SOME PROMISING TECHNOLOGIES TO ENHANCE SUSTAINABLE AND ENVIRONMENTALLY FRIENDLY AGRICULTURAL AND RURAL DEVELOPMENT IN GHANA

Second Edition

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SARUDEP-GIZ

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Our sincere gratitude also goes to all the farmers for their hospitality, patience and cooperation. We hope that the findings would contribute to the improvement of their livelihood.

FOREWORD

The world population is increasing day by day and the arable land to feed it is decreasing day by day, due to various forms of land degradation.

The authors of this report are convinced that some basic and already available technologies would help to improve food security worldwide and assist especially the poor farmers in developing countries to enhance their livelihood. Most of the technologies mentioned here are also of value to large-scale farmers in order to produce food in a more environmentally friendly way.

"With the World Food Programme, an appropriate mechanism exists to respond to food crises. However, its capacity to address the real scale of the global problem is far too limited, as it reaches only about 10 percent of the world's hungry, let alone the diet-deficient malnourished" (Braun, J. von, 03/ 2011).

"The response needed to cope with the food crisis must include action in production and technology innovation, trade and grain reserves policies" (Braun, J. von, 03/ 2011).

This report should serve as a basis to set priorities in choosing technologies to render degraded farmlands productive again.

The authors are requesting readers of this report to kindly contribute by adding their experiences and make corrections if necessary.

Please send your comments to: eckart_frey@yahoo.com

CONTENT

1.0 LEGUMINOUS COVER CROPS AS IMPROVED FALLOW

1.1 General Characterization

The term 'fallow' refers to an agricultural land being allowed to lie idle in order to replenish exhausted nutrients. A fallow system may be described as natural (bush fallow), enriched (planting of certain tree spp. into natural system), and improved system.

An improved fallow is deliberately planting fast growing leguminous spp. as sole crop to improve soil fertility. Improved fallowing is an *in situ* of building up mainly N and organic matter in soils as part of crop fallow rotation. An improved fallow may be of woody or herbaceous spp.

1.2 Feasibility to Farmers

Land fallowing is an age old farming system practice, for example bush fallow. Improved fallow is a new soil fertility paradigm shift for *in situ* accumulation of large quantities of N in soils.

1.3 Benefits, Constraints and Possible Improvements of Technology

Benefits

- Ability to suppress obnoxious weeds such as *Imperata* spp. including Striga grass
- Improve physical and biological soil properties through erosion control
- Transfer nitrogen (N) from legumes to soil
- Retains soil moisture
- Increase crop yields (cereals) following the leguminous cover crop
- Shortens fallow period
- Using deep-rooted fallow spp., cover crops can utilize subsoil water far from the reach of annual crops in the dry season thereby encouraging build-up of biomass in the dry season
- Woody fallow for longer duration is ideal for accumulation of larger biomass
- Helps establish permanent cropping by minimizing shifting cultivation
- Improve livestock productivity as a feedstuff

Constraints

- No availability of germplasm of improved fallow plant spp. and accessions
- Insufficient supply of improved fallow plant seeds
- Unreliable rainfall to enable full establishment of improved fallow plants
- Insufficient land availability
- Competition with food crops and other farming activities
- Lack of technical know-how
- Farmers perceive it as waste of resources
- Farmers do not see immediate results
- Animals consume crop residues
- Produce are mostly not edible and not marketable
- Destruction by fire
- Leguminous cover crop needs the same or similar care and costs as a cash crop

Possible improvement of Technology

- Awareness creation
- Promote establishment of seed farms and nurseries
- Conduct on-farm analysis of improved fallow related systems
- Introduce fast growing and high biomass legumes
- Adequate supply of inputs
- *Mucuna* should be established as a pure stand at the onset of the rainy season
- Control of animals and fire
- Timely land preparation and planting
- Use of food legumes as cover crops
- Animal traction may help overcome tillage problems
- Introduction multi-purpose legumes
- Plant cover crops on fields earmarked for fallowing

1.4 Sustainability

- Deep rooted plants are able to retrieve nutrients from sub soils to top soils
- Fallow systems are able to meet most plants N and some level of P requirements which reduces total cost of fertilizer needs of the farmer

1.5 Marketability (Market inquiry)

- Seed production as an alternative source of income
- Woody fallow spp. is a source of fuel wood for sale

1.6 Dissemination of Technology

- Promote on-farm demonstrations
- Intensify extension education
- Develop and use bulletins, fact sheets and guides for promoting the technology

1.7 Environmental Compatibility (suitability) of Technology (Emission of CO_2)

- Adoption of fallow systems facilitate the rejuvenation of degraded farm lands
- Fallow systems replenish soil fertility
- Woody fallow systems provide an alternative source of fuel wood thereby reducing deforestation.

Fig. 1:
Mucuna pruriens as improved fallow, suppressing obnoxious weeds such as *Imperata cylindrica* etc. and improving soil fertility.

(Photo by E. Frey)

2.0 LEGUMINOUS COVER CROPS (CROTALARIA RETUSA) INTERCROPPED INTO CEREALS OR OTHER CROPS

2.1 General Characterization

A legume intercrop is a spatial mixed-planting of species in a field with a selected cash crop

2.2 Feasibility to Farmers

A *Crotalaria* crop as intercrop is capable of managing parasitic nematodes. *Crotalaria* intercrop is very compatible with cash crops as they do not interfere with other crop development.

2.3 Benefits, Constraints and possible Improvements of Technology

Benefits

- *Crotalaria retusa* should be used as an intercrop
- As a cover crop it serves as a non-host to many pests and pathogens
- It does not compete with crops if planted after last weeding of main cash crop
- Vigorous growth provides enough ground cover
- Ability to fix N symbiotically with rhizobium
- Impact of rain drops reduced
- Reduced weed growth
- Two crops are produced at the same cost
- Improved soil fertility
- Efficient use of soil nutrients
- *Crotalaria* could serve as green manure
- Reduced risk of complete failure

Constraints

- *Crotalaria* has a rather short term effect in the agricultural production systems
- Requires more labour
- Improved method of intercropping needed
- Difficulty in tillage (reshaping)
- Lack of seeds
- Yield lower than in sole crops
- Possible nitrogen fixing not felt immediately
- Reluctance of many farmers to plant non-food legumes
- Planting is tedious
- Difficult to apply weedicides

Possible improvement of Technology

- Awareness creation
- Conduct on-farm evaluation of *Crotalaria* and cash crop interrelated technologies
- Find optimum plant densities
- Row planting
- Find optimum planting dates

2.4 Sustainability

- Integrating *Crotalaria* as a cover crop with other pest management strategies provides an alternative to the use of nematicides, providing as a new sustainable agricultural cropping system

2.5 Marketability (Market inquiry)

- Seed production for commercial purposes

2.6 Dissemination of Technology

- On-farm demonstration
- Exchange visits to organic farm sites
- Encourages farmer to farmer extension

2.7 Environmental Compatibility (suitability) of Technology (emission of CO_2)

Crotalaria intercrop, apart from suppressing incidence of root knot nematodes and weeds,

- adds organic manure and serves as a source of green manure
- slows down erosion.

Fig. 2:

(Photo: E. Frey)

Crotalaria retusa inter-cropped into maize as a cover crop does not compete with the cash crop if planted after final weeding of maize.

3.0 USE OF FARMYARD MANURE

3.1 General Characterization

- Farmyard manure is a heterogeneous organic material.
- It consists of dug, crop residue, and/or household material in various stages of decomposition.
- Farmyard manure is mostly available and produced in farms, and is an important organic resource for agricultural production in livestock-based farming systems.

3.2 Feasibility to Farmers

- Farmyard manure is a cheap source of readily available nutrients and organic matter produced on farms
- It is a resource from agricultural production in livestock-based farms including waste

3.3 Benefits, Constraints and possible Improvements of Technology

Benefits

- It considerably improves soil physical properties and nutrient uptake
- Farmyard manure increases exchangeable kation and regulates soil pH
- It has long lasting effect
- Increases cereal yield
- Low costs
- Makes good use of local resources
- Helps control erosion (organic matter)
- Controls Striga and other obnoxious weeds
- Keeps moisture in soil

Constraints

- Nutrient breakdown cycle takes a much longer time before being available to plants
- Farmyard manure is not a readily available plant food
- It is a major source of weed seeds
- It is quite bulky and requires haulage implements
- Requires large volume to apply to a unit area of land
- High labour and time input in application
- Variable nutrient levels due to different types of materials and level of decomposition
- Quantity limited by number of animals and available crop residues
- Poor storage facilities
- Use of compound farmyard manure restricted to compound farms
- Poorly decomposed farmyard manure harms crops

Possible improvement of Technology

- Confine animals during dry season and at night
- Provide improved housing for livestock
- Crops residues as bedding to increase quantity

- Introduction of animal traction to ease transport problems
- Improved animal feeding will improve quality of farmyard manure
- Improve Farmer-Fulani relationship
- Improve storage to improve seed quality and destroy weed seeds
- Farmer has to be encouraged to harvest farmyard manure
- Can be composted to make nutrient more readily available
- Combination with inorganic fertilizer addresses nutrient imbalances of farmyard manure
- Creating awareness
- Identifying best time of application

3.4 Sustainability

- The use of natural resources makes it environmentally friendly and sustainable
- Crop and animal residue do not require use of extra chemical inputs
- All farmers regardless of their financial abilities can gather, store and use farmyard manure

3.5 Marketability (Market inquiry)

- Requires haulage equipment which could be capital intensive

3.6 Dissemination of Technology

- On-farm demonstration
- Exchange visits to organic farm sites
- Encourages farmer to farmer extension

3.7 Environmental Compatibility (suitability) of Technology (Emissions of Greenhouse Gases)

Research shows that traditional, anaerobic storage of manure is a non-efficient method of its management. It often leads to a negative impact on the environment as a result of gaseous emissions, input of pathogens into the natural environment or leaking out of mineral compounds (Jensen Jepson 2005, Harrison et. al 2006). Nevertheless, volumes of farmyard manure (crop residue, weeds, kitchen and household material, etc.) that could be a nuisance can be converted into useful material by micro-organism into soil improving medium.

Fig. 3:

(Photo: E. Frey)

Farmyard manure helps increase the fertility of soils low in organic matter content in Northern Ghana and increases and sustains crop yields.

4.0 DYNAMIC KRAALING

4.1 General Characterization

The cattle are confined overnight on the field that need to be fertilized and their location shifted within the field at certain intervals. The number of nights on each spot varies with the season.

4.2 Feasibility to Farmers

- Requires minimal use of chemical fertilizer
- Does not require any special training skills before adoption

4.3 Benefits, Constraints and possible Improvements of Technology

Benefits

- Improves soil fertility and nutrients structure
- Reduces labour required to transport manure
- Controls Striga
- High cereal yields
- Use of mineral fertilizer not necessary
- Animals are controlled
- Reduces farmers' expenses
- Has long lasting effects
- The fields in need of fertilizer can serve as land for grazing
- Predation on the livestock is reduced

Constraints

- Few farmers own cattle
- Un-decomposed manure may harm crops
- Requires labour to keep animals in the fields in the absence of movable fences and also to protect them from thieves
- Fulani people may compete with farmers for the dung, depending on the contract terms
- Competitive use of dung as it is also used for plastering houses, cooking fuel, and its liquid form is applied to crops as repellent to protect the plants from being eaten by straying animals

Possible improvement of Technology

- Awareness creation
- Establishment of pastures
- Ascertain the right time to move animals
- Find agreements between farmers and Fulanis
- Use movable wire fence
- Let farmers take care of animals by themselves
- Rotate animals in the field long enough before cropping season

4.4 Sustainability

- A certain amount of the manure is deposited directly as the animals pass through arable and grazing lands
- The technology is particularly important to farmers with limited access to alternative resources and transport facilities

4.5 Marketability (Market inquiry)

- The technology promotes cattle numbers, beef yield, quality and market values
- Effective use of arable areas in so as to produce marketable surpluses

4.6 Dissemination of Technology

- Exchange visits to farm sites
- Can be promoted through farmer to farmer extension

4.7 Environmental Compatibility (suitability) of Technology (Emission of CO_2)

- Relatively high greenhouse gas emissions.

5.0 PREPARATION AND USE OF COMPOST

5.1 General Characterization

Compost is a bio-chemically decomposed organic waste (crop residue, kitchen waste, cow dung, urine, etc.) by micro-organisms. It is a uniform mass of rotten, nutrient-rich manure. Composting produces an organic fertilizer that is balanced in plant nutrients.

5.2 Feasibility to Farmers

- Compost materials are readily available within and around households and farmsteads
- Compost making is practical and does not necessarily requires any special training time or skills before adoption
- Requires the use of mainly local materials

5.3 Benefits, Constraints and possible Improvements of Technology

Benefits

- Good compost is a ready source of nutrients and does not need further breakdown
- It has long lasting effect
- Good use of crop residues and household refuse
- Improves soil fertility
- Matured compost does not cause excess weeds
- Use of compost minimizes the use of extra chemical inputs
- Compost generally improves soil aggregates stability
- It stabilizes vulnerable soils against erosion
- Compost increases soil organic matter content, reduces bulk density and increases porosity
- Destroys weed seed and insects
- Can be done in the dry season if water is available

Constraints

- High demand of time and labour in application
- Variable nutrient levels due to quality, types of materials and levels of decomposition
- Low availability of compost material in drier areas
- Poor decomposition of material could be a source of weed seeds
- Compost is often a poor source of K due to leaching losses during decomposition
- Transport problem
- Farmers have little knowledge about the technology
- Quantity usually very limited
- High water requirement
- Bush fires destroy organic materials in the dry season
- Minimum of 3 to 4 tons/ha required

Possible improvement of Technology

- Awareness creation
- Not to burn crop residues during dry season

- Use the right composition of N-rich and C-rich materials
- Help farmers to get means of transport
- Investigate trade-offs between different gaseous and leaching forms of pollutants following compost application, e.g. CO_2 emissions

5.4 Sustainability

- Use of raw materials (crop and animal residue) does not require use of extra chemical inputs
- All farmers regardless of their financial abilities can make and use compost.

5.5 Marketability (Market inquiry)

- Can be packaged and sold for promoting urban gardening
- Can be packaged and sold as a seeding and potting medium for nurseries, pricking out and planting
- Compost is affordable and economical to resource by poor farmers

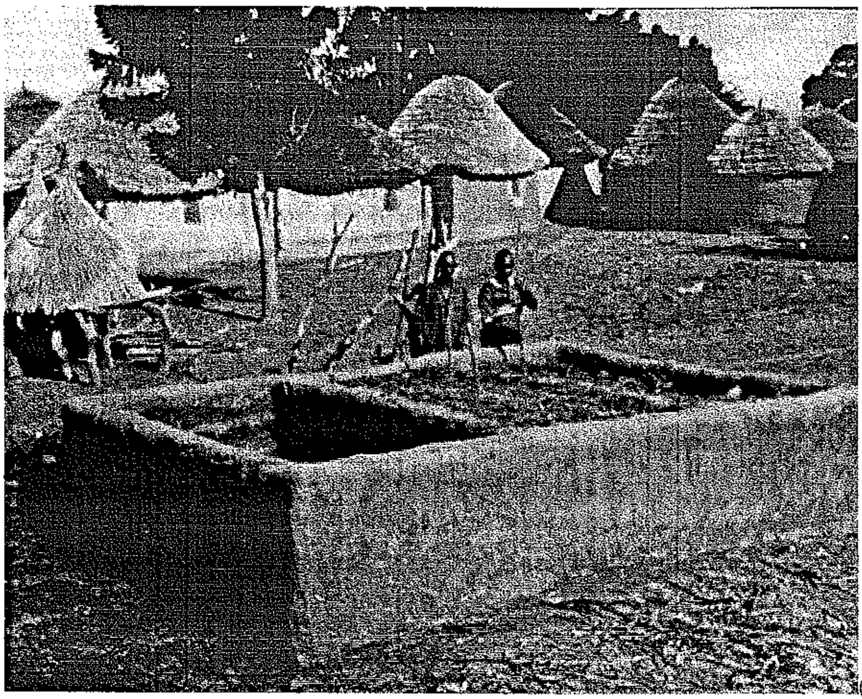
5.6 Dissemination of Technology

- On-farm demonstration
- Exchange visits to organic farm sites
- Can be promoted through farmer to farmer extension

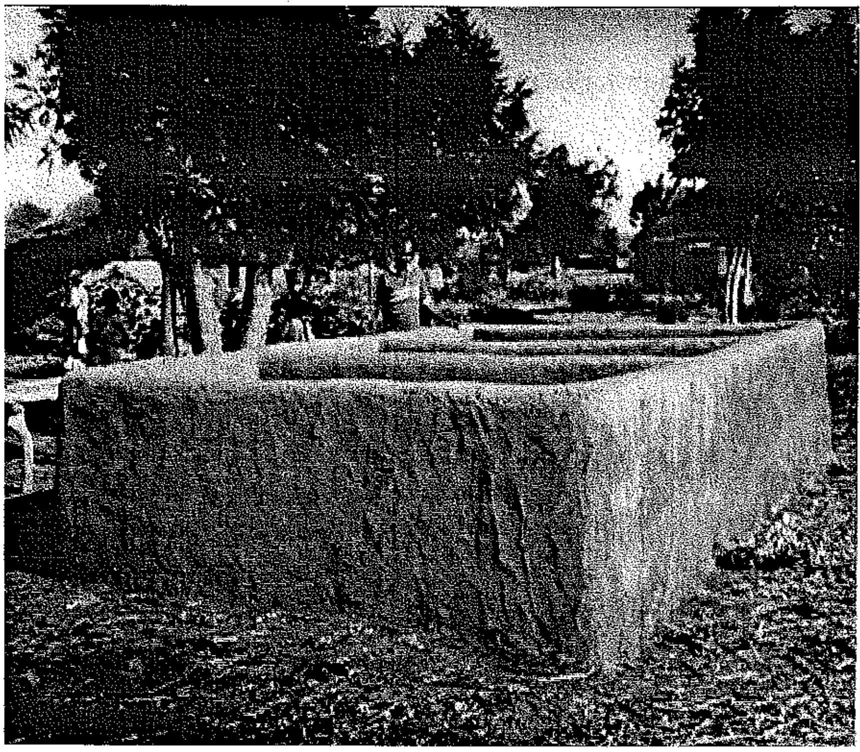
5.7 Environmental Compatibility (suitability) of Technology (Emission of CO_2)

- Volumes of vegetation, crop residue, weeds, kitchen and household materials, etc. converted biochemically by micro-organisms into soil improving material.
- Compost is a natural product from recycled natural resources hence environmentally friendly

Fig. 4 and 5:



(Photo: E. Frey)



(Photo: E. Frey)

The pictures above show compost pits built entirely with local materials. There is plenty organic material existing in communities which when mixed with animal manure can produce a highly efficient COMPOST.

6.0 PLANTING OF (NON-FRUIT) TREES ON DEGRADED FARMLANDS

6.1 General Characterization

Neem (*Azadiracta indica*) and *Senna siamea* were planted near Gambaga and other sites in the Northern Region of Ghana. Four rows of Neem were planted at 3m x 3m alternative with four (4) rows of *Senna siamea* at the same spacing. The species selection was informed by the availability of seedlings, fast growth, evergreen habitus and their adaptability to the local environment.

6.2 Feasibility to Farmers

Tree planting has become a major priority in urban and community forestry programme. The Neem for instance is age old specie planted around houses to provide shades because of their fast growing and evergreen nature. Neem and *Senna siameo* do not demand watering in the dry season and so are easily adoptable by farmers.

6.3 Benefits, Constraints and possible Improvements of Technology

Benefits

- Rejuvenate degraded land
- Serve as firewood and rafters for local construction
- Used for the construction of agricultural implements
- Pruning of trees improves soil fertility
- The leaves serve as animal feed, especially *Senna siame*
- Serve as windbreak
- Check environmental degradation
- Sink of CO_2 for climate change mitigation
- Oil is extracted from Neems seeds
- Leaves and seeds are used as insectides
- Leaves and bark of Neem used for medicinal purposes
- Serve as timber in the long-term

Constraints

- Extra labour needed for planting during rainy season
- Farmers do not see long-term effect
- Destruction by bushfire and animals
- Lack of seedlings
- Land tenure system

Possible improvement of Technology

- Awareness creation
- Promote establishment of seed farms and nurseries
- Control of animals and bushfire
- Plant on deserted lands, especially stony and rocky lands

6.4 Sustainability

- Sustainably provide for firewood and other wood needs of rural people within a shorter period
- Easily adaptable as they withstand drought conditions, bushfire and do not require much technical know-how by farmers to establish
- Provide sufficient maintenance during the establishment period

6.5 Marketability (Market inquiry)

- Seed production as an alternative source of income
- Plantations provide wood for industry and create jobs

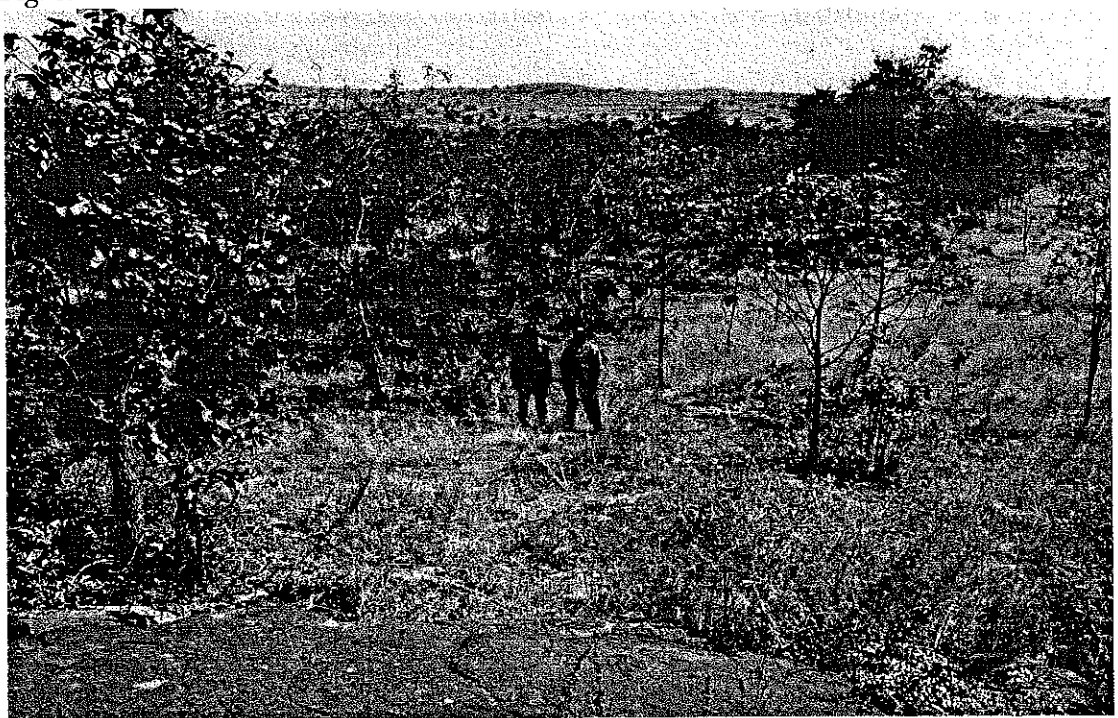
6.6 Dissemination of Technology

- Intensify extension education
- Encourage farmer to farmer extension

6.7 Environmental Compatibility (suitability) of Technology (Emission of CO_2)

- Facilitate the rejuvenation of degraded farm lands
- Contribute to reducing greenhouse gasses through carbon sequestration
- Provide an alternative source of fuel wood thereby reducing deforestation
- Enhance biodiversity of wildlife.

Fig. 6:



(Photo: E. Frey)

Neem (*Azadirachta indica*) and *Senna siamea* on degraded farm lands near Nalerigu (NR) 3.5 years after planting.

Fig. 7:

(Photo: E. Frey)

Neem trees (*Azadiracta indica*) and *Senna siamea* planted near Nalerigu (NR). A Vetiver grass hedge planted below the trees helps to collect moisture and to prevent erosion. The trees and Vetiver grass will have a mitigating effect on environmental degradation and green house gas production.

7.0 VETIVER GRASS, ITS PROPERTIES AND USES

INFORMATION ON THE VETIVER SYSTEM, A WORLD TECHNOLOGY FOR SOIL AND WATER MANAGEMENT IN THE TROPICS AND SEMI-TROPICS AS DEMONSTRATED BY SARUDEP IN GOASO, BRONG AHAFO REGION, GHANA

7.1 Introduction

To show the severity of threatening global environmental disaster, only soil erosion will be mentioned here, "*The soil which is carried off by erosion totals 20 billion tons a year worldwide. That represents the equivalent irreversible loss of between 5 million and 7 million hectares of arable land*" (Vietmeyer, N.D. et al. 1993).

7.2 Properties of Vetiver

- Forms a dense, permanent hedge, which prevents soil erosion through runoff
- Is perennial and therefore survives for decades (if not for generations) with little maintenance
- Does not spread by seeds if the cultivar *Chrysopogon zizanioides* is chosen as planting material and therefore cannot escape and become a weed
- Can grow in a wide range of climates: from 200mm to 6000mm of rainfall and from 10°C to 55°C. It thrives well in a wide range of soils from high acidity to alkalinity
- Is both a xerophyte and a hygrophyte which, once established, can survive several months of drought and several weeks of flooding
- Has a deep and extensive root system which can penetrate more than 3m vertically
- The deep and extensive root system has a mean tensile-strength (the load it will support without breaking) of approximately one-sixth of mild steel (Hengchaovanich, D. 2002), which enables the plant to "nailing" soils to steep slopes.

7.3 Uses of Vetiver Grass

- Controls soil erosion by reducing runoff, increasing in situ soil moisture and depositing up to 10cm of silt behind the vetiver hedges annually
- Enhances crop growth by increasing in situ soil moisture
- Recharges groundwater supplies
- Stabilizes terrain and structures such as dams, river banks, canals and buildings on steep slopes

- Rehabilitates polluted sites such as landfills, industrial waste dumps and mine tailings
- Purifies polluted water by reducing soluble N and soluble P and by absorbing toxic substances such as heavy metals and others
- Used as fodder, thatch, mulch and others

7.4 Watershed Management and Management and Vetiver Grass

A holistic approach to global water management issues means to prove the different functions of the Vetiver grass approach in different parts of the watershed. The Vetiver system applications will help to solve many problems confronting watershed management in the tropics and semi-tropics. (The following is adapted from Grimshaw, R.G. 2003).

Upper Watershed

These areas, in the past, were generally heavily forested and the sources of springs and rivers and no protection was needed. Today, these steep slopes are mostly denuded and badly eroded, resulting in severe runoff carrying heavy silt loads.

Here Vetiver planted across slopes can form gully protection to reduce runoff and sediment flows, which will help in groundwater recharge. Along with other measures such as reforestation, Vetiver will help improve the situation where springs and rivers flow longer and more consistently.

Middle Watershed

In the tropics and semi-tropics the middle watershed are mainly used by upland farmers. Soil erosion and with it water availability and water quality are limiting agricultural and rural growth. "The Vetiver system does and should play a vital role in improving soil and *in situ* moisture conservation, improving groundwater, stabilizing small reservoirs, riverbanks and farm to market roads" (Grimshaw, R.D. 2003)

Lower Watershed

"These are generally flatlands, often very wide river valleys or plains" (Grimshaw, R.G. 2003). These areas are normally heavily populated, supporting intensive agriculture and industry. These activities result in creating serious environmental problems such as depleted groundwater sources, over-use of chemicals, dirty water supplies and consequently leads to serious sewage and water disposal problems.

Here Vetiver can help to:

- Stabilize roads and steep slopes from municipal land fill and mine tailings
- Protect industrial construction sites
- Reduce chemical leachate from intensively farmed lands
- Improve water quality polluted by industrial discharge

- Reduce substantially the wave and flood damage to riverbanks and flood embankments in coastal plains.

7.5 Documentation of Vetiver Technology

- Soil erosion control on farmlands, using Vetiver grass (*Chrysopogon zizanioides*) in the Northern Region (this page)
- Sustainable protection against soil erosion and stabilizing of earthen dam walls, using Vetiver grass in the Northern, Upper East and Upper West Regions (see pages 20, 21)
- Stabilizing of riverbanks, using Vetiver grass in the Brong Ahafo Region (see page 22)
- Protecting mudslides prone permanent structures on steep slopes from collapsing, using Vetiver grass in the Brong Ahafo and Western Regions (see page 23)
- Recharge of Groundwater level, using Vetiver Grass in the Brong Ahafo Region (see 24)

Fig. 8:

(Photo: E. Frey)

This well established Vetiver grass hedge together with the cultivation of *Crotalaria retusa* renders a degenerated light sandy soil near Gambaga (NR) enables to grow maize AGAIN.

Fig. 9:

(Photo: E. Frey)

Finishing touches on rehabilitation of the Fushego broken dam near Tamale (NR) in July 2008.

Fig. 10:

(Photo: E. Frey)

Vetiver grass planted in July 2008 along contours to stop SOIL EROSION and to stabilize the newly repaired dam wall.

Fig. 11:

(Photo: E. Frey)

Heavy downpours in August 2008 created deep EROSION RILLS on the steep slope of the dam wall but could not remove the well established VETIVER PLANTS.

Fig. 12:

(Photo: E. Frey)

Two years later (December 2010) the EROSION RILLS had completely disappeared and the VETIVER HEDGES are beginning to build terraces by slowing down the flow of water and collecting soil and organic debris behind the VETIVER HEDGES.

Fig. 13:

(Photo: E. Frey)

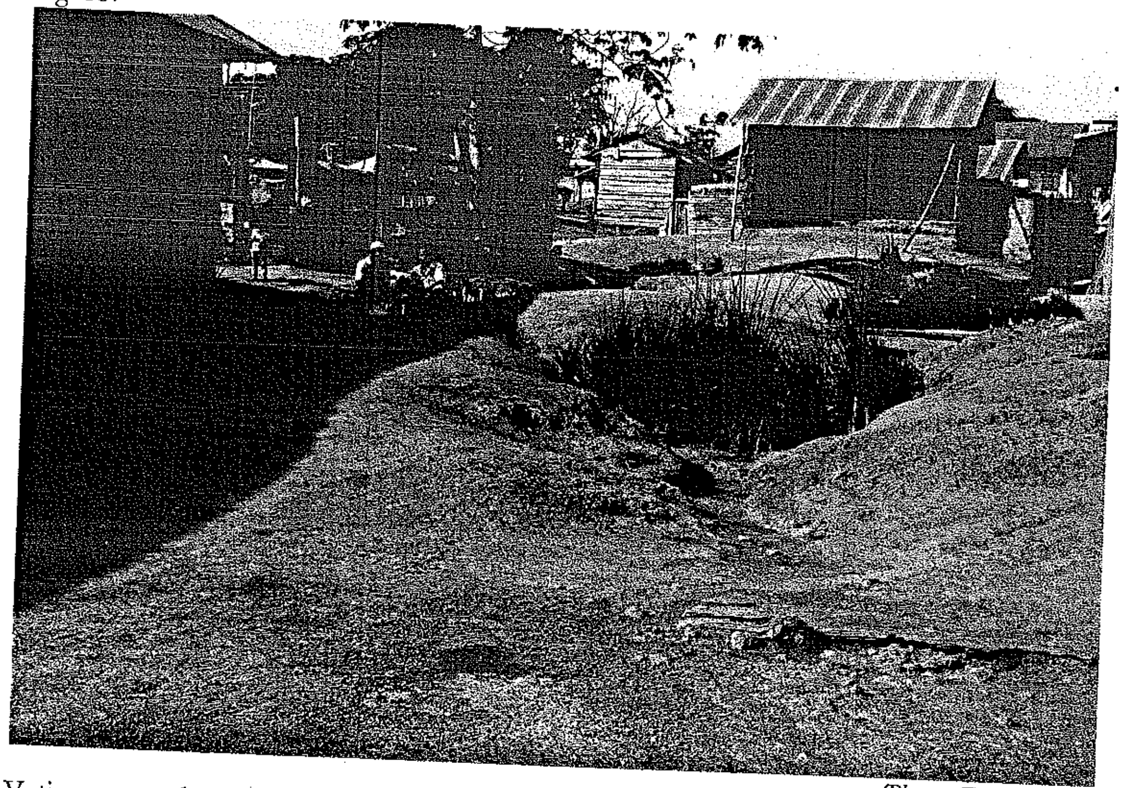
Establishing Vetiver grass at a very steep riverbank of river Goa in Brong Ahafo Region.

Fig. 14:

(Photo: E. Frey)

Stabilization of the Goa riverbank (in Goaso, BAR), using Vetiver grass.

Fig. 15:



(Photo: E. Frey)

Vetiver grass planted across deep erosion-gullies in a community near Goaso (BAR), helps to control erosion, to avoid mud slides and ultimately the collapse of houses.

Fig. 16

(Photo: E. Frey)

A well on a 2% slope in Goaso (Brong Ahafo Region) dries up by early February because much of the falling rain run down the slope without infiltrating into the soil. Vetiver grass planted above and below the well is slowing down incoming water which can then infiltrate and recharge the ground water. Eventually, owners of the well are experiencing no more water shortage.

THE WAY FORWARD

SARUDEP (Sustainable Agricultural and Rural Development Programme) is determined to support the most efficient ways to fight against land degradation and against the pollution of the environment as:

- Establishing Vetiver grass nurseries in all the ten (10) Regions in Ghana
- Implementing permanent demonstration of increased crop production by using sustainable and environmentally friendly technologies (methods)
- Increasing the number of sites that demonstrate the rehabilitation of degraded farmlands by
  a) planting Vetiver grass against erosion
  b) planting trees on completely depleted land
- Increasing the number of water bodies protected either by Vetiver grass or by trees against erosion of banks and walls
- Protecting buildings and other structures in communities against erosion and mudslides by planting Vetiver grass
- Spreading the inter-planting of leguminous cover crops into cereals or other crops to increase soil fertility and crop yields
- Establishing of more barriers against erosion on very sloppy land to recharge the groundwater level and to refill dried-up wells.

ANNEX A. SOME GENERAL INFORMATION ON GREENHOUSE GASES IN AGRICULTURE

Production and Use of Animal Manure and Compost in Agriculture

Agriculture has been recognized to contribute about 81% of nitrous oxide (N_2O) and 70% of methane (CH_4). A significant quantity of methane is emitted during storage of liquid manure, whereas nitrous oxide is emitted from the storage of manure and from the soil following manure or fertilizer application. Good composting practices that balance the C : N and provide adequate aeration and moisture will minimize GHG emissions. The preparation and use of compost on fields do not only reduce nitrous oxide and methane emissions, but also reduce the need of synthetic chemical fertilizer, of which production requires intensive fossil fuel energy and seriously impacts human and environmental health (Pimental, et al., 2005). Other benefits of the use of compost include a significant reduction in need for pesticides (avoiding emissions associated with their production), improved health and workability of soils, resulting in less fuel consumption during tillage and increased capacity of soil to hold or sequester carbon dioxide.

Differences in Greenhouse Gas Emissions

Carbon dioxide (CO_2)

- CO_2 (Carbon dioxide) is the most significant gas emitted during composting, but it is not considered in green house gas calculations because it is biogenic and not anthropogenic.
- A high proportion of the CO_2 emitted during composting is utilized by micro-organisms, so only a small amount is released into the atmosphere

Methane (CH_4)

- Landfills are the single largest direct human source of methane (CH_4) because decomposition of compostable materials such as food waste and paper under anaerobic conditions (without oxygen) produces CH_4 (Platt *et al.*, 2008.)
- Although CH_4 is a significant GHG (21 times the impact of CO_2), its emission from well-managed compost facilities is negligible because the aerobic and appropriate moisture level encourage aerobic decomposition of the materials (Valzano *et al*, 2001).

Nitrous oxide (N_2O)

- Nitrous oxide (N2O) is emitted from commercial and inorganic fertilizers, combustion of fossil fuels, and decomposition of nitrogen-rich organic residues.
- N2O is about 310 times more effective as a GHG than CO_2 (Valzano *et al* 2001)

ANNEX B SARUDEP ACTIVITIES

SARUDEP ACTIVITIES

Region	District	Technology	Number of Communities
Northern	Tolon-Kumbungu	Leguminous cover crops as improved fallow (Mucuna)	5
Northern	Yendi	Leguminous cover crops as improved fallow (Mucuna)	4
Northern	Cheriponi	Leguminous cover crops as improved fallow (Mucuna)	3
Northern	Gambaga/ Nalerigu	Leguminous cover crops as improved fallow (Mucuna)	3
Northern	Tolon-Kumbungu	Leguminous cover crops (Crotalaria retusa) intercropped into cereals and other crops	7
Northern	Yendi	Leguminous cover crops (Crotalaria retusa) intercropped into cereals and other crops	2
Northern	Gambaga/ Nalerigu	Leguminous cover crops (Crotalaria retusa) intercropped into cereals and other crops	2
Upper East	Talensi	Leguminous cover crops (Crotalaria retusa) intercropped into cereals and other crops	1
Upper East	Sandema	Leguminous cover crops (Crotalaria retusa) intercropped into cereals and other crops	1
Northern	Tolon-Kumbungu	Use of Farmyard manure	15
Northern	Tolon-Kumbungu	Preparation and use of compost	19
Northern	Tolon-Kumbungu	Dynamic kraaling	1
Northern	Gambaga/ Nalerigu	Planting of (non-fruit) trees on degraded farmland	2
Northern	Tolon-Kumbungu	Soil erosion control on farmland using vetiver	4
Northern	Gambaga/ Nalerigu	Soil erosion control on farmland using vetiver	3
Northern	Tamale	Sustainable protection against erosion and stability of earthen Dam walls	4
Northern	Karaga	Sustainable protection against erosion and stability of earthen Dam walls	1

Upper East	Talensi	Sustainable protection against erosion and stability of earthen Dam walls	1
Upper East	Bongo	Sustainable protection against erosion and stability of earthen Dam walls	3
Upper East	Navrongo	Sustainable protection against erosion and stability of earthen Dam walls	2
Upper East	Sandema	Sustainable protection against erosion and stability of earthen Dam walls	2
Upper West	Wa West	Sustainable protection against erosion and stability of earthen Dam walls	1
Upper West	Wa East	Sustainable protection against erosion and stability of earthen Dam walls	1
Upper West	Jirapa	Sustainable protection against erosion and stability of earthen Dam walls	1
Brong Ahafo	Goaso (Asunafo)	Stabilizing of River banks	1