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Framework Guidance for the Agricultural Sector and Soil Carbon

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1. Introduction: Land Use in the Maldives

This draft Framework Guidance document calls attention to evidence and possible recommendations for advancing an official Agricultural Policy on Soil Carbon. Sections 3 to 5 provide the recommendatory component of this Framework Guidance.

In developing an Agricultural Policy on Soil Carbon it is important to acknowledge prevailing land use within the Republic of Maldives.

Agricultural systems in the Maldives consist of a mixture of traditional and new practices. One of the problems is to find an agricultural system that is both productive and sustainable. The limitations of the physical environment make that search difficult.

The traditional agricultural systems are composed of settled home gardens and types of shifting cultivation. Home gardens are continuously replenished with household waste and leaf litter, preventing soil erosion from becoming a major problem. Shifting cultivation also ensures that the area planted has time to recover its organic content with little erosion. However, if storms and heavy rains coincide with clearing or burning, some erosion may occur.

Undoubtedly, the more modern, larger, settled nurseries and agricultural plots are more prone to erosion. Large monocrops are usually kept clear of weeds and other vegetation. Heavy winds and rains rapidly deplete the topsoil. Successive crops are usually planted before the fallow period, exacerbating erosion. Fertilizer usage on those plots is high and little compost is utilized. The large-scale removal of trees also contributes to soil erosion on the islands.

Land ownership is one of the current problems regarding land resource management in the Maldives. Outside the home gardens, plots of land are leased to individuals only for short periods; farmers, therefore, do not to invest time in soil rehabilitation after they have harvested their crop. That is not a major problem on an island such as Meedhoo where the quality and availability of land is good, and where a plot can be left fallow for a number of years. However, problems arise on islands where agriculture is intensive and available land is scarce, e.g., Thoddoo Island in the Ari Atoll.

Watermelons are grown every year, with all available land being utilized. Since farmers are allocated plots for a single growing season, little effort is made to rehabilitate the land after harvesting. Such a scenario will eventually result in severe productivity problems caused by pests, diseases and nutrient depletion. Some form of extended leasehold (10-20 years) may encourage more sustainable land utilization.

2. Agriculture in the Maldives

Fisheries account for 8 percent of GDP. Concerns have been raised by government and other stakeholders about possible declining fish stocks in some species such as yellow fin tuna; long-term outlook for increased GDP contributions; capital/labour substitutions and continued reductions in primary fishing employment; a continued dependence on tuna (89 percent of total fish catch) and in particular skipjack tuna (78 percent of all tuna harvested); and low product diversity. Several factors that appear to be limiting more robust growth in fisheries include continued public sector involvement in the tuna industry, impediments to private sector investment, inadequate physical infrastructure for fisheries and marine transport, and limited institutional and human resource capacity, particularly in the Ministry of Fisheries, Agriculture, and Marine Resources. The sector is also highly vulnerable to external shocks from fluctuating tuna prices in the world market.

At the same time, the country's narrow economic base needs to be expanded, particularly agriculture, which presently accounts for less than 3 percent of GDP. Most of the domestic agriculture demand is met through imports: the ratio of food imports to domestic food production is 10:1. While some islands contain sufficient soil and water conditions to support increased agricultural production for certain horticultural products, fishing is still seen as the traditional livelihood opportunity. The absence of a vibrant private land market limits the access to finance by prospective farmers. Transport and logistical issues also affect the supply of competitively priced inputs to agricultural islands, as well as the supply of high quality produce to the capital of Male and the major tourism islands; much as 25 percent of perishable production can spoil before reaching Male.

Agricultural Production and Yields		Maldives	Asia (excl. Middle East)	World
Cereals, 1999-2001				
	Average production (000 mtons)	0	951041	2075387
	Percent change since 1979-81	-91 %	61 %	32 %
	Per capita production (tons per person)	0	279	343
	Percent change since 1979-81	-95 %	17 %	-4 %
	Average crop yield (kg per ha)	933	3678	3096
	Percent change since 1979-81	16 %	48 %	41 %
Roots and tubers 1996-1998				
	Average production (000 mtons)	7	259954	638438
	Average crop yield (kg per ha)	4976	X	12958
Pulses, 1996-1998				
	Average production (000 mtons)	0	23517	55469
	Average crop yield (kg per ha)	688	X	808
Meat, 1999-2001				
	Average production (000 mtons)	1	86935	233218
	Percent change since 1979-81	66 %	236 %	71 %
Agricultural Land,				
Total cropland (000 ha), 1999		3	482065	1501452
Hectares of cropland per 1,000 population, 1999		11	143	251
Arable & Permanent Cropland as a Percent of Total Land Area, 1998		10 %	19.3 %	11.3 %
Percent of cropland that is irrigated, 1999		X	35.5 %	18.3 %
Agricultural Inputs				
Average annual fertilizer use, 1999				

	Total (thousand metric tons)	X	71926	141360
	Intensity (kg per hectare cropland)	X	149	94
Pesticide use, 1994-1996 (kg/ha cropland) {c}		X	X	X
Number of tractors, 1997		X	5757829	26334690
Agricultural workers as a percentage of the total labour force, 1990		32.3 %	X	X
Percent of GDP Generated from Agricultural Activities, 2000		X	6.3 %	5 %
Food Security				
Variation in Domestic Cereal Production, 1992-2001				
	(average percent variation from mean)	53.8 %	3.7 %	3.5 %
Net Cereal Imports and Food Aid as a Percent of Total Consumption {b}, 1998-2000		X	4.7 %	X
Food Aid as a Percent of Total Imports, 1998-2000		X	8.7 %	X
Average Daily Per Capita Calorie Supply, 1999 (kilocalories)		2298	2710	2808
Average Daily Per Capita Calories from Animal Products, 1999 (kilocalories)		441	367	460
Percent of children that are underweight, 1995-2000 {c}		43 %	X	27 %
Footnotes:				
a.	The index of agricultural production is a ratio of country's net agricultural output in 1996-98 relative to the base period 1989--91. This ratio is then multiplied by 100 to obtain an index number.			
b.	Negative values, indicating a net export of grain, are not shown. Cereal consumption is defined as production plus imports minus exports.			
c.	Data are for the most recent year available within the given time range.			

(Primary Source: World Resources Institute)

3. Integration with other Sectors of the Economy

There are two recommendations that apply to the integration issue as follows:

- Any food imported by either the private sector (e.g. resorts) or public sector (e.g. government) should have a sustainable supply strategy, ensuring that food is sourced in a sustainable manner and imported according to the most efficient seasonal production and transportation methods.
- Preference should be given to locally produced food wherever possible noting that ten times more produce is imported rather than locally grown.

4. Soil Carbon Sequestration:

4.1. Introduction

Soil carbon sequestration is so important that we explain this in some detail. To begin, land use significantly affects soil carbon stocks. There appears to be strong evidence that soils accumulate carbon: soils under grassland and forest act as sinks, sequestering up to 100 million tonnes of carbon per year, although soils under arable land act as net emitters, releasing between 10 and 40 million tonnes of carbon per year. Carbon is lost from soils when grasslands, managed forest lands or native ecosystems are converted to croplands, a process that is slowly reversed when cropland is converted back.

Of the five principal global carbon pools, the ocean pool is the largest at 38.4 trillion metric tons (mt) in the surface layer, followed by the fossil fuels (4.13 trillion mt), soils (2.5 trillion mt to a depth of one meter), biotic (620 billion mt), and atmospheric pools (800 billion mt). If the fluxes among terrestrial pools are combined, annual total carbon flows across the pools average around 60 billion mt, with managed ecosystems (croplands, grazing lands, and plantations) accounting for 57 percent of that total. Thus, land managers have custody of more annual carbon flows than any other group.

Increases in soil organic material have important productivity and resilience benefits. These benefits include improvement in soil quality, increase in use efficiency of inputs, reduction in soil erosion and sedimentation, decrease in nonpoint source pollution, and lower rates of anoxia or hypoxia (dead water) in coastal ecosystems. Global food security cannot be achieved without restoring the quality of degraded soils,

The potential for carbon sequestration in the Maldives's soils has not been studied in detail. However, there are a number of international studies that have been carried out on carbon sequestration in soils. For example, the information compiled by the Global Change and Terrestrial Ecosystems Soil Organic Matter Network[1] developed initial linear relationships between management practices and annual changes in soil organic matter.

More recently, in depth studies (Smith P. et al., 2000, West & Post, 2002; Smith J. et al., 2005) have dealt more specifically with the impacts that different practices could play in carbon sequestration and in meeting Kyoto targets[2]. West & Post (2002) for example found that relatively simple changes from a conventional tillage scenario to a no-till management practice can sequester up to 57 $\pm$ 14 g C m^{-2} yr^{-1} (higher than previously estimated).[3] It is suggested that sequestration appears to peak roughly around 5 to 10 years after a change in management practices, reaching an apparent new equilibrium 15 to 20 years after (West & Post, 2002). This is in line with the findings from previous studies (Mann, 1986 cited in West & Post, 2002) in which land use changes moving from forests and grasslands to agricultural lands had a short and rapid loss of carbon in the first 30 cm of soil, with a global average of around 1500 g C m^{-2}.

In addition, another study (Davidson and Ackerman, 1993 cited in West & Post 2002) detailed losses in soil organic carbon from the soil column after 30 years of cultivation, where the first 5 years of cultivation showed the highest loss with the system stabilising afterwards. This provides an idea of the timescales involved to see effects after Republic of Maldives policy

[1] See http://www.rothamsted.ac.uk/aen/somnet/index.htm

[2] Under LULUCF improved land Management of agricultural soils practices are valid, Article 3.4 of the Kyoto Protocol.

[3] IPCC 2007 guidelines for carbon accounting (based on Houghton et al., 1997 as cited in Alcamo et al., 2007) suggest using a factor of 1.05 in temperate regions to take into account changes from conventional tillage to no-till practices, and that this should apply to a 30cm depth.

implementation, a minimum of 5 years that policies must be in place, with an additional longevity of 10 to 30 years in order to insure the sustainability of policies and their effects. Given a soil stabilisation period of 50 – 100 years to adjust to land-use changes; this could be interpreted as that signs of soil stabilisation should be present at present in soils that underwent changes in the 70s, perhaps, the fact that this has not been documented is an indication that climate change has and is affecting agricultural soil stabilisation. However, it is more likely that the pressures on land and the changes in land management and practices have masked any effects due to climate change or stabilisation.

4.2. Measures to improve Carbon Sequestration from Soils

It is clear, in light of what has been discussed, and in particular the size of the soil carbon store, that soils have a vital role to play in climate change mitigation. It is important to prevent the loss of soil carbon to the atmosphere and explore the potential to increase existing carbon stores as a contribution to meeting climate change mitigation targets. Consistent with the work of other states, this requires the attainment of the following objectives:

・Significantly reduce the rate of loss of stored soil carbon

・ Ensure land managers understand how to reduce emissions and mitigate climate change through improved management practices.

Moreover, it is necessary that cost-effective methods are developed for protecting and increasing soil carbon without increasing emissions of other greenhouse gases, including giving consideration to emerging technologies such as biochar.

4.2.1 Examples of Techniques to Increase Soil Carbon Sequestration

Examples of soil and crop management technologies that increase soil carbon sequestration include:

- No-till (NT) farming with residue mulch and cover cropping;
- Integrated nutrient management (INM), which balances nutrient application with judicious use of organic manures and inorganic fertilizers;

- Various crop rotations (including agroforestry);
- Use of soil amendments (such as zeolites, biochar, or compost);
- Improved pastures with recommended stocking rates and controlled fire as a rejuvenate method.

It is a further important point, taking into account Kyoto targets, that the combination of improved agricultural land management practices with increased bio-energy crops should play an important part in future Republic of Maldives agricultural strategy. This is doubly true if, as the IPCC 2007 report suggests, climate change plus increased atmospheric CO_2 lead to overall small increases in crop productivity which could be heightened through adaptation policies.

By reference to a possible comparative approach, the EU Soil Strategy (2006) defines soil as a non-renewable resource given that the formation processes are on geological time-scales while the loss of topsoil can be quite fast leading to a negative replacement balance. "when the rate of change of a soil property with time is negligibly small, the soil is said to be in steady state with respect to that property" "the rate of soil development is extremely variable, theoretically, the rate of soil formation sets the upper limit to the acceptable rate of soil loss by erosion: this may be unattainably low for a soil under agriculture so that the soil profile becomes thinner with time".

More recently, the development of the international voluntary sector has led to many protective measures and Copenhagen proposals. Among these, the VCS (Voluntary Carbon standards) have proposed various methodologies related to Agriculture Forestry and Other Land Uses (AFOLU) in order to account for carbon storage improvements that would result in the partial or total protection of soil as a carbon source (VCS, 2008). The most widely debated of these proposals is the framework for Reducing Emissions from Degradation and Deforestation (REDD), where soil carbon accounting is an important issue (Saunders, 2008). These developments support the creation of a soil carbon strategy for the agricultural sector.

Indeed, on a global scale, it is suggested that as the world population continues to grow, ever greater areas of grasslands and forests are converted to croplands, and soils that are currently carbon sinks will turn into net emitters. The most effective strategy to prevent global soil carbon loss would be to halt these land conversions – but this may conflict with growing domestic demand for food in the Maldives, a problem that is made worse by overdependence on food imports.

4.2.2 Agricultural Supports

In relation to recommendations within this Framework Guidance for agricultural supports the following should be considered:

- Crop mixes to include more plants that are perennial or have deep-root systems in order to increase the amount of carbon stored in the soil;
- Companion planting to increase biomass as a shade crop in agricultural practices;
- Cultivation systems that leave residues and reduce tillage, especially deep tillage, in order to encourage the build-up of soil carbon;
- Shifting land use from annual crops to perennial crops, pasture, and agroforestry in order to increase both above- and belowground carbon stocks;
- Activities that restore degraded and desertified soils and ecosystems, especially those affected by accelerated erosion, salinization, and nutrient depletion.

In this regard, carbon offset payments could be allowed for carbon sequestered in soils where low-cost monitoring is available. On this point, funds for the development of these monitoring systems should be part of any outcome.

Paying resource-poor farmers and smallholders for soil carbon sequestration would contribute to GHG mitigation, provide much needed resources to support development and adaption of improved crop technologies and reduce rural sectoral poverty.

4.2.3. Technology

In relation to agriculture technology applications concerning soil carbon, biochar (a well-established technology) is a promising way forward.

4.2.3.1 Biochar

Biochar is a practice that converts agricultural waste into a soil enhancer that can hold carbon, boost food security and discourage deforestation. The process creates a fine-grained, highly porous charcoal that helps soils retain nutrients and water.

Biochar can be an important tool to increase food security and cropland diversity in areas with severely depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies.

Biochar also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and causing pollution.

The Maldives does import a significant quantity of dung from India for use as fertiliser, the cost of this could be displaced by creating biochar locally.

Pre industrial agricultural land in Mid-West America contained 30-40 tonnes of carbon per hectare, after many years of intensive agriculture it now holds between 5 and 7 tonnes per hectare.

Benefits include:

- Reduced leaching of nitrogen into ground water
- Possible reduced emissions of nitrous oxide
- Increased cation-exchange capacity resulting in improved soil fertility
- Moderating of soil acidity
- Increased water retention
- Increased number of beneficial soil microbes

4.2.4. Building the resilience of soils to a changing environment

Building the resilience of soils to a changing environment would involve, *inter alia*, the following:

- Achieving the ability to better understand the impact of climate change on the Maldives' soils and identify what must be done to enable them to adapt;
- Develop the evidence base in the Maldives on the impact of climate change on soils;
- Ensuring that farmers have the information and guidance necessary to be able to secure the resilience of their soils in the face of a changing climate;
- Periodically reviewing soil protection measures and guidance to update them based on new evidence on climate change adaptation; and,
- Review other Republic of Maldives' guidance (perhaps by way of an amended Building Code for the Maldives) on how soils should be managed during construction activities including consideration of whether additional guidance is needed to take account of climate change impacts

Once understanding of the impacts of climate change on soils develops, it will be possible to work with the agriculture and land use planning sectors to understand how soil management practices may need to change to adapt to climate change and to make soils more resilient to change. It will thus be possible to advise and encourage farmers in the Maldives to change their practices and ensure that soil protection guidance is developed to reflect new knowledge.

4.2.5. Good peat management

Hammond (1971) surveyed the peat deposits of the Maldives. Alkaline peats with a pH of over 7.8 were reported by Koohafkan et al. (1998) Rapid peat growth (2-7 mm y -1) has been reported from the mangrove forests. Moreover, Hammond, R.F. (1971) surveyed peat deposits on Makandudu, Milandu and Forkaidu Islands in Milandummandulu.[4]

[4] North Atoll. Report to the Government of the Maldives. United Nations Development Programme (FAO TA 3013, VI +27p.)

In this context, it is important that opportunities for peat protection and restoration are explored which do not lead to carbon benefits being negated by disproportionate increases in greenhouse gases emissions.

4.2.6. Using regulation and incentives

Regulatory measures and incentives are required to protect soil carbon in the Maldives. There is a need for measures already in place in the Maldives to be considered and in order to ensure that they work effectively to protect soil carbon. Moreover, as shall be seen below, there is need to consider what further measures are required to meet carbon soil sequestration objectives, including in relation to peat protection.

Although the scientific evidence of overall trends in soil carbon is far from overwhelming, it necessary, in light of the preventive and precautionary principles, to ensure that the existing carbon store is protected. This means that all future policy development on soils in the Maldives should be guided by the need to protect existing carbon stores. This would require a Strategy to establish a new high level goal of significantly reducing the rate of loss of soil carbon by 2020.

Significantly reducing the rate of loss of stored soil carbon will require that stakeholders understand how to reduce emissions and mitigate climate change through improved management practices that should be produced through Government guidance linked in part to stewardship for environmental sustainability.

4.2.7 Increasing the Evidence Base

In order to develop the evidence base on the impact of climate change on soils, further research should be undertaken into the impact of climate change on soil, soil functions and soil threats including the impact of climate change on peat soils and habitats in the Maldives. This would ensure that farmers and other land managers have the information and guidance necessary to be able to ensure the resilience of their soils in the face of a changing climate

In an international context, there have been very few climate change impact studies directly focused on soils or soil functions. Where soils had been considered the focus had been on only a few soil parameters, such as carbon, and was mostly limited to the use of soils for growing crops.

In the Maldives there is a need for research to explore how soil threats such as erosion compaction and organic matter decline, are likely to be affected by climate change. This research should use soil threat models which are integrated with conventional climate change impacts models as they apply to the Maldives.

It may also be necessary to conduct a study on carbon soil sequestration to be carried out in the Maldives itself, as it is likely that different types of agricultural adaptation may be appropriate at different locations and dependent on different scenarios

The soil research referred to above should seek to improve our understanding in the Maldives of the potential to increase levels of soil carbon and protecting existing carbon stores, focusing in particular on:

This should also include monitoring. There is therefore an urgent need to improve monitoring of soil carbon stock and trends to ensure that soils play a more prominent role in a future climate change mitigation agreement.

- Trends in soil carbon;
- Management practices to protect and enhance carbon storage in soils;
- Greenhouse gas fluxes, especially methane fluxes, from a range of peat soils pre- and post-restoration; and,
- The value of the broad range of ecosystem services provided by peat soils

5. Overcoming the Barriers to Carbon Soil Sequestration

It is wise to address possible barriers to implementation of these recommendations particularly for farmers and other land use managers.

Despite significant economic potential for GHG mitigation through agricultural carbon sequestration, there are many barriers that could prevent the implementation of these measures. However, in relation to the need to sequester carbon in soils, the technique is cost competitive and immediately available, requires no new or unproven technologies, and has a mitigation potential comparable to that of any other sector of the economy.

In relation to two other barriers that farmers in particular typically face (i.e., economic and risk-related barriers) the following is worth considering.

5.1 Economic barriers

Economic barriers include the cost of land, competition for land, continued poverty, the lack of existing capacity, the low price of carbon, population growth, transaction costs and monitoring costs. A significant barrier to implementation of mitigation measures in poorer parts of the world is economics. Given the challenges that farmers already face, climate change mitigation may be a low priority. Capacity building and education in the use of innovative technologies and best management practices would also serve to reduce barriers.

Maximizing the productivity of existing agricultural land and applying best management practices would help to reduce greenhouse gas emissions. Ideally agricultural mitigation measures need to be considered within a broader framework of sustainability.

It is suggested that competition with other land uses is a barrier that necessitates a comprehensive consideration of mitigation potential for the land-use sector. It is important that agricultural land management options are considered within the same framework to optimise mitigation solutions. Costs of verification and monitoring could be reduced by clear guidelines on how to measure, report and verify GHG emissions from agriculture.

The economic barriers to implementing soil-related carbon strategy could also be overcome by ensuring and rewarding land use planning, the use of adequate rewards and incentives for soil carbon, and related soil quality promotion in relation to agricultural sector-affecting land uses. In this regard, Programmatic Clean Development Mechanism projects for soil carbon should be prioritised.

5.2. Risk-related barriers

Risk-related barriers include the delay on returns due to slow system responses, issues of permanence (particularly of carbon sinks) and issues concerning leakage and natural variation in carbon sink strength.

For a number of land use practices - especially those involving carbon sequestration - risk-related barriers such as delay on the small returns available and potential for leakage and sink reversal, can be significant barriers.

Education, emphasising the long term nature of the sink, could help to overcome this barrier, but fiscal policies (guaranteed markets, risk insurance) might also be required.

There is often a societal preference for traditional farming practices and, where mitigation measures alter traditional practice radically (not all practices do), education and extension would help to reduce some of the barriers to implementation.

List of References

Bertaud (2002) "The Issue of Urban Land in the Maldives"

ClimSoil Report "Review of Existing Information on the Interrelations between Soil and Climate Change (2008)

European Commission Press Release "Climate Change and Soil Importance" (2009)

European Commission Proposal for a Soil Framework Directive (COM (2006) 232)

Intergovernmental Panel on Climate Change Guidelines for Carbon Accounting (2007)

Lutterkort (2009) "Impacts of Climate change in Europe 2000-2020"

Report to the Government of the Maldives by the United Nations Development Programme (2009)

United Kingdom Department for Environment, Food and Rural Affairs "Safeguarding our Soils – A Strategy for England" (2009)

United Kingdom Stern Review (2006)

United Nations Economic and Social Commission for Asia and the Pacific Maldives Report (1997)

World Bank Report "Sustaining Growth and Improving the Investment Climate in the Maldives" (2007)

World Resources Institute Maldives Biodiversity Statistics (2003)