SOIL AND WATER FOR SOCIETY: SHARING SOLUTIONS

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Abstract
Soils have been closely linked to the civilization and wealth of a nation. Currently, soils are considered important in world development issues such as food security, poverty alleviation, land degradation and the provision of environmental services. However, soils undergo degradation due to climatic factors and adverse agricultural practices which lead to reduced food production. There is a strong need to reduce soil degradation process through the application of various solutions. Some of these solutions include: shifting cultivation, use of cover crops, use of crop residues, tree litters and prunings, use of spot trees, dumping of kitchen refuse, proper crop combination and arrangement, mulching, agroforestry and use of Vetiver grass. A review and adoption of these methods would be a step in the right direction to stop the process of soil degradation and thus conserve soil and water.

Additional Keywords: soil degradation, land capability classification, soil conservation, Niger Delta, women, soil conservation.

Introduction
Soils are increasingly being regarded as a determinant factor for the wealth of any nation as they are closely associated with world development issues such as poverty alleviation, food security and the general well being of the people. Tropical soils consist mainly of Oxisols, Ultisols, Entisols and to a lesser extent, there are Inceptisols, Aridisols and Alfisols. These soils respond to the distinct tropical climate and are highly prone to leaching. They also respond to degradation at a fast rate.

Ashaye (1987) defined soil as a 'three dimensional body occupying the uppermost part of the earth's crust and having properties differing from underlying rock material as a result of interactions between climate, living organisms (including human activity), parent material and relief over periods of time and which is distinguished from other soils in terms of differences in internal characteristics and/or in terms of the gradient, slope complex, micro-topography, stoniness and rockiness of its surface'. Soil is simply regarded as the upper 15 cm of the horizon where the living organisms operate as a community to carry out various metabolic processes that are beneficial to plants, animals and man. Agricultural operations are carried out on the soil for the production of food for the teaming population. Food production worldwide involves various operations that prepare the soil for the growth of the desired crop. These processes coupled with plant nutrient uptake tend to lead to soil degradation. Soil degradation leads to a reduction of soil available for food production which eventually has implication for food security. Awareness of the need for soil conservation arose in the United States of America in the 1930s. There had been a lot of irreversible soil loss by erosion before that time. In the tropics, descriptions of erosion and its consequences date back to the 1930s. Ainslie (1935) reported an account of erosion in Nigeria.

For Africa, agriculture contributes significantly to the formal economy and employment that is about 70% of the workforce. Within this is also the substantial contribution of the small -scale farmers. Agriculture as practiced in most of Africa is rain-fed except in northern African countries and the western Indian Ocean island states, where irrigation potential has been well developed. Most African countries experience large inter-annual and intra-annual variations in rainfall, with frequent extreme in flooding or drought. Thus vulnerability to crop failure translates into economic insecurity. According to the World Bank, 1994, many African economies are dependent on a narrow range of agricultural commodities, creating greater vulnerability to failure resulting from outbreaks of pests, climatic variations, price fluctuations and so on. The extent of land under cultivation has risen steadily from 166 million ha in 1970 to 202 million ha in 1999. The area under permanent pasture increased rapidly during the latter half of the 1980s and then declined sharply to 892 million ha in 1999 (FAOSTAT, 2000).

In West Africa, land cover and land use are largely determined by the climate and a dramatic degradation is seen from north to south in rainfall and vegetation cover. In the north, average annual rainfall is 350-850 mm yr^{-1} and savannas are the dominant ecosystems along the southern border of the Sahel (Mali, Mauritania, Niger and northern Senegal). Here climate variability is greatest and drought is common and often severe. Cultivation is limited and represents 4% of the land area in Mali and Niger (FAOSTAT, 2001).

Land Quality and Productivity

As a result of pressure to increase production, marginal land is being brought under cultivation or grazing, fertilizer and pesticides are widely used in commercial operations although the application of organic matter in small- scale practice is declining and fallow periods are reduced. These activities, although designed to increase productivity can result in exhaustion of the production capacity of the land manifested as: declining yields, vegetation and soil degradation and loss and in extreme cases, desertification. Climate variability and change, inappropriate land use or land tenure policies add to the pressures and magnify the impacts (Plate 1). The current situation is that approximately 22% of the vegetated land in the region (494 million ha) has been classified as moderately, severely or extremely degraded (UNU, 1998). As shown in Figure 1, Africa is not unique in experiencing land degradation, but the effects of food security and the anticipated impact of climate change make land degradation a priority issue.

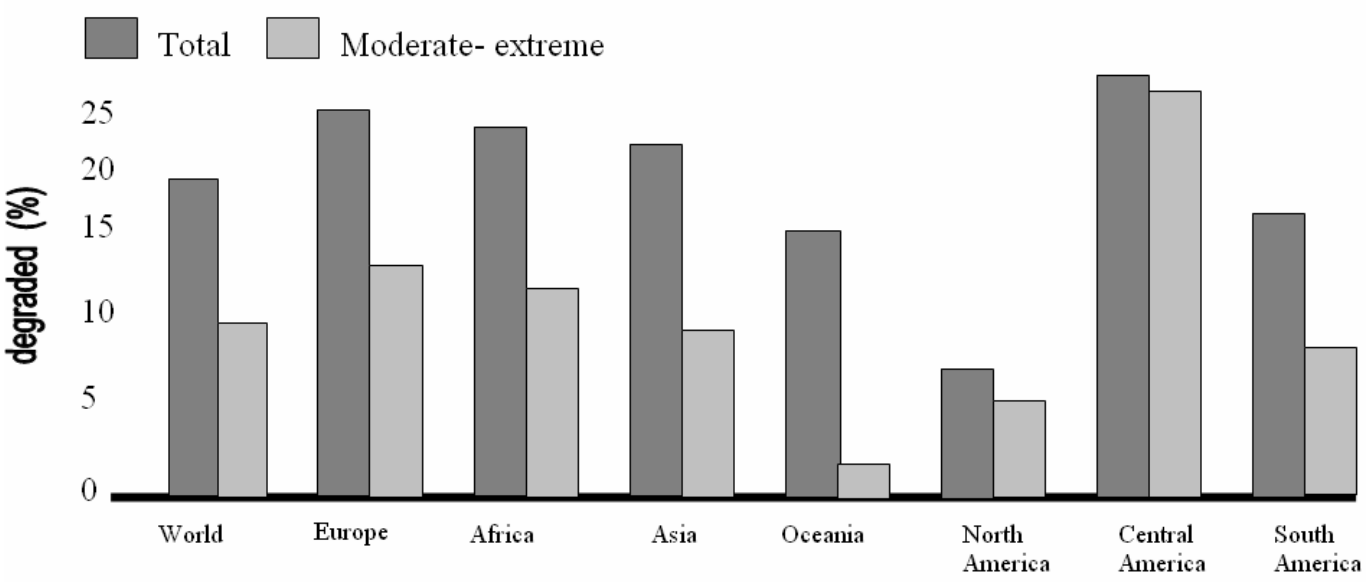

Figure 1. Regional comparison of land degradation (Source: UNU, 1998)

Plate 1. Shows wind and water erosion extensive in many parts of Africa, placing millions of peasant farmers at risk of food insecurity

Land degradation and reduced productivity can be categorized as: hydrological and chemical degradation, physical degradation and biological degradation. Hydrological and chemical degradation encompasses waterlogging, salinization, sodication and chemical pollution and industrial pollution. Physical degradation includes deterioration of soil structure and the occurrence of compacted layers that can be due to overstocking, inappropriate use of machinery, mining and quarrying activities, frequent waterlogging and exposure to erosion. Biological degradation refers to the loss of nutrients and microorganisms vital for maintaining healthy productive crops and is due to exhaustion of soil fertility as a result of intensive cropping, removal of crop residues, nutrient deficiencies and insufficient organic matter.

Land Rights and Soil Degradation

The issue of land rights in Africa is a highly complex, sensitive and social issue, closely linked with poverty and land degradation issues. Traditional land tenure system was developed in accordance with variations in physical conditions and cultures although they were largely centred on communal access to resources and sharing of benefits. A farmer who does not have land right cannot freely apply certain soil amelioration principles such as the planting of trees to reduce soil degradation. This system is also highly unfavourable to women. The traditional laws only grant women access to resources through their husbands or fathers. If they become widowed, they loose

access to the land as they could be forced to leave the land. Women also have lower income and may not be able to purchase the land. Women are discriminated against in the acquisition of credit facilities and they are commonly given marginal lands.

Soil Degradation Processes

Goodland and Brockman (1992) mapped out the pathway of the relationship between forest clearance and crop failure as shown in Figure 2.

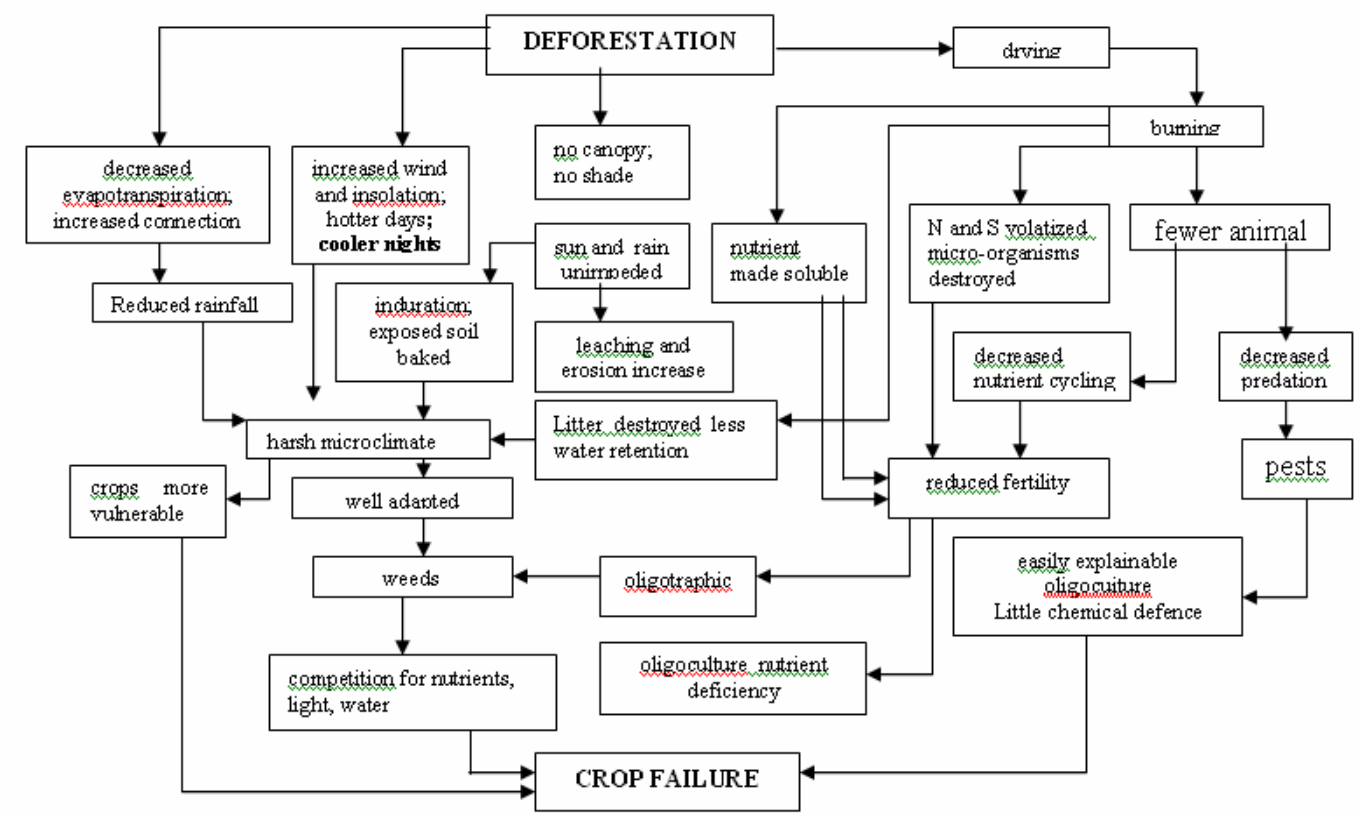

Figure 2. The relationship between forest clearance and crop failure (Source: Goodland and Brookman 1992)

The action of deforestation triggers off a series of events that finally end up in crop failure. There are points of interjection in the process to reduce or reverse to a certain extent the process of soil degradation. These interjection points would be discussed in details as sharing of solutions.

Soil Degradation and Conservation in Nigeria and Methods of Solution

That food production generally lags behind the demand has always been a great concern to agriculturists and planners. This is particularly true of the tropical environment where in spite of the use of improved cultivars and commercial fertilizers among other agricultural inputs, astronomical yields are hardly realized because of very severe soil constraints including high soil temperature, low activity clays, low organic matter contents, flooding, drought etc. Nigerian soils therefore like other tropical soils are not only characterized by low yields but are also prone to a rapid decline in productivity brought about by intense or continuous cultivation.

The fertility of the soil for agricultural production under uncleared natural forest vegetation perhaps poses a ceiling to soil fertility status. Such forest soils have a dark layer of top- soil of varying thickness that is rich in organic matter and nutrients and is of good physical condition. The condition of this layer gives an indication of the productivity of the soil. It is no exaggeration that the wealth of a nation can be predicted by the condition of this soil layer. Once a piece of land is exposed by cutting down the forest, subsequent cultivation is accompanied with a continuing but variable decline in fertility because of the main processes – leaching, cropping and erosion. Lower productivity need not follow when a forest- land is cleared and put to agricultural use if sound management and conservation practices are put to use.

Soil Management Principles

In order to achieve high and sustained production as well as preserve ecological stability, the following factors according to Babalola (1987) must be borne in mind when the land is cleared for agricultural production:

- Preservation of the delicate ecological balance among vegetation, climate and soil
- Maintenance of a regular and adequate supply of organic matter on the soil surface.
- Encouragement of soil faunal activity.
- Maintenance of physical condition of the soil suited to land use.
- Replenishment of nutrient removed by cropping
- Creation of a desirable nutrient balance and soil reaction.
- Prevention of a build up of pests and undesirable plants.
- Adaptation of a natural nutrient recycling mechanism to avoid leaching losses of nutrients
- Preservation of ecological diversity.

Soil Conservation Efforts

Various soil conservation efforts have been carried out under different soil types and ecosystems. The traditional farmers carried out soil conservation in their farms using different methods.

The Coastal Niger Delta Region of Nigeria

Soil characteristics

Table 1 shows the characteristics of soil sampled across the Niger Delta of Nigeria. The soils generally are of acid reaction with mean pH in water of 4.8 (range 4.6- 5.0). Organic matter average is 2.45%, total nitrogen, 0.08% and cation exchange capacity of 12 meq $100g^{-1}$ soil. The soils are deficient in nitrogen and are low in fertility. These means are low compared to the international soil samples as shown in the Table 1 obtained from FAO (1982).

Table 1. Mean soil physico-chemical properties Niger Delta soils.

S/N	Clay %	Silt %	Sand %	OM %	pH	CEC Meq $100g^{-1}$	Total N %
Coastal plain sand	15.9	11.4	73	2.52	4.6	7.7	0.08
Meander belt Delta	23.9	41.5	35	2.60	4.8	16.3	0.07
Mangrove swamp	11.4	27.2	46	2.24	5.0	N/D	0.08
International average				1.3	7.1	27.3	0.13

The farmers basically have this kind of soil for agricultural purposes. The zone is characterized by high rainfall that ranged over 1000 mm yr^{-1}. The rains fall every month of the year with high intensity in the months of April to October. Rain intensities of 120-160mm/hr are frequently recorded. These torrential rains cause flood, erosion, run-off and siltation on agricultural fields. The long- term effect of erosion is that it removes the top- soil that then affects the soil fertility. The poor resource farmers in the region are aware of the adverse effect of erosion. They devise two ways of achieving soil conservation. These are cover approach and barrier approach. Under the cover approach, the farmers practice shifting cultivation, use of cover crops, crop residues, tree litters and pruning, spot trees, dumping of kitchen refuse and proper crop combinations and arrangement

Shifting cultivation

This is the most wide spread farming system whereby annual crop production is alternated with periods of vegetative fallow. In times past, the fallow period could be for 7 years. However, population growth, industrialization and urbanization have reduced the fallow period to between 3-5 years depending on the population of the area. Over time, the vegetation cover becomes dense. (Plates 2, 3, 4). The farmers in Akwa Ibom state use 1-4 year fallow with the input of inorganic fertilizer. Mertz (2002) in a classical paper observed that there should be a rethinking on the relationship between the length of fallow and crop yield in shifting cultivation. He suggested that there was no relationship between fallow period and yield.

Use of cover crops

The use of cover crops for soil conservation is more pronounced in plantations of rubber, oil palm etc., and is practiced by large scale farmers. The cover crops used are Mucuna, Centrosema and Pueraria spp. These cover crops are occasionally slashed to reduce the density of the cover.

Plate 2. One year fallow

Plate 3. Two years fallow

Plate 4. Three years fallow

Plate 5. Agricultural plot, shaded by trees, in the Dogon Region, Mali

Crop residue

The deposition of crop residues on the farm is carried out during crop harvest. This is carried out in both food and tree crops. During the harvest of oil palm, the fronds are left behind while maize stalks, sugar cane leaves, cassava leaves are also left behind. The women carry out the processing of cassava and they often left the peels on the farm especially when the processing starts in the farm.

Tree litters and prunings

On every traditional farm, there are scattered trees such as Newbouldia sp. *Penthocletra macrophylla, Elaiese guinensis, Mangifera indica, Acioa barterri* and other leguminous crops. These trees shed their leaves that provide cover and reduce the direct impact of raindrops on the land. Prunned coppices from stumps and weeded grasses are spread on the farm. These spot trees also act as wind break and reduce the direct fall of rain on the land, by converting the rain drops into stem flow (Plate 5).

Dumping of kitchen refuse

In homestead farms, farmers mostly women, dump refuse from the kitchen such as yam, cocoyam and plantain peels, leafy or vegetable materials on the farm. The dumped refuse reduce the impact of rain- drops and thus conserve the soil.

Proper crop combination and arrangement

The polycropping system is practiced in this region. Here, five or more crops can be grown on a piece of farm-land. There could be a situation where yam, melon, telferia, maize, okro, pepper and egg plants and cassava are grown together in one farming season. All the crops except cassava are planted either on the first day or within the first two weeks of planting. Maize and melon are harvested off in about three months after planting to give room to other crops to spread out. Cassava is introduced into the plot when yam is about six months old such that in another three months when the cassava would open out to close canopy, the yam is mature and harvested. The crops are planted in staggered pattern such that they all have access to the sunlight and easily form large area cover on the plot within the first three months of cultivation.

Multi strata system

This is a multi storey garden where perennial, biannual and even annual crops are grown together on the same piece of land. They are not all planted at the same time. A typical farm would have plantain, cocoyam, coconut or oil palm on the same land such that the land surface is almost completely covered from the direct effect of rains and wind.

Barrier Approach
This approach does not provide cover but focuses on reducing or breaking the current of run off thereby promoting sedimentation as well as infiltration.
Some of the techniques are hedgerow, stump retention, staggered planting, inverted mounds and ditches.

Scientific Intervention
Agricultural Extension Workers, as part of their function, introduce soil conservation packages to farmers in the Niger Delta region of Nigeria. A typical success story is the Green River Project by the Nigerian Agip Oil Company (NAOC). This company works with a group of farmers as part of their community development policy.

The story
In an initial survey before the inception of the Green River Project, the farmers practiced soil and water conservation through various practices such as: shifting cultivation, prohibition of the felling of trees, mixed cropping and discriminatory bush burning that is, no bush burning during the fallow period. A typical farmer's soil conservation time table is as follows:
1. Before planting:

a. Fallowing: The farmland is allowing to fallow for 4-6 years depending on the pressure on available land.
b. Bush clearing/bush burning: Farms and cleared and allowed to dry for 2-4 weeks after which they are burnt.
c. Preparation of mounds, beds ridges: Farmers in the low land areas prepare mounds and beds to check erosion and leaching of soil nutrients

2. After planting:
The type of soil conservation effort depends on the type of crop. Farmers practice mulching for crops planted during the dry season. The weeded weeds are also left in the farm to decay while some weed litter are placed on the mounds to conserve moisture.

3. Post harvest
Stalks, leaves and other materials from the harvested crops are usually left on the farm.

Soil Conservation Programme by NAOC Staff
The Green River Project introduced the use of cover crops, alley farming, proper use of fertilization, use of multifunctional kits and agroforestry systems to the farmers. Mucuna sp. was introduced as the cover crop because it established easily in the field. For the alley cropping, the project introduced the combination of Flemingia spp. hedges in the plots planted with cooking and desert bananas. In an agroforestry system, plantations of *Irvingia gabonensis* and *Treculia africana* were introduced. A multifunctional kit that aids aeration, incorporates nutrients and aids root penetration was also introduced to the farmers. This helped in soil conservation. They however observed the following initial problems of adaptation:

- Land ownership rights
- Farmers found it difficult to grow fruits that were not edible and purely for soil conservation.
- The removal of fallow cover crops before the planting of desired crops was considered an extra job.
- The incorporation of cover crops which is through the use of machines also limited the number of farmers adopting this method.

Application of Solution
Use of indigenous soil classification and management practices
Umaru and Kyiogwom (1997) recorded that farmers in some parts of Northern Nigeria had classification based on soil texture and colour and classification based on topography. They had four classes based on soil texture as follows:
Jigawa: This is a general term for sandy, light soils. Based on colour and crop production capability, the jigawa is further divided into Farar jigawa, Janbali and Bakar jigawa.
Tsakwanya or Marji: These are red coloured shallow, hard- soil that contain a high proportion of gravel.
Laka: This refers to dark, hard and heavy soil that crack when dry.
Fako: This is used to describe any soil whose top- soil has been washed off through erosion and leaving the hard pan on the surface.

The two classes based on topography are: Bayen fadama which is usually hard to till and is found in fadama valley with a sub class - Taibi which refers to shallow silt deposit found in fadama and Bayen tudu which is soft sandy soil with low water holding capacity.Based on these criteria, a soil production capability and fertility depletion period for soils were designed.

Table 2. Crop production capabilities and fertility depletion periods (FDP) for soils.

Soil type	Major crops grown	Best crops	FDP (years)	Fertility ranking
Farar jigawa	groundnut, millet, cassava, sorghum, cowpea, sweet potato, cotton	groundnut	three	6
Jambali	same as for Farar jigawa	Cowpea	two	7
Barka jigawa	same as for Farar jigawa	millet, groundnut	five	5
Tsakwanya/Marji	millet, cowpea, groundnut, cotton, sorghum	Cotton	one	8
Laka	sorghum, rice, sugarcane, cowpea, vegetables	all crops in column 2	indefinite	1
Fako	cotton, millet, cowpea, sorghum	early maturing sorghum	zero	9
Bayen fadama	rice, potato, millet, sorghum	all crops in column 2	ten	2
Taibi	cowpea, rice, sweet potato, cassava	all crops in column 2	seven	3
Bayen tudu	millet, sorghum, cowpea, groundnut	Millet	six	4

Any soil management interjections would ensure the continuous use of the land while preserving the soil from degradation.

Agronomic and Mechanical Methods

In Kebbi state of Northern Nigeria, farmers used a combination of agronomic and mechanical methods to combat soil erosion. Noma (1997), reported that contour ridges constructed across slopes to arrest soil erosion; stone bunds which create a permeable barrier to initiate terrace formation; trash lines made up of crop residues (stalks of millet, sorghum and maize) to form barriers and upon decomposition improve soil fertility; and woven sticks used as permeable barriers to initiate terrace formation.

Use of Organic Fertilizer

John *et al.* (1997) recorded that pelletized composts were resistant to the forces of erosion and leaching which reduced nutrient losses. Table 3 shows the response of *Amaranthus cruentus* to the the application of various organic fertilizers. It was observed that pelletized poultry manure (poultry manure + 20% clay - PM2) caused the highest fresh weight of 14.4 g per Amaranthus plant. This was successfully applied on farmers' plots. They concluded that the use of the organic pellets which is slow release of nutrients throughout the growing season of the plants, would also encourage sustainable agriculture.

Table 3. Response of *Amaranthus cruentus* to the application of various organic fertilizers.

Organic fertilizer	Dry wt/plant (g)
Sawdust only (SD)	0.5 e
SD +poultry manure (PM)	3.5 d
PM +20% clay (PM2)	14.4 a
PM +10% clay (PM1)	9.6 b
PM	10.8 b
Control (soil only)	0.3 e
C.V.(%)	12.1

Means with the same letters are not significantly different (P<0.05).

Use of Trees

On a typical dry land, Folliott *et al.* (1995) identified eight ways of locating trees and shrubs in the farm as follows:

- wind break planting to protect agricultural crops and pastures against wind desiccation and minimise soil erosion by wind.
- Interplantings with agricultural crops to protect crops, enrich the soil, and provide wood and non-wood products.

- scattered plantings to enrich soils, provide wood, fodder and browse and provide thermal protection for livestock.
- linear plantation as protection buffers along roads and water ways to protect infrastructure and adjacent fields, provide shade, and contribute to the production of wood, fodder, browse and non-wood products.
- greenbelt plantings around villages and urban centres for physical and psychological benefits.

Mulching
Application of Siam weed (*Chromolaena odorata*) mulch to a maize plot significantly improved the yield. Ojeniyi and Falade (1997) observed that the application of Siam weed mulch at rates higher than 6t/ha significantly ($P<0.05$) increased the total yield of maize and also increased the N, P, K, Mg, Ca and pH of the soil (Table 4).

Table 4. Soil chemical properties as affected by Siam weed mulch treatment

				Exchangeable bases (meq/100g)		
Mulch rate(t/ha)	**Total N%**	**Avail. P (mg kg^{-1})**	**Soil pH**	**K**	**Ca**	**Mg**
0	0.23	9.7	5.5	0.43	3.9	1.7
3	0.24	11.9	6.5	0.56	4.2	1.9
6	0.27	16.3	6.3	0.60	5.4	2.6
9	0.29	19.8	6.4	0.62	5.9	2.7
12	0.33	25.5	6.5	0,64	6.4	3.8
LSD($P<0.05$)	0.08	6.9	0.5	0.24	0.7	1.4

Agroforestry
The form of agroforestry where rows of trees or shrubs (the hedge rows) are intercropped with herbaceous crops in the spaces between the alleys is called alley cropping. This system has been widely adopted by farmers in western Nigeria, Kenya and Sri Lanka. This is mostly through the extension services effort of IITA and ICRAF.

Use of Vetiver grass
Vetiver grass is used in India, China, Ethiopia and some other countries to conserve soil and water. They are planted on slopes and grow under conditions ranging from 200 to 6,000 mm of rainfall annually and at 2,800 meters above sea level in Ethiopia.

Women and Soil and Water Conservation
Women are involved in most of the phases of cultivation and so are involved in the conservation of soil and water. Some of the processing of agricultural crops such as cassava is carried out in the farms. The women return the cassava peelings to the farm. Maize cobs are harvested while the stalk and leaves are left on the farm. The awareness that the soil needs to be conserved through the return of litter to the farm is increasing among female farmers. The Kenya water for health organization (KWAHO) grew out of the National Council of Women of Kenya to address to needs to repair and maintain handpumps as the were installed in various communities. With financial support from UNIFEM, KWAHO mobilized and trained the communities, mostly women to repair pumps that have broken down thus leading to water conservation. The overflow and waste of water from broken pumps were stopped. The Green Belt Movement that also developed out of the National Council of Women of Kenya helped communities to develop green belt of trees in open spaces. Over 50000 women are involved in raising trees for use in farms and other eroded areas. In India, women who depended on the forest for their livelihood stopped woodcutters from felling trees by embracing the trees. This movement called CHIPKO has now grown to include afforestation and safe drinking water for villages as additional priorities. In Nigeria, women would generally throw all kinds of wastes into their homestead garden to conserve the soil. The homesteads could range from 0.9 ha to about 1.5 ha. Vegetable stalks are left in the farm after the seeds and fruits have been harvested.

In Niger, women were the main participants in the Keita Integrated Development Project that was launched in 1984, in order to address the declines in agricultural production caused by drought, desertification and population growth. Women were involved in dune stabilization, land reclamation, soil and water conservation, reforestation, crop production, rural engineering, training and setting up credit and alternative incomes (Carucci, 2000).

Conclusion

Hyams (1976) in his book 'Soil and civilization' observed that the wealth of a nation was tied up with her soil. Dwelling on the 'soils of western Andes: the Inca empire' he reported on the soil conservation principles to include:

- mixed cropping - 'The exhaustion of the soil was delayed by the practice of interplanting the maize with a legume, a bean which was trained up the growing maize stalks;
- the principle of manuring;
- cultivation in the Andean valley;
- women were the primary cultivators until the entrance of capitalism when agriculture shifted from feminism to masculinity. He concluded that this led to the death of the soils;
- mulching;
- terracing was used as a means of increasing the crown revenues without taking land at the expense of the people;
- no building was ever put on fertile coastal valleys which might bear a crop, houses were confined to such sites as were naked rock;
- shifting cultivation; and
- irrigation.

Hyams also quoted Markham thus 'In 1853, I examined the irrigation system of this valley very carefully. All that nature has supplied in the way of water is a small water course which is frequently dry for six years together, and at best only a little streamlet trickles down during the month of February. The engineering skill displayed by the Incas in remedying this defect is astonishing. Deep trenches were cut along the whole length of the valley and so far into the mountains that the present inhabitants have no knowledge of the place where they commence. High up in the valley, the main trenches or *puquios* are some four feet in height with floor, roof and sides lined with stones. Lower down they separated into smaller *puquios* which ramify in every direction over the valley and supply all the estates with delicious water throughout the year, feeding the little streams which irrigate the fields. The larger *puquios* are several feet below the surface and at intervals of 200 yards there are manholes, *ojos*, by which workmen can get down into the channels and clear away any obstruction'. I strongly believe that we must 'discover to recover'. Therefore there is a strong need for continued basic soil research which should be multidisciplinary, interdisciplinary and multifaceted in nature. We should continue to share solutions as globalization is also needed in the area of soil and water conservation.

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