loosen compacted soil
- Improved water infilttration
- Maintain or increase soil organic matter
- Prevent soil erosion
- Suppress weeds
- Reduce insects pests & diseases

Green manuring

- Suppression of soil- borne diseases

Constraints

Biophysical factors, faced by land users who are mostly smallholder armers.

Only few species of exotic and traditional legumes performed well across most sites.

Environmental stress and constraints e.g. water limitation, drought, soil acidity, nutrient deficiency etc.

Some crops recommended by researchers were not suitable to farmers needs or criteria

Technologies developed to improve agricultural production & soil fertility in SSA

Benefits

1 Organic matter content
3. Soil structure
4. Soil water holding capacity
5. soil fertility (nutrients & microbial activity)
6. crop yield

Crop residue cover

Composting

Constraints, cover

- Not so appreciable in wet conditions
- May habour pests and diseases
- Dependent on local biophysical and socio-economic environment

Constraints , composting

- Labour intensive and machinery is rarely available to smallholders
- Low nutrient content, require large application to fields thus increase cost
- Competing use of residues in sub humid and arid areas (livestock, burning, and construction)

Source: Ouédraogo et al. (2001); Mando et al. (2005) ; Danso et al. (2007)

Major issues still confronting SSA

- Soils of Africa cannot sustain high productivity and growth without organic inputs (see table below).
- The population of Africa is expected to double by 2050
- Demand for food will increase
- Global warming may alter soil fertility patterns

Table 4: Typical characteristics of some soils in Africa

Order Soil Taxonomy	FAO	Relative amount of major minerals	Mineral in soils (%)	Organic matter (%)	CEC Cmol(+)/kg
Alfisols	Chromic Lixisols	KK-5; MT-3	KK-55	0.93	3.9
Entisols	Haplic Arenosols	KK-4	KK-15	0.81	6.2
Mollisols	Chromic Livuisols	KK-3; MT-3	KK-34	1.72	20.1
Oxisols	Rhodic Ferrasols	KK-4	KK-43	2.24	17.2
Utilsols	Ferric Acrisols	KK-5	KK-43	0.71	5.0
Utilsols	Rhodic Ferrasols	KK-5	KK-41	1.44	11.5
Vertisols	Vertisols	KK-4; MT-3	KK 33	1.63	34.1

(Key: KK= Kaolinite, MT= Montmorillonite; 5= Dominant; 4= abundant , 3= Moderate

Source: Lungu et al., 2015 (un published)

Major issues still confronting soil fertility in Africa

Options to build up SOM

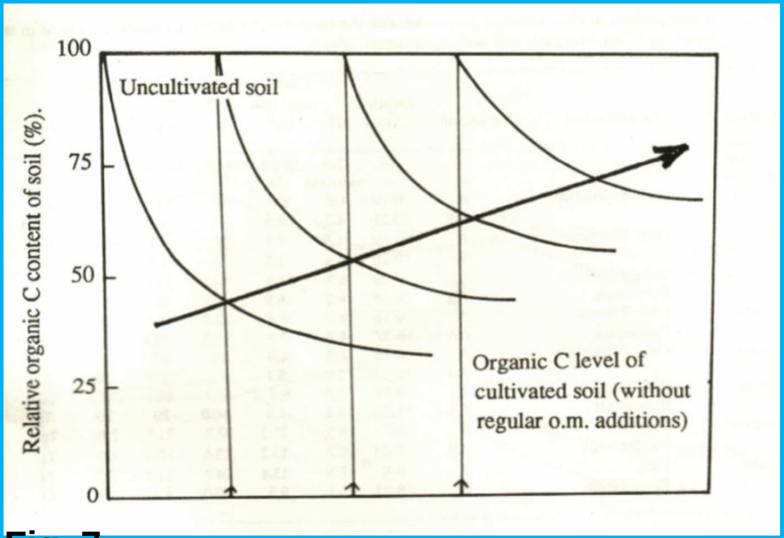


Fig. 7

The Way Forward?

- Maintaining high equilibrium levels of soil organic matter is key to sustainable production on tropical soils.
- Annual additions of residues and manipulation of the decomposition rate of organic matter

Need to investigate the biophysical, socio-economic and cultural issues that prevent the adoption of agroforestry, cover cropping & green manuring, composting, residue cover & mulching .

Integration of the above into Organic Agriculture (crop rotation, intercropping)

Why Organic Agriculture an Option for the Tropics?

A. Potential to Support the Multispicies African Farming Systems

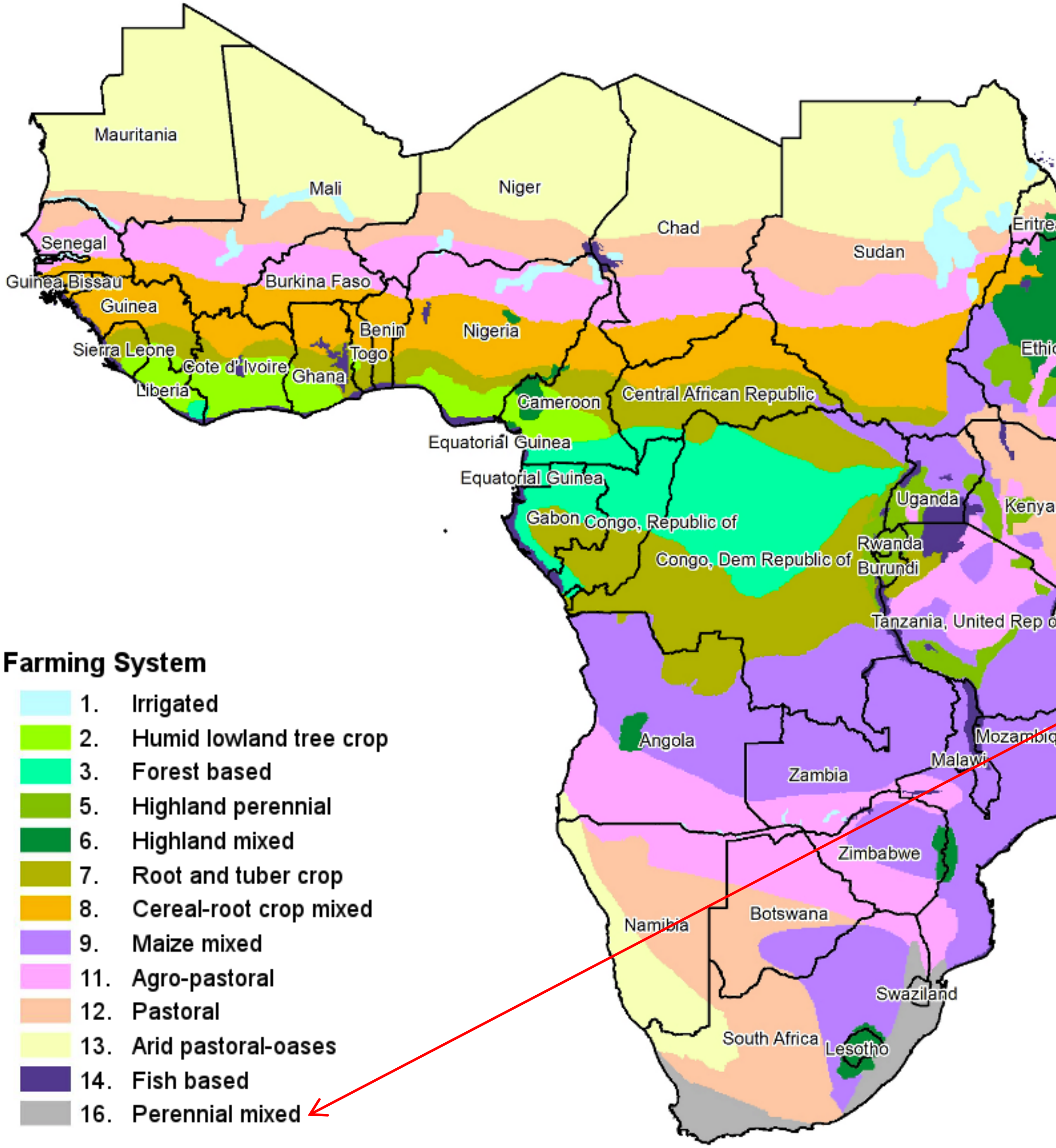
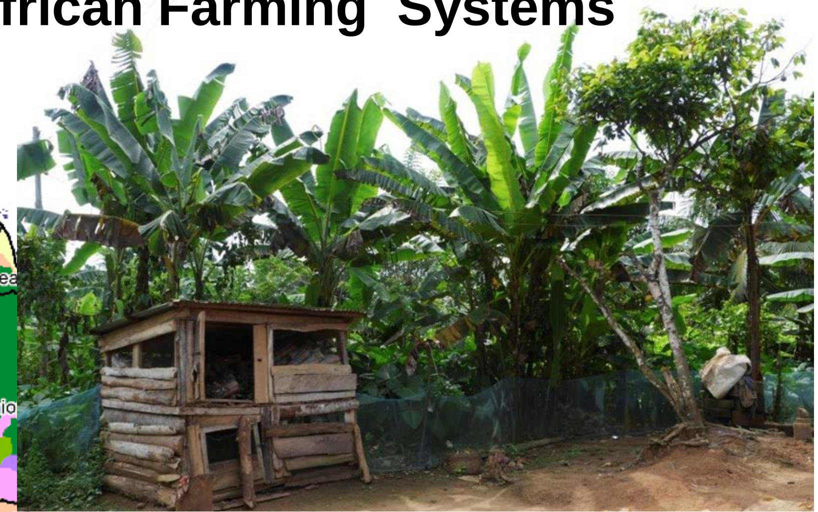


Fig. 8: Map of Africa



Cocoa
Plantain
Cocoyam
Maize
Oil Palm

Fowls
Small ruminants?
Citrus?
Avocardo?

Why Organic Agriculture an Option for the tropics?

Case study : Kenya

Table 5: Long term systems comparison trial in Kenya (Chuka and Thika) (2007= B, &2012= A)

		Texture					B	A	B	A	B	A
Site	Soil type	Clay	Silt	Sand	Crops	Treat	**pH**	**pH**	**CEC**	**CEC**	**Org C**	**Org C**
Chuka		%	%	%					Cmol (+) /kg	Cmol (+) /kg	g/kg	g/kg
	Humic	75	13.2	11.8	M, B, V, P	Conv-High	**5.7**	**5.5**	**18.8a**	**20.6b**	**24.7**	**27.3**
	Nitisol				M, B, V, P	Org-High	**5.8**	**6.0**	**17.8a**	**26.7a**	**21.7**	**27.1**
					M, B, V, P		**5.7**	**5.5**	**16.8a**	**17.8b**	**24.5**	**26.8**
					M, B, V, P	Org-Low	**5.8**	**5.9**	**16.5a**	**16.5b**	**22.0**	**26.2**
Thika												
	Rhodic	82.5	11.4	5.8	M, B, V, P	Conv-High	**5.4**	**5.6**	**11.0**	**18.0a**	**23.0**	**19.2**
	Nitisol				M, B, V, P	Org-High	**5.3**	**6.9**	**10.5**	**20.1a**	**22.1**	**18.1**
					M, B, V, P	Conv-Low	**5.4**	**5.2**	**10.8**	**14.7b**	**22.8**	**18.7**
					M, B, V, P	Org-Low	**5.4**	**5.4**	**11.8**	**14.9b**	**22.4**	**17.7**

Percentage change in organic carbon (org-C) at Chuka : Conv-High = 11%; Org-High= 25%; Conv-Low = 7%;

Org-Low = 19% . CEC, Cation exchange capacity ; High input (229 kg N/ha: 128 kg P/ha); Low input (47 kg N/ha: 31kg P/ha)

Source Adamtey et al., Forth coming; M= maize; B= Beans; V= vegetables; P= Potato

Why Organic Agriculture an Option for the tropics?

Case study : Zambia

Table 6 Influence of Agro Ecological Region on Adoption of Agricultural Practices

Sustainable Agricultural practices adopted	Area (agro-ecological region)		
	Chongwe & Rufunsa (I/IIA)	Livingstone (I/IIA)	Mongu (IIB)
Fertility trees	87.0%	62.5%	60.0%
Green manures	63.0%	25.0%	33.3%
Compost	52.2%	37.5%	26.7%
Animal manure	84.8%	87.5%	100.0%
Manure & leaf extract	34.8%	75.0%	46.7%
Crop rotation	84.8%	87.5%	73.3%
Cover crop	47.8%	100.0%	10.0%
Intercrop	65.2%	87.5%	60.0%
No burning	56.5%	87.5%	80.0%
Mulching	21.7%	37.5%	66.7%

Source: SCIAF. 2014. Kulima 2013/14 annual report (unpublished)

Overcoming Inadequate Residue use in OA in SSA

A. Use of Solid Waste in Agriculture

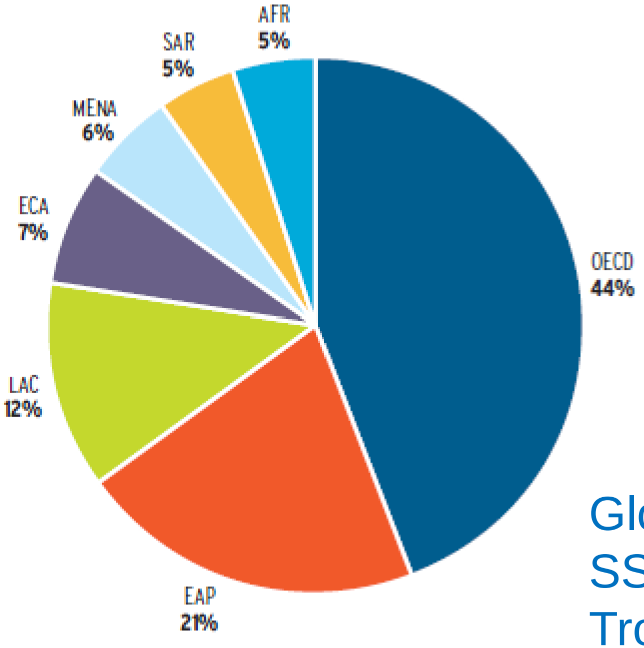


Fig. 8: Waste Generation by Region

Source: World Bank 2012

OECD = Organization for Economic Co-operation & Development
ECA = Europe and Central Asia
AFR = Africa Region
SAR = South Asia
MENA = Middle East & North Africa
LAC = Latin America & Carribbean
EAP = East & Pacific Asia

Global waste generation = 1.3 billion tons/year
SSA (waste generation) = 62 million tons /year
Tropical region (waste generation) = 49.8% of Globa generation

Projections in 2025

Global waste generation = 2.2 billion tons/year
SSA (waste generation) = 124 million tons /year
Tropical region (waste generation) = 49.8% of Globa generation

Overcoming Inadequate Residue Use in OA in SSA

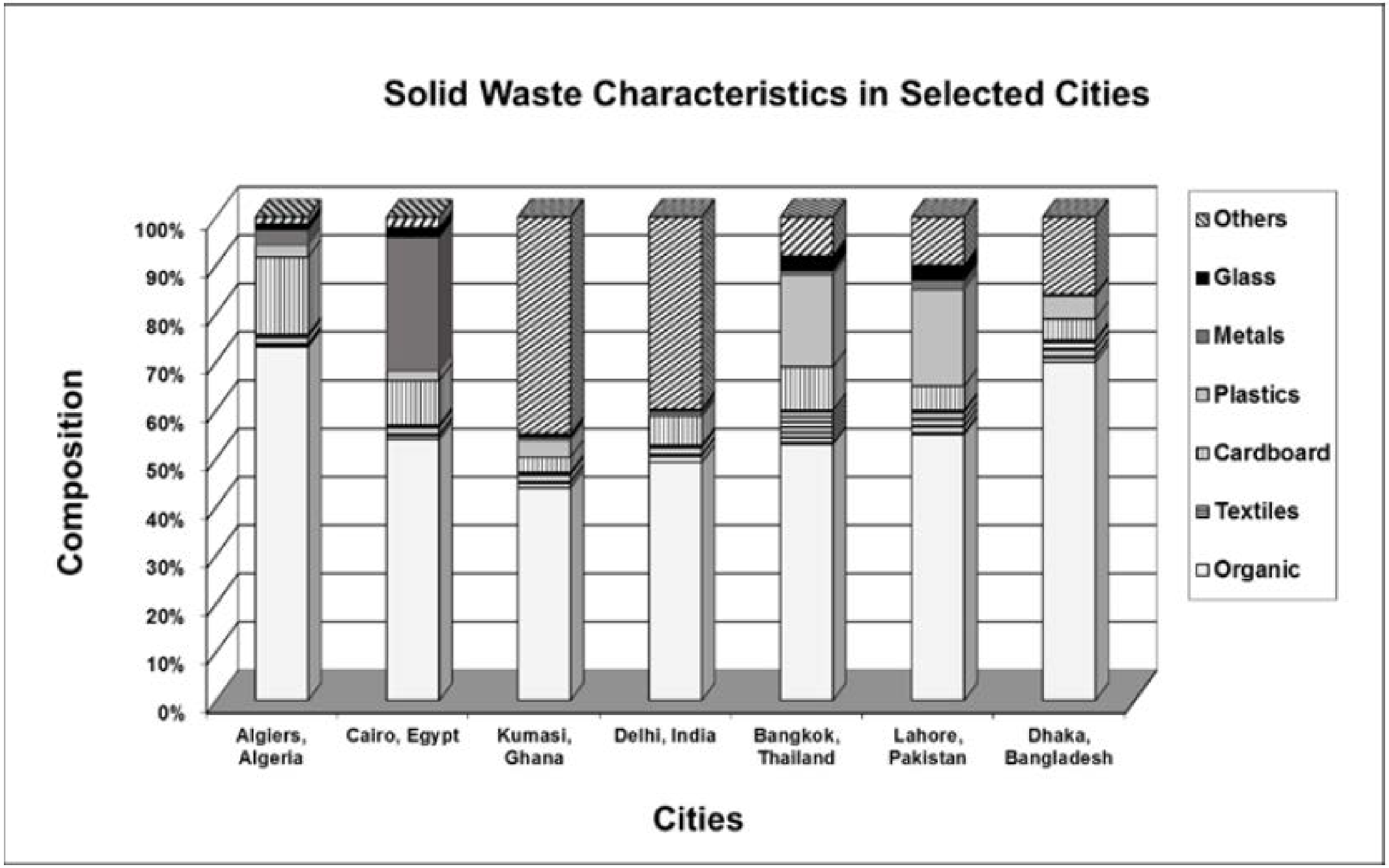


Fig. 9: Mucipal solid waste fractions in selected cities of Africa and Asia

Organic fraction (average) = 50% of the total waste generation

0.65 billion tons of organic fraction is generated **per year** in the tropics

31 million tons of organic fraction is generated **per year** in SSA

Projection in 2025

61 million tons of organic fraction will be generated **per year** in **SSA**

Source: Cofie et al. 2006

Overcoming Inadequate Residue use in OA in SSA

Quality of compost from MSW in some cities of Ghana

Table 8: Concentration of Heavy Metals in Composting Materials (mg/kg dry weight)

Composting materials	Pb	Zn	Cu	Fe	Mn	Cd
Household waste $(HW)_1$	74	56	22	1,958	160	*
Household waste $(HW)_2$	38	115	12	2,070	451	*
Market waste $(MW)_1$	39	54	38	2,449	186	*
Market waste $(MW)_2$	47	64	15	1884	450	*

Table 9: Concentration of Heavy Metals in Compost (mg/kg dry weight of compost)

Compost Heaps	Pb	Zn	Cu	Fe	Mn	Cd
Compost heap 1	87	146	63	11,748	249	*
Compost heap 2	47	128	43	8,405	258	*
Threshold values[a]	**150**	**400**	**100**	**-**	**-**	**1.5**

* Trace amount (below detection)

[a]WRAP (2002) The Waste and Resource Action Programme (WRAP), Supplement 6

Challenges Associated with MSW compost ing in SSA

- ❖ High cost of operation hindered private sector involvement.
- ❖ Over emphasis placed on electricity demanding and often fragile mechanised process rather than labour intensive operations.
- ❖ Unstable compost quality.
- ❖ Inadequate attention to biological processes requirements for example under tropical conditions.
- ❖ Lack of vision and marketing plans for the final product (i.e. compost).
- ❖ Poor accounting practices that neglect the fact that the economics of composting rely on externalities such as reduced water contamination, avoided transport and disposal costs.
- ❖ Difficulties in securing financies.
- ❖ Lack of enabling institutional (e.g. Private-public partnership) framework

Source:Hoornweg et al.,1999; Cofie et al. 2006; Drechsel et al., 2010

Current Research Policies & MSW Management or Composting in SAA

Gaps in existing research policies

Case study: Ghana

1. The constitution does not make a direct reference to composting.
2. The Environmental Sanitation Policy does not incorporate incentives that could attract private sector participation in composting.
3. The Local Government Act does not include waste separation at source and this may affect compost quality.
4. National Fertilizer Policy provides subsidy on mineral fertilizer but not on compost.

THANK YOU for your Attention !

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THE WAY FORWARD

Interventions to Reuse MSW for fertility management in the Tropics

1. Unless there are people caring for their soils, policies will not work. General **awareness and education** is key to susccesful soil fertility management.

2. Policies and market mechanisms that make **returning nutrients to productive land, economically attractive to farmers.**

3. Policies on waste management (including incentives for source seperation of waste, waste collection and recycling (composting) , capacity building and knowledge sharing) so that reuse of nutrients is ensured, including ways to make sure these policies are implemented on the ground in tropical countries.

4. Policies incentive for organically-sourced fertilisers, that also **take into account the health of the farming community**.

THE WAY FORWARD

Interventions to Reuse MSW for fertility management in the Tropics

5. Much more **research and development on different options for reusing waste, including development of best techniques for composting in different scenarios and on producing high quality compost specific for particular types of soils and crops**

6. Policies to develope the local animal production industry in terms of industrial livestock operations, amount that is produced and consumed, and the waste management. To integrate animal waste into MSW composting

7. Societal change in understanding and value of **waste, not as waste, but as a resource** that needs consideration and care.

Current Research Policies & MSW Management or Composting in SAA

Case study: Ghana

Table 7a

Policy, Act	Key issues
Constitution of Ghana 1992	▪ empowers parliament to pass all laws on the enviroment ▪ direct states to take appropriate measures to promote the develpment of agriculture & inductry ▪ It encourages all citizens to protect & safeguard the environment
Environmental Sanitation Policy 20010	▪ seek to promote benefits of alternative use of waste through reduction, re-use, recycling and recovery. ▪ reference is made to recycling through composting ▪ it seeks to ensure that site for treatment & disposal of waste are safe & hygienic
Local Government Act , 462, 1993	▪ place MSW including composting under the responsibilities of MMDAS ▪ it mandates the MMDAS to set up waste management departments

Current Research Policies & MSW Management or Composting in SAA

Case study: Ghana...

Table 7b

Policy, Act	Key issues
Environmental Protection Agency Act, 490 1994	▪ main government institutions or agency responsible for environmental protection & compliance ▪ demands environmental impact assessment prior to issuing a permit for compost plant construction ▪ responsible for controlling the generation, treatments, storage, transportation 6 disposal of waste
National Fertilizer Policy Act, 2013	▪ directs overall approaches & practices in the compost sector ▪ It acknowledge organic fertilizer from organic materials such as sewage, animal manure & plant residues prepared through composting, fermentation, etc.
Plants and Fertilizer Act 2010	▪ it directs that no person shall import, manufacture or distribute fertilizer in commercial quantities unless the person is registered ▪ it directs on how to register a compost plant, seek certification for a compost product

Table 1a

USDA Soil Taxonomy	FAO Soil Taxonomy	Description
Alfisols	Luvisols, Eutric, Nitosols, & Lixisols	Gray to brown surface soils. Medium to high b nutrients and organic content
Andisols	Andosols	Volcanic soils, moderate to high fertility, P fixat allophane
Aridisols	Solonchalk & solonetz	Dry or desert soils, high in base nutrients & low matter
Entisols	Various	Soils with poorly developed layers. Wind depos
Fluvents	Fluvisols	Alluvia soils usually of high fertility
Psammets	Arenosols & Regosols	Sandy, **acid, infertile soils**
Gelisols		
Histosols	Histosols	Wet, highly organic soils (> 20% organic matter
Inceptisols	Various	Young soils with A-B-C horizon development. Fe highly variable
Aquepts	Glysols	Poorly drained moderate to high fertility
Tropepts	Cambisols	Well drained inceptisols (Dystropepts= **acid**, **inf** Eutropepts=high base saturation
Mollisols	Chernozems	Thick, dark soils high in organic content and ba derived from calcareous materials
Oxisols	Ferrasols & Plinthisols	Deep, **highly weathered**, **acid, low base status** excellent structure & good drainage
Spodosols	Podzols	Sandy surface horizon underlain with a horizon of organic & amorphous C, Fe & Al compounds infertile or low in base nutrients
Utisols	Acrisols, Dystric, Nitosols & Alisols	Similar to **Oxisols** except for a clay increase with depth. Texture from sandy to clayey
Vertisols	Vertisols	Dark heavy clay soils that shrink and crack when dry. Moderately high base status

Why Soil Research in the Tropics?

Inherent low soil fertility

- Dominance of low activity clays in the clay fraction.
- Low CEC
- Low organic matter
- Low capacity to retain & supply nutrients
- High P fixation
- Low base cations
- Acidic, pH < 5
- Low micronutrients