Sustainable Management Practices for Agricultural Lands in the Central Highlands of Sri Lanka
Part 2 – High Input Vegetable Cultivation

Rehabilitation of Degraded Agricultural Lands in
Kandy, *Badulla* and *Nuwara Eliya* Districts of the Central Highlands
GCP/SRL/063/GFF

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1. Introduction:

In Sri Lanka, vegetable cultivation is one of the most important sectors in agriculture. Diverse agro-ecological regions of Sri Lanka are well suited for the cultivation of different kinds of vegetable crops. Moreover, it is considered as an important component in the daily diet of people of Sri Lanka and so that, there is a constant demand for vegetables in local market. At present, national vegetable production meets nearly 60 % of the vegetable requirement. Due to significant contribution to the vegetable production, *Nuwara Eliya* is one of the important districts of the country and it is one of the major production areas of upcountry vegetables such as carrot, beet, leek, cabbage, bean, potato, tomato etc.

The cultivation of exotic vegetables was first introduced by persons of European origin who settled inthe region, following the institution of the plantation estates. The non-indigenous varieties of vegetableswere introduced into the country to meet their preference.Certain intrinsic qualities of these crops such as their appearance, keeping quality, the flavour and easy preparation might have contributed to their spread among local population, in particular, amongst theurban dwellers. These vegetables are prepared differently in Sri Lanka to the way they are done in thecountries of their origin could have been adapted over generations according to local needs, tastes andconditions. Traditionally, in Sri Lanka the vegetables, including those non-indigenous food varieties, are prepared as curries to accompany the meal of rice. The curries are prepared by cooking these vegetables with chillie, spices, and coconut milk. Potato is also prepared mostly as a vegetable.

Potato and vegetable cultivation in the *Nuwara Eliya* district is important for a number of reasons.First, much importance has been attached to potato growing as an import substitution food crop. Second, this form of farming has helped to provide an increasing population with an acceptable level ofliving in an area where land scarcity is high and alternative employment opportunities are low.

Vegetable cultivation in *Nuwara Eliya* is practiced on hilly areas because land is limited and cultivation is done with high values crops. Farmers expect high return to investment as such cultivation is done in two or three times per year without giving any resting period for lands. Since land is exposed for many moths per year, it is vulnerable to erosion.

The fast growth in the agricultural sector in Sri Lanka has led to resource degradation, with adverse impact on sustainability. The major source of environmental damage associated with agriculture is land degradation, particularly soil erosion on the steeply sloping lands of central hills. Soil erosion is concentrated in hill country where watersheds of major rivers are located. District-wise, *Nuwara Eliya* shows the highest amount of soil erosion, about 58% of the potato-cultivated land found to be prone to severe soil erosion (Abeygunasekara, 2004)[1]. Table 1 shows soil erosion status in *Nuwara Eliya*, Kandy and *Badulla* Districts[2].

Table 1. Eroded lands in the three Project Districts

Erosion category	**Extent in ha (%)**		
	Nuwara Eliya	**Kandy**	***Badulla***
Low	20,443 (12%)	29,968 (16%)	22,000 (07%)
Moderate	35,638 (21%)	19,127 (10%)	24,800 (08%)
High	50,513 (30%)	69,036 (37%)	89,900 (30%)
Very high	45,470 (26%)	58,932 (31%)	79,100 (26%)
Extremely high	18,511 (11%)	12,097 (06%)	88,000 (29%)
High, very high and extremely high	**114,494 (67%)**	**140,065 (74%)**	**257,000(85%)**

1.1. Potato Cultivation

In the late 1960s potato cultivation was introduced into the country as an import substitution crop, andthe import of potatoes was stopped. However, imports were allowed by the Government when production was low to curtail escalating prices. For instance, during December 1994, the scarcity of locallyproduced potatoes resulted in substantial price increases. The retail price is going up to as much as Rs. 80.00/ kg. As soon as the Government reintroduced the import of potatoes, the price declined by morethan 50%. By March, with the influx of locally produced potatoes into the market, the retail price of potatoes was further reduced to Rs. 26.00. Thus potato producers have enjoyed a good

[1]Abeygunasekara J 2004 "In Sinhala" (Lets" protect the watersheds), 2: 51- 55.
[2]Dharmakeerthi, R.S. and W.D. Wickramasinghe, 2015. Status and national priorities of soil resources in Sri Lanka, Presentation made at the Conference on International Year of Soils organized by Soil Science Society of Sri Lanka, FAO and Department of Agriculture, Peradeniya

price for theirpotatoes even with the prevailing high transaction costs, when imports are stopped.

In 2005, about 2,424 ha of lands were cultivated by approximately 25,000 farmers to produce 76,900mt of consumer potatoes. Sri Lanka has imported 28,010 t of potatoes (40% of the national potato requirement) in 2005 (Department of Census and Statistics, 2005)[3].

Due to the comparative income advantage of potato cultivation, farmers tend to use steeply sloping lands, which are not recommended for seasonal crops, while increasing soil erosion. Both the climate and terrain are prone to soil erosion, and serious damage to land and water resources are experienced in the cultivation of potato. Damage is mostly due to inappropriate soil conservation measures. Owing to the high cost in soil conservation farmers do not adopt proper soil conservation measures which lead to land degradation in areas cultivated with potato. Some farmers adopt soil conservation measures, which are not adequate to arrest soil erosion problem satisfactorily. The impact of these improper cultivation practices has caused soil erosion and other environmental problems.

It has been found that the soil erosion rate in *Nuwara Eliya* potato lands can be as high as 15 t/ha/year (Samarakoon, 2004)[4]. As a root crop, potato cultivation causes acceleration of soil erosion due to the ground being loosened in several cultivation practices such as land preparation, weeding, fertilizer application, earthing up and even harvesting. This situation is somewhat similar to other vegetable cultivation. According to the same study the average soil replacement cost in *Nuwara Eliya* district potato lands was US$ 33/ha (Rs 3,343/ha).

1.2. Present Status

It is true that most of the upcountry farmers apply soil conservation practices for their fields. They use either mechanical, biological or cultural conservation measures or a combination of them. However, for appropriate sustainable land management, all mechanical, biological and cultural practices should be applied together, while following recommendations of Department of Agriculture. However, farmers who are facing similar soil erosion problems may adopt different combinations of soil conservation

[3] Department of Census and Statistics 2005 Food Balance Sheet, Department of Census and Statistics, Colombo, Sri Lanka
[4]Samarakoon SMM 2004 "An economic assessment of on -site effect of soil erosion due to potato cultivation in NuwaraEliya district." M.Sc.in Natural Resource Management Dissertation Postgraduate Institute of Agriculture University of Peradeniya, Unpublished.

practices, to achieve different levels of soil conservation. It can be categorized as good, average or poor conservation, based on farmers' variable socio-economic conditions.

Different farmers may have different attitudes towards sustainable land management. Those attitudes may also affect the selection of land management. Sometimes farmers who have good attitudes also may not practice at an appropriate level due to the socio-economic constraints and lack of proper knowledge.

Past agricultural practices, such as application of large quantities of fertilizer and agrochemicals to obtain higher returns from high value crops and no resting periods for the land, have lead to increased erosion hazards and increased pollution of the important surface and sub-surface water reservoirs. In surface reservoirs the accumulation of nutrients has led to create eutrophication and threaten aquatic species and block water ways. Much of the intensive cultivations are practiced in areas where natural water bodies are present, and pollution of these water bodies may contribute to health problems in the surrounding communities.

Two important aspects are briefed below in developing sustainable vegetable cultivation in Central Highlands.

Intensive vegetable cultivation systems in *Nuwara Eliya* and *Badulla* Districts:

> This is the major vegetable producing area and contributes significantly to the national economy. It engages a large number of plantation workers, predominantly Tamil and female or house wives. This system has a very high impact on the environment due to heavy application of agrochemicals, and the areas are highly vulnerable to erosion.

Vegetable cultivation in upper slopes of mountains in *Nuwara Eliya* and Kandy Districts:

> These areas act as watersheds for most of the river basins and major tanks and lakes in the country. Earth slips and erosion are the major problems. Siltation of major tanks reduces the water storing capacity which affects the country's electricity supply and water supply for irrigation and flooding. Farm income in this system is insufficient to feed the family. Hence, farmer encroachment occurs into nearby protected forest lands to increase the cultivated land area.

1.3. Ecological Factors

Temperature and precipitation levels and soil types that prevail in certain locations in the central highland region favour the cultivation of both potatoes and other non-indigenous varieties of vegetables ona cash crop basis. In this respect, the region enjoys a number of features that give a comparativeadvantage to the growers of non-indigenous food crop varieties, the most important being the cool temperature prevalent in the hill country almost throughout the year. For example in highland areas the average maximum and minimum temperatures are 25.8^0C and 16.8^0C respectively. These values are further as lower as 20.2^0C and 11.5^0C in *Nuwara Eliya* region.

A favourable environment appears to determine to a large extent not only what could be grown indifferent ecological niches in the district, but also yield and the quality levels obtained. Potatoes produced in the *Nuwara Eliya* potato growing areas fetch a higher market price than for instance, thoseproduced in the Jaffna district. Most hill country vegetables have an appealing appearance and keeping quality over both indigenous and non-indigenous vegetables produced elsewhere except in *Welimada*, another major vegetable producing area situated in the *Badulla* District. Water spouts and natural waterstreams that are found throughout *Nuwara Eliya* too provide a bountiful source of cool natural waterfor cleaning operations connected with the harvested crops and this is a further natural advantage thehighland vegetable producer enjoys.

The major type of soil found in the area is Red Yellow Podsolic and Mountain Regosols located on amountainous terrain. These soils are considered to be suitable for vegetable cultivation. Thus the model soil type found in the area constitutes a natural resource favourable for growing non-indigenous food crop varieties like potatoes, beans, cabbage, carrot and knolkhol.

The market quality of the produce, it should also be noted here, is manipulated by other means too. For instance, the colour and size of vegetables and potatoes are also influenced by the degree to whichnutrients used as the rate and timing of the yield is determined by provided inputs such as plant growth regulators. The range of natural advantages the upcountry vegetable producer enjoys has also been enhanced by anumber of external factors at the national level. Prior to the outbreak of the ethnic disturbances in thecountry in early 1980s, the Jaffna district was a major supplier not only of non-traditional vegetables tothe local market but also a substantial proportion of the locally produced potatoes. The civil war situationthat has erupted from ethnic rivalries since 1983 in the Northern regions of the country hasresulted in disrupting the production and supply of these high value cash crops from the Jaffna districtto the market. This has given the central highland vegetable and potato farmers an advantage and after the war even at present, two central highland districts, *Nuwara Eliya* and *Badulla* have a near monopoly of the supplyof potatoes to the market.

1.4. Social and Institutional Factors

Beside micro-economic policies of the Government and the ecological environment that favour the cultivation of non-indigenous food crop varieties in the region, a range of localized social and institutionalfactors appears to influence the adoption of these agricultural practices in the area. An agricultural holding of 0.4 ha (or less in a significant number of cases), operated by the farmer, would hardly be adequate to maintain an average family of 5-6 members. If the land is cultivated with any other subsistence crops such as those grown in other partsof the country or in the district itself, the income generated will be quite insufficient to maintain anaverage family.

On the other hand, there is little scope, in ecological terms, to cultivate rice or undertake upland mixed crop gardening or growing of minor export crops. Labour is much more intensively used in the market gardening systemthan in subsistence crop farming. Thus market gardening has resulted in a labour market which is partly supplied by the poorer land operators, landless labour in the area andmostly by the surplus labour of the estate sector. In other words, if not for intensive market gardening,a significant portion of the work force would be unemployed, underemployed or forcedto migrate.

In discussing the socio-economic factors influencing vegetable cultivation as a market-oriented venture, aspects of human resource skills applied in this type of farming system also haveto be taken into account. Entrepreneurial skills including a working knowledge of how the marketsystem works are important.

2. SustainableVegetable Farming

In Sri Lanka, most of the vegetable farmers apply modern agricultural techniques such as intensive land preparation methods, synthetic fertilizer, hybrid seeds, and agrochemicals. Ultimate results are high cost of production, environmental pollution, biodiversity reduction, habitat destruction and risks to human health and welfare. Sri Lankan people consume the fresh vegetables in their day- to- day meals, knowing that nutritional value and safety of the fresh vegetables are very important. By increasing farmers' knowledge, there is potential to develop ecological farming systems to control the ill- effects of modern farming technologies.

Sustainable production has been suggested for enhancing productivity for future generations through the use of locally available resources such as manure and compost. Reduction of dependency on chemically synthesized fertilizers for maintaining yields is an important step towards increasing agricultural production in the long run. The importance of bio-fertilizers such as manure and compost is widely documented.

Local farmers in Sri Lanka are reservoirs of valuable indigenous knowledge, yet there is no guarantee that their understandings behind these applications are scientifically correct. Farmers' knowledge on applications of ecological farming can be improved through interventions and the role of an agro-ecologist is important in this regard. Therefore, education is often needed and outside expertise is essential to assist local people to understand, identify, and develop future situations of the ecological vegetable production sector. Farmers’ knowledge of soil fertility building, crop selection, and land preparation can also be increased by using experts.

2.1. Function of the Organic Fertilizer

It is well established that the application of organic fertilizer helps to improve the biological, chemicaland physical qualities of soils. They help to adhere fine soil particles together to form soil aggregatesand increases the water and nutrient retention capabilities of the soil. Organic fertilizer is heavilyapplied in potato and vegetable cultivation. Thus, it appearsthat in market gardening, organic fertilizers fulfils a function, by improving the ability of the soils to resist the impact of rainfall, leaching of soils and stimulating soil microbialactivity.

Beside these physical functions performed by the organic matter, some of the micronutrients that arenot included in inorganic fertilizers, which are lacking in the soils, too are supplied by the organic manure.

Sustainability

Potato dominant exotic tubers and vegetable gardening, is asystem of farming involving an intensive use of land, labour and agro-chemicals resulting in a considerableoutput for the local market. The competitive advantage however is with the favourable elements in certain ecological niches of a generally ecologically fragile region. Not all the lands that aresuitable for growing of exotic vegetables are available for the propose as much of this land is used forother crops like tea.

Neither the existing demand nor the cost of production makes the expansion of vegetable cultivation anattractive proposition. The existing demand is influenced by the price factor, which is relatively higherthan the prices fetched by non-indigenous vegetable varieties. A glut production may result in a reduction of the price, but producing at such low price becomes uneconomic in terms of the high productioncosts. Also, significant price fluctuations are a common experience often resulting in withsubstantial financial losses to the farmer. The return obtained by the farmer is also influenced by thehigh cost of transportation of the produce to urban centers and the margins of profit made by thewholesale and retail chain. Similarly, neither does the country have modern cold room facilities tostore this type of highly perishable produce for use in lean seasons nor has the scope for expandingexports been fully realized.

A number of considerations should be taken into account when assessing the sustainability of thissystem of farming. These would include the examination of ecological, physical and the socio-economicfactors impacting on the system or the advances in the production technique that could determineits viability. For example, one may start with the lands, as one of the fundamental natural resourcesessential for agricultural production. Likewise, the changing pattern and the intensity of inputsused for crop production, their supply and the possible difficulties in obtaining their supplies are someof the considerations in the assessment of sustainability of this farming system or factors affecting itssustainability. Both input and producer prices, their changes and the possible effects these changesmay have, include yet another set of factors that should be considered in such an assessment.

Vegetable farming is sustainable when it leads to long-term: farm profitability; improvements in the quality of life of farming families; the vitality of rural communities, villages and small towns; and the protection and conservation of the natural environment, especially soil, air and water. Vegetable farming is sustainable when it also considers: futures perspective but includes the wisdom from the past; the impacts of transporting food to markets; the health of the people who live near the farm and those who will be consuming the produce; and the quality of the vegetable that is grown.

Following strategies are essential for sustainable vegetable farming:

i. Attitudinal change of farmers through continuous awareness programmes;
ii. Availability of bio-fertilizer and bio-pesticides by encouraging farmers to produce and promoting fertilizer and bio-pesticide production as a business avenue;
iii. Development of market linkage for healthy vegetables;
iv. Demonstration sites to show the performance of sustainable vegetable farming; and
v. Development of the vegetable farm as an agro-ecosystem
vi. Introduction of crop varieties that need less inputs

3. Selected DS Divisions for the Project

High input vegetable cultivation is mostly practiced in *Nuwara Eliya, Welimada, Bandarawela* and *Uva Paranagama* DS Divisions in the Central Highlands. Soil type is Red and Yellow Podzolic soils. *Bandarawela* and *Nuwara Eliya* series are the dominant soil series in the vegetable farming areas (Table 2).

Table 2. Basic details of selected DS Divisions

District	DS Division	Extent (ha)	No. of GNs	AE Regions	Soil types	Annual rainfall (mm)
Kandy	*Delthota*	5,700	29	IU 2, IM3c	RYP	1,100-2,100
	Doluwa	9,440	33	WU 2b, WM 2a, WM 2b, IU 2	RYP, RBL, IBL	1,800-2,200
Nuwara Eliya	*Nuwara Eliya*	47,800	72	WU 3, WU 2a, WU 2b, IU 3d, IU 2, WU 2b	RYP	1,300-2,400
	Walapane	32,000	125	IU 2, IM 1a, IM 1c, IL 2	RYP, RBE, IBL	1,600-2,100
Badulla	*Uva Paranagama*	13,330	68	IM 1a, IU 2, IU 3d, IU 3e	RYP	1,300-2,100
	Hali Ella	16,504	59	IM 1a, IU 3e	RYP	1,600-2,000
	Welimada	18,040	64	IU 3e, IU 3d, IU 3b	RYP	1,300-1,800
	Bandarawela	7,030	35	IU 3c, IU 3e, IU 3a	RYP	1,400-1,900

Nuwara Eliya Series

This is a Red Yellow Podzolic (RYP) soil, deep and moderately well drained found on hilly to steeply dissected landform. Top soil is high in organic matter and texture is sandy clay loam. The soil is vulnerable to erosion but high in clay content and available water. Main land use is vegetable cultivation.

Bandarawela Series

This is a Red Yellow Podzolic (RYP) soil, deep well drained found on rolling to hilly terrain. Texture is clay loam with somewhatgravelly. It bears good available water content, but is poor in nutrient and organic matter contents. It is susceptible to erosion and acidic in reaction. Most dominant land uses are tea and vegetable cultivation.

4. SLM Technologies

Sustainable Land Management (SLM) Technologies have evolved from different countries are now being shared by World Overview of Conservation Approaches and

Technologies (WOCAT)[5] for other countries to find possibility of their effective adoption. The WOCAT database on SLM Technologies contains a full range of different case studies documented from all over the world. WOCAT's database currently comprises datasets around 600 technologies from 50 countries.

SLM is defined as the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions.

Various SLM technologies are being practiced around the world. Following are the most relevant practices, which could be adopted in vegetable cultivation.

1. Integrated Soil Fertility Management (ISFM)
2. Conservation farming
3. Organic farming or ecological farming
4. Rotational cropping
5. Integrated crop-livestock management
6. Agro-forestry
7. Cross-slope barriers on sloping lands or Sloping Agricultural Land Technology (SALT)
8. Rainwater harvesting
9. Smallholder irrigation management
10. Biodiversity conservation and sustainable use

5. Recommended SLM Practices

Most of the soils in Sri Lanka are highly erodible. Although the problem of soil erosion has been well recognized in the Central Highlands and effective conservation measures have been clearly identified, still severe land degradation is taking place in most of the cultivated lands due to unattended soil erosion.

Following SLM practices are recommended for sustainable vegetable farming lands

5.1. Agronomic practices for vegetable farms

i. Mixed cropping (with different harvesting times and rooting depths)
ii. Minimum tillage
iii. Application of organic fertilizer
iv. Contour planting
v. Mulching

[5]WOCAT was organized as an informal global network of national, regional and international institutions providing tools and methods that allow SLM specialists to identify fields and needs of action and to share their valuable knowledge in land resources management.

5.2. Vegetative methods for vegetable farms

i. Biological hedges
ii. Grass hedges
iii. Cover crops

5.3. Structural methods for vegetable farms

i. Stone bunds
ii. Terracing,
iii. Gully control structures.

6. Description of the Proposed SLM Technology

6.1. Short description of the SLM Technology

Definition: Improvement of existing commercial vegetable farms in the Central Highlands towards sustainable vegetable farming.

6.2. Detailed description of the SLM Technology

This technology involves growing vegetables in paddy lands or in upper terraced lands. The cropping pattern may be various vegetables in rotation, potato and vegetables in rotation and in some cases paddy, potato and vegetables in rotation. The purpose of practicing such rotational farming in these lands is to avoid high incidence of pest and diseases, decline in soil fertility levels and the market demands. The sustainable vegetable farming system is proposed to these lands by adopting following strategies.

i. Adoption of sustainable land management practices
   a. Structural – stone bunds, terracing, leader drains
   b. Vegetative – green hedges and cover crops, rows of perennial legumes or fruits (pears)
   c. Agronomic – mulching with drip irrigation, mixed cropping (different crops in the same plot. Ex. Carrot, leaks, lettuce), relay cropping, incorporation of compost or animal manure,
   d. Adoption of soil test based fertilizer and lime recommendations,
   e. Establishment of live fence - Gliricidia (*Gliricidia sepium*), **Kahakona** (*Cassia siamea*), Pawatta (*Adhatoda vasica*), Kathurumurunga (*Sesbania grandiflora*), Wild sunflower *(Tithonia diversifolia)*, Halmassandambala (*Lablab purpureus*), Chow chow *(Sechiumedule)*
ii. Attitudinal change of farmers through continuous awareness programmes; healthy (safe) vegetable farming
   a. Conducting TOT programmes

    b. Training topics - SLM (Introduction to soil, soil degradation, soil conservation), Nutrition based agriculture, Farm waste management, Crop management, Present status of soil fertility in intensive cultivated vegetables, mitigation of and adaptation to climate change, Indigenous knowledge, New technologies (absorbents, purifications etc.)

iii. Farming practices – GAP, Promotion through demonstration of machinery for grass cutting instead of weed killing or removing totally to reduce the soil erosion

iv. Availability of organic manure by encouraging farmers to produce and promote organic manure fertilizer production as a business venture;
    a. Plot demonstrations
    b. Establishment of organic manure production units
    c. Introduction of Super water absorbents for water limited areas
    d. Demonstration of farm waste management
    e. Introduction of pest repellant species (chives, coriander, marigold etc.)
    f. Promotion of insect proof nets to discourage chemical usage

6.3. Description of SLM practices

Terraced farm lands

Terracing is converting a steep slope into a series of steps with horizontal or nearly horizontal ledges (shelves), and vertical or almost vertical walls (risers) between the ledges. The wall is vulnerable to erosion and is protected by vegetative cover and sometimes, faced with stones or concrete (Fig. 1 and 2). There is no channel but a storage area is created by sloping the shelf into the hillside. The basic bench system can be modified according to the nature and value of the crops grown. Where tree crops are grown, the terraces are widely spaced, the shelves being wide enough for one row of plants, such as rubber. Riser banks are planted with grass or ground creepers. With more valuable crops, such as upcountry vegetables grown in the highlands, the shelves are closely spaced and the steeply sloping risers frequently protected by stone walls. Level bench terraces are used where water storage is also a requirement. The riser is raised over the shelf to store water; the entire riser may be formed by soil, where soil is stable enough. This kind of bench terrace is found in mid and upcountry, where rice is grown in drainage valleys.

Fig. 1.Terracing with stone bunds

Fig. 2.Terracing without stone bunds

The risk of collapsing riser walls of the terraced lands is high. Thus, riser banks need a protective measure. In the absence of stones these banks need to be stabilized with legume hedge like in Sloping Agricultural Land Technology (SALT).

SALT is a package technology on soil conservation and food production, integrating different soil conservation measures in just one setting. Basically, SALT is a method of growing field and permanent crops in 3-meter to 5-meter-wide bands between contoured rows of legume trees such as gliricidia. These trees are thickly planted in double rows to make hedgerows. When a hedge is 1.5 to 2 meters tall, it is cut down to about 75 centimeters and the cuttings (tops) are placed in alley-ways to serve as organic fertilizers.

The advantages of SALT are that it is a simple, applicable, low-cost, and timely method of farming uplands. It is a technology developed for Asian farmers with few tools, little capital, and little learning in agriculture. Contour lines are run by using an A-frame transit that any farmer can learn to make and use. A farmer can grow varieties of crops he is familiar with and old farming patterns can be utilized in the SALT system.

Stone bunds with grass hedges

A stone bund is used on a steep slope, where the soil is not stable enough to keep as risers in terraced lands and where stone is available for such work. The foundation for the stone bund is laid down to 22.5 cm and the bund is raised about 45 cm from the upper side. Generally, these bunds are constructed for width of 60 cm.

Grass hedges are established at the upper side of the stone bund to reduce the force of water flow on the stone bund (Fig. 3). Species recommended are *Vetiveria zizanioides* (Sinhala: *Savendara*; Tamil: *Vettiver*), *Cymbopogon nardus* (Sinhala: *Heen-pengiri*; Tamil: No name known); *Cymbopogon citratus* (Sinhala: *Sera*; Tamil: *Serai*)). Pruning has to be carried out 2-3 times a year and the pruned biomass can be placed as a mulch to the crop.

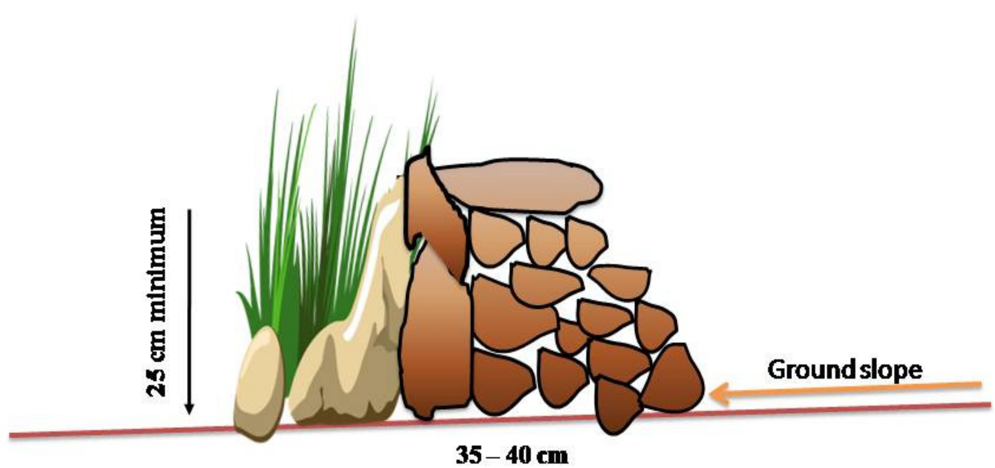

Fig. 3.Stone bund with grass hedge

Compost production unit

Composting is the natural process of decomposition of organic materials by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, green manures, aquatic plants, industrial wastes, city wastes, food garbage etc. enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. The end product of the process is compost or humus which, is of value in agriculture. In addition, compost could be considered as a value added product of organic materials, which has a high commercial value when compared to many other forms of organic materials. This is recommended especially for potato and vegetable farm lands.

Discussions made with vegetable cultivators in *Nuwara Eliya* DS Division reveal that one of the constraints they face in intensive vegetable cultivation is to purchase and transport adequate compost from nearby areas. Thus, the Project is seeking possibility of developing small scale compost production units with progressive farmers as a business venture. Few farmers will be selected from Project DS Divisions (*Nuwara Eliya, Welimada, Bandarawela and Uva Paranagama*), where vegetable cultivation is practiced. Farmers willingness to produce composts, availability of land and material sources are the criteria for farmer selection. Special consideration needs to be made with farmers, who practice livestock.

A farmer who has three cement tanks as shown in Fig. 4, he can produce about 20 m^3 of compost in every 3 month period. The project will support to construct these tanks and in packaging process after providing them with proper training.

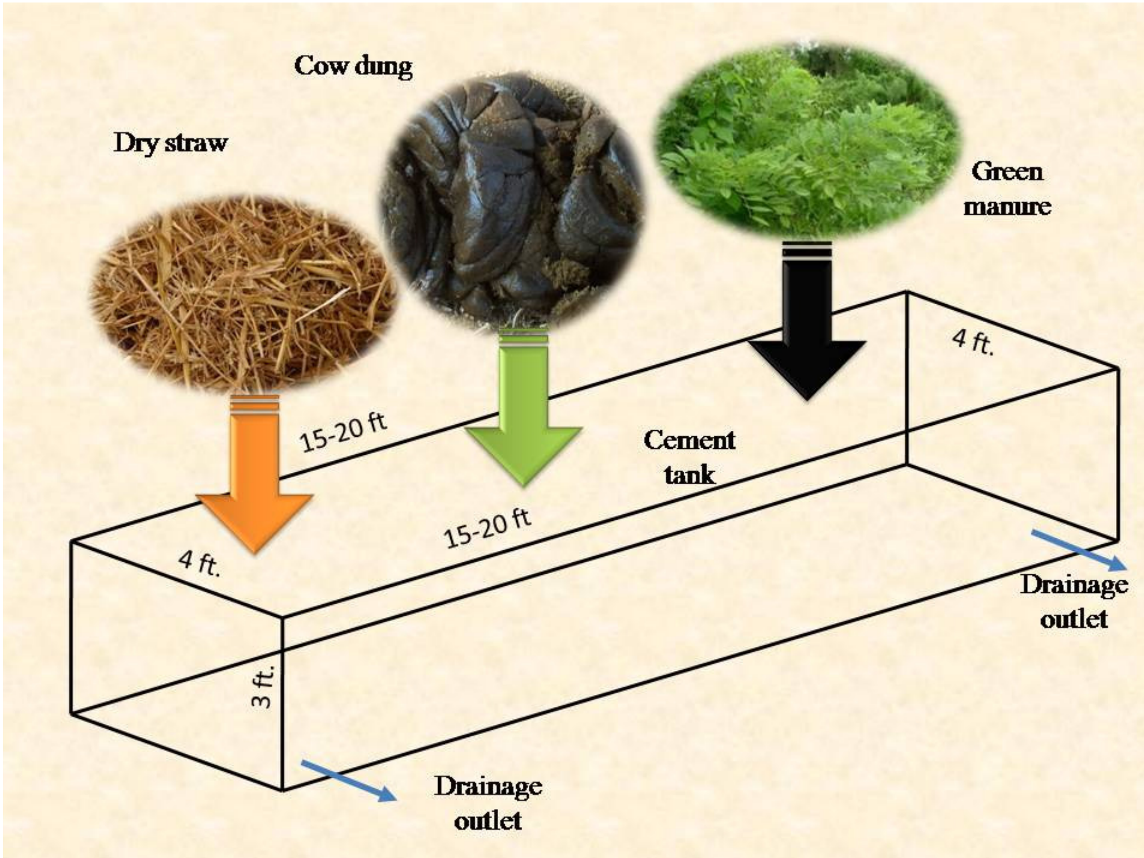

Fig. 4.Cement tank for compost production

These compost tanks can be placed parallel to contour terrace at the upper side of the stone bund.

On-farm Compost Preparation

The on-farm compost preparation method is done over a short period of time and in a systematic way of putting the materials together. This method is most suitable for the rainy season when there are plenty of materials, e.g. weeds, crop residues, green materials from live fence, to put into the compost. However, the place for making compost should be well-drained and easy to protect from floods and excess rain. The compost can be made either by piling in a heap or heaps, or in a pit or pits. This method can also be used by vegetable growers when they clean their fields before the next crop is planted. The residues left after the crop is finished, harvested, such as stems and leaves from pumpkins, potatoes, tomatoes, capsicum, leaves and stalks from cabbage, etc. and any damaged crops that cannot be sold or eaten, can be collected together and organized for making compost.

Selecting the site:

The following factors need to be considered:

i. The site should be accessible for receiving the materials, including water and/ or urine, and for frequent watching/monitoring and follow-up.
ii. The site should be protected from strong sunlight and wind, e.g. in the shade of a tree, a building or wall.
iii. The site should be protected from high rainfall and flooding.
iv. The site should be free of diseases, which would affect crops.

Preparing the site:

i. Clear the site of stones, weeds and grasses, but do not cut down any young trees. Instead, put the site so it is in the shade of the tree(s). The tree(s) will grow, provide shade and protect the compost heap.
ii. Mark out the area for the compost heap. A minimum area is 1.25 m x 1.25 m. If it is smaller than this, the heap will dry out quickly so compost will not be made properly. The area can be larger, up to 3 m x 2.5 m.
iii. Dig a shallow trench in the ground the same size as the compost heap. Make the trench about 20–25 cm deep. The bottom and sides of the trench should be smeared with water or a mixture of cow dung and water. This seals the pit so that moisture with nutrients does not leak out of the base of the compost heap.
iv. The foundation layer of compost making materials is placed in the trench or pit.
v. The trench holds moisture during the dry season.
vi. Materials are added in layers to make the heap, as described in more detail below.

The layers in making the compost heap

The foundation layer:

i. Dry plant materials, e.g. paddy straw, grass species, which are thick and long, are used for the foundation. These need to be broken into short lengths (about 10–15 cm long). The stalks can be crushed, and then chopped.
ii. Spread the dry materials evenly over the bottom of the trench to make a layer 15–25 cm thick, as deep as a hand. Then sprinkle water with a watering can or scatter water evenly by hand over the dry plant materials so they are moist, but not wet.
iii. The foundation layer provides ventilation for air to circulate, and excess water to drain out of the upper layers.

The three basic layers:

1. The compost heap is built up of layers of materials, like in a big sandwich. The basic sequence is:

Layer 1: A layer of dry plant materials, or mixture of dry plant materials with compost making aids like good soil, manure and/or some ashes. The layer should be 20–25 cm thick, i.e. as deep as a hand. The compost making aids can be mixed with the water to make slurry. Water or slurry should be scattered by hand or sprinkled with a watering can evenly over this layer making it moist but not soaking wet.

Layer 2: A layer of moist (green) plant materials, either fresh or wilted, e.g. weeds or grass, plants from clearing a pathway, stems and leaves left over from harvesting vegetables, damaged fruits and vegetables. Leafy branches from woody plants can also be used as long as the materials are chopped up. The layer should be 20–25 cm thick. Water should not be sprinkled or scattered over this layer.

Layer 3: A layer of animal manure collected from fresh or dried cow dung, or chicken droppings. The animal manure can be mixed with soil, old compost and some ashes to make a layer 5–10 cm thick. If there is only a small quantity of animal manure, it is best to mix it with water to make slurry, and then spread it over as a thin layer 1–2 cm thick

2. Layers are added to the heap in the sequence, Layer 1, Layer 2, Layer 3, until the heap is about 1–1.5 metres tall. The layers should be thicker in the middle than at the sides so the heap becomes dome-shaped. If the heap is much taller than 1.5 metres, the microbes at the bottom of the heap will not be able to work well.
3. Layers 1 and 2 are essential to make good compost, but Layer 3 can be left out if there is a shortage or absence of animal manure.
4. Place one or more ventilation and/or testing sticks vertically in the compost heap remembering to have the stick long enough to stick out of the top of the heap (Fig. 5). Ventilation and testing sticks are used to check if the decomposition process is going well, or not. A hollow stick like bamboo makes a good ventilation stick as it allows carbon dioxide to diffuse out of and oxygen to diffuse into the heap. A testing stick is needed as it can be taken out at regular intervals to check on the progress of decomposition in the heap.

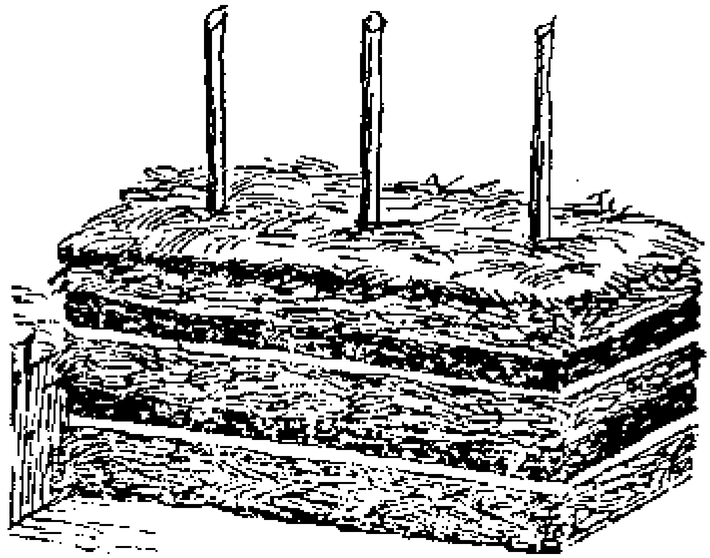

Fig. 5. Compost layering with hollow stick for ventilation

Making the covering layer:

The finished heap needs to be protected from drying out, and also from animals pushing into it and disturbing it.

i. The covering layer can be made of wet mud mixed with grass or straw, with or without cow dung, or wide leaves of colocasia, banana etc., or any combination of these materials, i.e. mud plaster covered with leaves or plastic, or leaves covered with plastic.
ii. The cover should be put on both the sides and the top of the heap with only the ventilation stick coming out of the top.
iii. The covering layer prevents rainwater from getting into the heap and damaging the compost making process; and helps keep heat inside the compost making heap. Special attention should be given on prevention of conducive environment for mosquito breeding and Dengue viral contamination.
iv. The compost heap can also be protected by putting a ring of stones or making a small fence around it.
v. The compost heap is best left untouched until there is mature compost inside it, or it can be turned over. If the compost is turned over, water should be sprinkled over the layers to keep all the materials moist. It is not necessary to try and keep the original different layers when turning over the compost – it is best if all the materials can be well mixed together, then added in layers about 20–25 cm thick and water sprinkled or splashed over them.
vi. A mature compost heap is about half the height of the original heap, and the inside is full of dark brown or black substance, humus, which smells good. When the compost is mature, it should be very difficult to see the original materials.

vii. This mature compost can be used immediately in the field, or it can be covered and stored until the growing season. When it is put in the field, it should be covered quickly by soil so the sun and wind do not damage it, and the nitrogen does not escape to the atmosphere. Therefore, it is best to put compost on the field just before ploughing and incorporation, or at the same time as sowing the crop. For row planted crops, it can be put in the furrow with the seed. For transplanted crops, it can be put in the hole with the seedling.

Live fence:

Live fence along the boundary is an essential element for the tea agro-ecosystem. Following tree species and creepers are recommended:

Trees: Gliricidia (*Gliricidiasepium*), Aramana (*Cassia siamea*), Pawatta (*Adhatodavasica*), Erabadu (*Erythrina variegate*), Neem (*Azadirachta indica*)

Creepers: Winged bean (*Psophocarpus tetragonolobus*), Halmessandambala (*Lablab purpureus*), Passion fruit (*Passiflora edulis*),

Trees nearby the live fence: Areca nut (*Areca catechu*), Toona (*Toona sinensis*), Sabukku (*Grevillea robusta*)

<u>Importance of live fencing:</u>

i. It makes protection from cattle, wild animals and thieves
ii. Legume trees planted along the fence provide large amount of green manure
iii. The tree belt of the fence acts as a wind barrier
iv. Creepers such as winged bean (*dambala*) provide nutritional vegetables
v. Some fence trees can provide fuel wood, timber and fencing poles
vi. Fence trees such as neem, *erabadu* (erithrina), *adathoda vasica* etc. provide medicines
vii. Fence environment is favourable for some predators
viii. Many vegetable plants such as winged bean, bean, bitter gourd, ribbed gourd, snake gourd, yard long bean etc. can be supported without any trellis
ix. The live fence increases the bio-diversity

Green manure hedges

Green hedge is a combined hedge of different plants. This is established across the slope like in SALT method. Importance of the green hedge is as follows.

i. The green hedge stabilizes the structural conservation measure.
ii. It produces large amount of green manure (Ex. N from Gliricidia, P from *Adhatoda* or *Pawatta* and K from Citronella)
iii. It acts as a wind barrier to reduce the advection effect to the crops

iv. It reduces the spread of pest.
v. It maintains the greenery of the farm land throughout the year

The green hedge consists of 3 main plants: legume tree, legume shrub and grass. Legume plants are placed at 1 m spacing on the bund and legume shrubs are planted in between. Grass is planted at downstream below the hedge (Fig. 6).
Example:

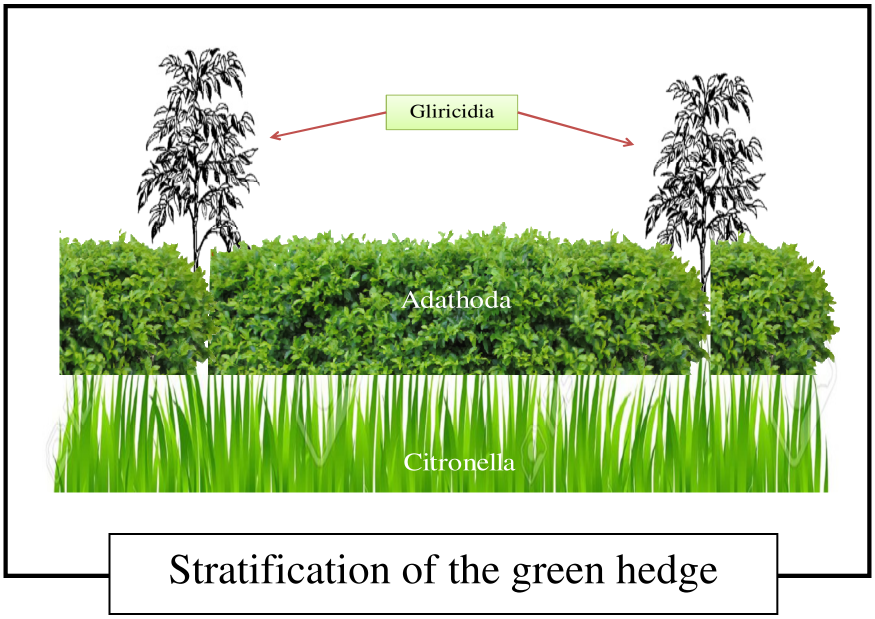

Fig. 6. Green manure hedge

Bio-pesticides

Bio-pesticides, used to replace synthetic pesticides, have active ingredients that cone from natural materials like animals, plants, bacteria, and certain minerals. Unlike synthetic chemical pesticides derived from petroleum products, the micro-organisms/ substances in bio-pesticides works slowly. However, they do not harm natural enemies and the environment while providing effective control of specific target pests such as weeds, insects, diseases etc. The active ingredients of bio-pesticides can be microbial or plant substances that control pests.

Grow following insect repellant plants wherever possible:

Sera
(*Cymbopogon citratus*)

Citronella
(*Cymbopogon nardus*)

Turmeric
(Curcuma longa)

Ginger
(Zingibera officinale)

Araththa
(Alpinacalcarata)

Kapparawalliya
(Coleus amboinicus)

Most of the bio-pesticides available have not yet been tested by the Department of Agriculture, Sri Lanka although farmers are using them in organic farming. Composition and concentration need to be decided carefully and with experience farmers will become professionals in applications. Farmers should be trained for these practices by well experienced organic farming experts.