Feasibility Study preparation - Climate resilient agricultural soils in the sub-catchments

Introduction: The attached concept note (Annex 1) proposes an integrated approach to developing climate resilient agricultural soils as an add-on to the EIPs. The intervention is firmly rooted in the Programmes of Action, first described by the Rwandan Government in 2011 and then used in 2015 as basis for Rwanda's Intended National Determined Contributions (INDC) presented during the UN Conference of the Parties 21 in Paris.

Action: The objective is to achieve the following:

1. Implementing agro-ecology techniques (living mulch, zero tillage (potentially using seed balls), soil stabilizing plants (e.g. Vetiver), and increased use of organic fertiliser);
2. Introducing the 'Push-Pull' strategy (with Napier grass (push) and Desmodium (pull));
3. Promote crop selection that improves water productivity;
4. Train farmers to ensure the integrated approach is implemented correctly.

Exercise: Develop a Terms of Reference and costed plan for the undertaking of a Feasibility Study (FS) that will generate data and justification for the adoption of a combined set of agricultural techniques based on Rwanda's Green Growth Programmes of Action. This set of techniques are expected to promote the development of climate resilient agricultural soils in Rwanda's sub-catchments.

Objective: Design and undertake a feasibility study that can efficiently assess the effectiveness of the selected techniques in building climate resilient agricultural soils. Key indicators of effectiveness in this assessment are crop productivity and soil erosion rates.

Next steps:

1. Examine work undertaken in EIPs in Nyabarongo and Sebeya to identify appropriate site(s) for a 'pilot'/test area(s) (incl. vegetation and topographical mix in a progressive terracing environment) and appropriate candidate farmers (incl. test site and neighbouring traditional practice sites for measurement purposes);

2. Identify an agronomist/agri-business extension service officer/academic with an interest in the subject (and data for research purposes);

3. Develop an M&E plan to measure the key indicators of a) soil erosion, b) crop productivity and c) pest control vis-à-vis neighbouring traditional practices;

4. Agree a project budget (incl. a reward/remuneration structure) for participation in the FS (mindful of input costs and potential output cropping losses incurred through participation in the FS);

5. Produce the TOR for the work to be undertaken;

6. Agreement on a procurement plan for the work.

Annex 1 – Concept note Climate Resilient Agricultural Soils

Introduction

Rwanda is a landlocked country with relatively high rainfall and an extensive reliance on rain-fed agriculture, representing 34% of Rwanda's GDP (2014) and employing 90% of its inhabitants (both directly and indirectly).[1] This reliance on agriculture makes the country highly vulnerable to climate change, as increasing temperatures and changes to rainfall patterns have the potential to cause significant economic damage to crop yields and infrastructure.

Four seasons characterize the country: a short-wet season (September-November), a short dry season (December-February), a long-wet season (March-May), and a long dry season (June-August). With a relatively high average rainfall, Rwanda is perceived as a water rich country, reducing the sense of priority regarding climate-resilient water resources management. The UN classified Rwanda as 'water stressed country', based on the division of total water resources through population size, resulting in total cubic meter of water per capita. Currently water utilization in Rwanda is low, hence water stress not apparent. However, water utilization is a foundation of Rwanda's development, which will eventually lead to the water stress predicted by the UN. In addition, precipitation is not homogeneously distributed over the country. Rainfall trends show and predict increasingly shorter and more intense rainy seasons[2], especially in the northern and western provinces, which are resulting in increased erosion risks in the mountainous areas of the country. Mainly the Eastern provinces have encountered both severe rainfall deficits leading to droughts, and excess rain causing floods. Although this increasing seasonal variability directly and indirectly affects most Rwandan sectors, it has pronounced impacts on the agricultural sector; increased uncertainty on the starting and ending of the rainy seasons impacts harvests, high intensity rains increase soil erosion, and droughts make rainfed agriculture increasingly challenging.

DPSIR Framework

This climate change adaptation concept note focuses on the improvement of degraded agricultural soils through several aggregated interventions proposed by the national Programmes of Action (PoAs)[3]. A DPSIR Framework was utilized to systematically describe the issues and proposed responses to increasing the climate resilience of agricultural soils. The DPSIR Framework is presented in Figure 1.

Driving forces

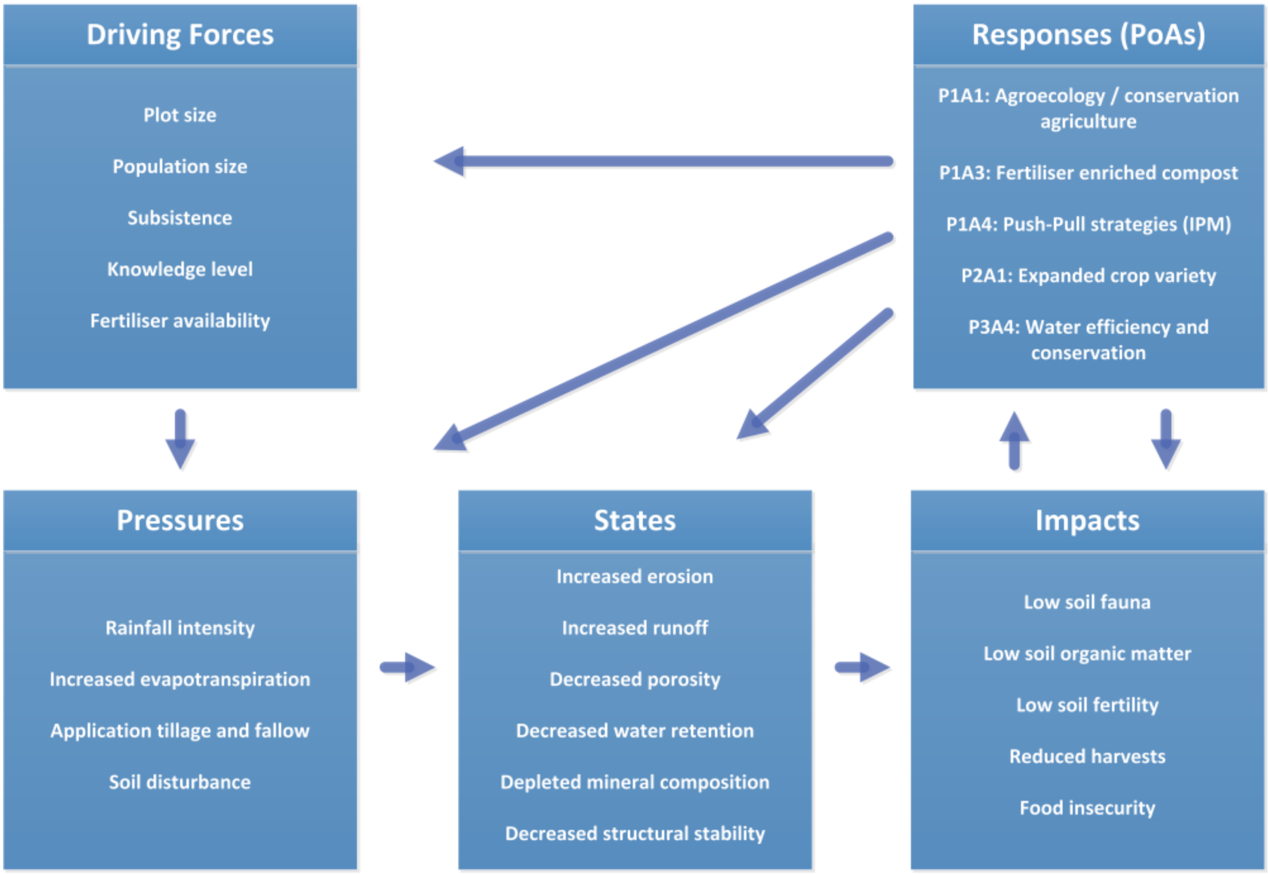
Rwanda has one of the highest population densities in Africa, with over 460 inhabitants per square kilometre[4]. The combination of a large (and growing) population on a relatively small land mass, results into very small agricultural plot sizes of on average 0.59 ha (and as low as 0.2 ha for almost 25% of the farmers), that rely extensively on rain-fed agriculture. National strategies aim to increase this average plot size to 1 ha, allowing for both more intensive and extensive agriculture.[5] Although the government has made progress in reducing the number of poor households, almost 80% of the rural population consists of subsistence driven farm families.[6] As their focus lies on survival, poverty reduction among these families is difficult, as only fractions of the produce are available to be sold on the national markets. In September

[1] Netherlands Commission for Environmental Assessment, Climate Change Profile Rwanda, 2015, pp2-5
[2] REMA, 2009
[3] Government of Rwanda, Green Growth, and Climate Resilience: National Strategy for Climate Change and Low Carbon Development, 2011
[4] World Bank database on population density: http://data.worldbank.org/indicator/EN.POP.DNST
[5] USAID, Agricultural land use consolidation and alternative joint farming models facilitation, 2007
[6] Ministry of Agriculture and Animal Resources, Strategic plan for the transformation of agriculture in Rwanda – Phase III, 2014

2007, the Rwandan government in turn started promoting the participation in the land consolidation schemes of the Crop Intensification Programme (CIP), to move away from this type of subsistence agriculture.

Due to subsistence, focused farming, limited local knowledge on sustainable agriculture (e.g. agroecology), and limited access to (organic) fertilisers, the Rwandan soil quality is often in advanced stages of degradation. This degradation results in significantly reduced land productivity, increasing the driving force for farmer families to further utilize the land to meet their own nutritional needs.

Figure 1: DPSIR Framework on agricultural soil health



Pressures

The global impacts of climate change have increasingly pronounced effects on Rwanda's agricultural soils. The recording of rainfall data in Rwanda started in the 1970s, with data points showing a progressive tendency towards shorter rainy seasons[7]. Although data collection on annual precipitation in Rwanda is fragmented, climate projections point towards a gradual increase in rainfall[8]. With higher precipitation levels, deposited in shorter rainy seasons, the intensity of rainfall is increasing. These heavy rains coupled with a loss of ecosystems services resulting from deforestation and poor agricultural practices have resulted in soil erosion, rock falls, landslides and floods which destroy crops, houses, and other infrastructure (roads, bridges, and schools) as well as loss of human and animal lives[9]. In addition, the average temperature in Rwanda is slowly rising. Higher temperatures lead to more evapotranspiration,

[7] Ministry of Lands, Environment, Forestry, Water and Mines, NAPA-Rwanda, 2006
[8] Rwandan Government, Rwanda's climate: observations and projects, Appendix E, 2011
[9] REMA, Rwanda State of Environment, and Outlook Report: http://www.rema.gov.rw/soe/chap9.php

causing the top soil to dry faster outside of the rainy seasons. With dryer and dustier soils, the influence of wind erosion escalates. Next to the influences of climate change, poor agricultural practices degrade the soils. Exploitation without fallow and/or agricultural rotation contributes to the depletion of nutrimental element stocks in the soils, due to lack of regeneration. Tillage and general soil disturbance in turn negatively influences the soils fauna and structure, further detailed on the paragraph on states and impacts.

States and impacts

High intensity rains on bare soils quickly overpower their inherent ability of water absorption, leading to sediment rich runoff, eroding the soils. Heavily eroded soils have no- or a thin layer of fertile top soil, leaving an increasingly smoother, rocky surface. This surface is progressively susceptible to increased runoff, posing challenges when attempting to restore the fertile top soil layers.

The commonly applied agricultural practice of tillage; in combination with general soil disturbances tend to significantly decrease populations of fungi, bacteria, nematodes, micro-arthropods, and macro-arthropods present in the top soil layers. In addition, plant pathogens are found to be more common in disturbed soils[10]. Conventional tillage stimulates the heterotrophic microbiological activity through soil aeration, resulting in increased mineralization rate, however through the resulting breakdown of soil structure, the upward and downward movements of soil fauna, such as earthworms; which are largely responsible for “humus” production through the ingestion of fresh residues[11], is decreased. This reduction in humus production in combination with reduced soil fauna movements and activity, results in a decrease of soil porosity. Reduced or zero tillage on the other hand regulates heterotrophic microbiological activity because the pore atmosphere is richer in CO^2/O^2, and facilitates the activity of the ‘humifiers’.

Consequently, the circumstances for rainfed agriculture become increasingly challenging, as rainfall must be able to penetrate the soil and be held there for the crops to use in the weeks after. Soil that is rich in organic matter is better able to perform this function[12]. Decreasing soil porosity, leading to low water retention, hampers crop growth as minerals are not readily available for uptake. The lack of fallow in turn escalates this problem, as these soils tend to be already depleted of nutritional elements due to insufficient regeneration time.

The intensity and frequency of climate hazards and its harmful effects, are emphasized by the topographical structure proper to Rwandan territory, a country particularly characterized by a very accidental relief and consequently very sensitive to erosion and landslides. Both progressive and radical terraces are widely applied in Rwanda, as terraced fields decrease both erosion and surface runoff, and may be used to support growing crops that require irrigation, such as rice. Soil stability is an important factor for any type of terracing, as landslides can completely remove the fertile top soil layer. Agroforestry and the planting of specific grass species assist in stabilizing recently terraced land.

Responses (Programmes of Action)

The combination of these drivers, pressures, states and impacts significantly contribute to reduced land productivity, food insecurity, and to keeping nearly 80% of Rwandan agriculture subsistence oriented. However, through the selection of the appropriate responses, climate resilience can be increased,

[10] Soil Ecology and Restoration Group, The effects of disturbance on soil characteristics relevant for revegetation: http://www.sci.sdsu.edu/SERG/techniques/disturbance.html
[11] FAO, The importance of soil organic matter: Key to drought-resistant soil and sustained food production, 2005
[12] AFSA, From slash and burn to ‘slash and mulch’, 2015

agricultural practices can be changed or improved, and more farmer families will be able to break away from poverty.

In December 2015 during the UN Conference of Parties 21 in Paris, a new legally binding climate change agreement was reached; the Paris Agreement. This agreement will come into force once the Kyoto Protocol expires in 2020, with 5-year commitment periods. The agreement will help the global abandonment of fossil fuels by the end of this century, and specifically aims to stop global warming "well below" 2 degrees Celsius, even attempting if possible to stay below 1.5 degrees Celsius.[13]

Countries agreed, before the start of COP21, to publicly outline their post-2020 climate actions in the so called 'Intended Nationally Determined Contributions' (INDCs). These INDCs significantly assisted with the establishment of the new international agreement, as from the start much more clarity was achieved on the stance and commitment of each country towards climate change. Rwanda chose to present the Programmes of Action' (PoAs) in their INDC; 14 sectoral programmes with actions and key indicators detailing where the Government of Rwanda sees the strongest opportunities for climate change development. The PoAs were first presented in the report 'Green Growth and Climate Resilience; National Strategy for Climate Change and Low Carbon Development' (NSCCLCD), published in 2011.

Five action points, originating from three Programmes of Action were selected in response to the issue of degraded agricultural soils in Rwanda. An overview of these action points is provided in Table 1, including their key indicators, expected contribution from the IWRMP, and specific intervention objective. The action points provide responses in agricultural techniques, top soil restoration, reducing soil degradation, organic fertiliser utilization, improved soil quality, crop diversification, and water use efficiency.

Building climate resilient agricultural soils

In response to the DPSIR as discussed above and utilizing the Programmes of Action as proposed by the Rwandan Government, an integrated approach to building climate resilient agricultural soils is described in Table 1 (starting on the next page). The interventions proposed here can be applied to the land husbandry interventions from the EIPs, considering the use of agroforestry to stabilize ditches and trenches. The intervention is visualized in Figure 2 (following Table 1).

Besides the importance of selecting a location where the different types of terracing interventions are near, it is important to include both male-headed and female-headed farms in the proposed interventions. Often, female headed farms, as compared to male headed farms, have less secured access to resources (land, inputs, and credit) and are less represented in famer organisations. Inclusion of both categories will provide insight into their respective agricultural practices and constraints in climate change resilience behaviour.

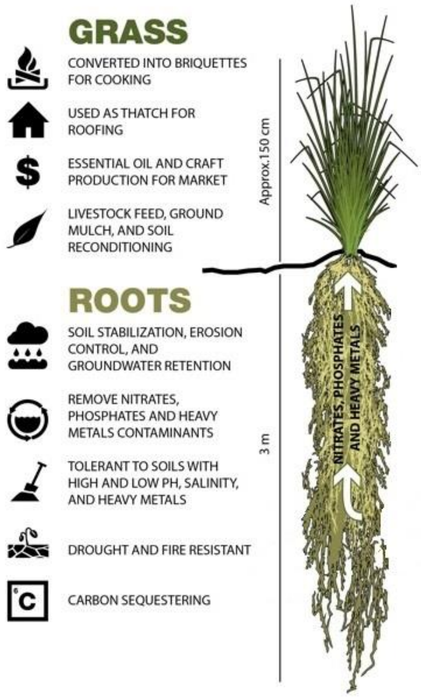
[13] Paris Agreement: http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm

Table 1: Climate resilient agricultural soils Programme of Action key indicators

Action	Key Indicator
Programme of Action 1: Sustainable intensification of agriculture Responsible stakeholders: **MINAGRI**, MININFRA, Municipal Authorities, ISAR, Private Sector, NGOs, REMA	
Action 1: Mainstreaming of agroecology, with a focus on improving the resilience of Rwanda's soils to climate change	% of farms up-taking climate changed mainstreamed agroecology technologies
Specific objective: Improve the top soil layers through the application of agroecology techniques	
Action 3: Fertiliser enriched compost	% of farms applying fertiliser rich compost
Specific objective: Improve soil fertility through the increased application of organic fertilisers (compost and manure)	

Once the Early Investment Projects (EIPs) are finished with the development of the terracing interventions, and the ground is sufficiently stabilized through agroforestry, the state of the top soil layers is not yet sufficiently developed to start productive agriculture. By using organic fertilisers (compost and manure, to be locally sourced) on the soil, any depleted minerals are restocked; followed by planting fast growing legumes covering the whole plot, as living mulch. Living mulch plants are used for several reasons:

1. the soils are quickly covered by living mulch, providing protection against high intensity rains, reducing the amount of sediment rich runoff, and wind erosion;
2. the root systems open the soil, stimulating the development of soil fauna in combination with the earlier applied organic fertilizers;
3. the living mulch reduces the evaporation from soil surfaces by 25-50%;
4. promotes soil microorganism activity, which in turn improves soil tilth and helps lessen soil compaction, improving water retention;
5. slows weed growth;
6. improves harvest yields; and
7. it acts as an insulating layer, keeping the soils and crop roots cooler[14].



The living mulch is used together with the crops to retain its benefit, which in turn does not allow for tillage farming of the land. Instead zero tillage farming is introduced; an agricultural technique which increases the amount of water that infiltrates into the soil, increases organic matter retention, improves cycling of nutrients in the soil, and significantly reduces soil erosion. This way of farming either requires special no-tillage equipment (e.g. manual seed drills) which must be supplied to the farmers, or a technique of creating 'seed balls' can be utilized.[15]

As this intervention will be applied to recently developed terraces, further ground stabilization planting, in addition to the agroforestry approach, will be beneficial in developing sufficient resilience to soil erosion. Vetiver (*V. Zizanioides*) is a globally utilized species of grass that counters soil erosion. Vetiver grass has a massive, finely structured root system with a high power of soil penetration. The innate strength of the roots enables it to penetrate through difficult soils, hardpan, or rocky layers with weak spots. The roots grow straight down into a mass as dense as the amount of leave it produces above ground. The roots penetrate 3 to 4 meters in to the substrate before slowly thinning out, which gives them the nickname of 'soil nails'. The grass is however not shade tolerant, which must be considered in relation to where the trees will be planted.

In addition to providing strength to the terraces, when lines of Vetiver are planted in an angle of several degrees (e.g. 10 °), these allow control over the runoff direction towards drainage gutters. This is especially beneficial against the highest intensity rainfalls, during which flooding might occur. The infographic above provides additional information on Vetiver characteristics. See Figure 2 for a visualization of the Vetiver approach.

Action	Key Indicator
Action 4: Mainstreaming of 'Push-Pull' Strategies (IPM)	% of farms up-taking 'Push-Pull' strategies
Specific objective: Improve soil health through the application of the 'Push-Pull' technique	

The "Push-Pull" strategy is a sustainable pest management technique that introduces certain species of plants to the cropping systems, to control plant parasites and pathogens such as stem borers and Striga weed. For Rwanda, the plant species for this technique are Napier grass (push) and Desmodium (pull) to manage pests in e.g. fields of maize, sorghum, millets, and raid-fed rice. The technique works by planting the desired crop alongside a 'push' plant (Napier) that repels pests, and planting a 'pull' crop (Desmodium) around

[14] Stanford, 'Benefits of mulch': http://bgm.stanford.edu/sites/all/lbre-shared/files/docs_public/CCWD_DroughtSurvivalGuide_Mulch.pdf
[15] Making seed balls, http://permaculturenews.org/2014/06/18/making-seedballs-ancient-method-till-agriculture/

Action	Key Indicator
the perimeter to draw insects out of the plot. The Napier grass and Desmodium can additionally provide a continuous supply of cattle fodder. Both Napier grass and Desmodium have low water and nutrient requirements, making its implementation accessible even on uncultivated lands. See Figure 2 for a visualization of how the 'Push-Pull' strategy is to be implemented on the terraces.	
Programme 2: Agricultural diversity in local and export markets Responsible stakeholders: **MINAGRI,** MININFRA, Municipal authorities, ISAR, Private sector, NGOs, REMA	
Action 1: Expansion of crop varieties, considering water consumption of each crop, benefiting water productivity	% of farms adopting crops that improve water use efficiency
Specific objective: Introduce site specific crop water use efficiency, considering the concept of water productivity	
Programme 3: Integrated Water Resources Management Responsible stakeholders: **RNRA,** MINIRENA, MININFRA, WASAC, REMA, MINALOC, MOH	
Action 4: Water security through efficiency and conservation, considering the concept of water productivity	% water use efficiency achieved
Specific objective: Introduce water conservation techniques to improve water use efficiency	
Rwanda can become more self-sufficient to meet its own market demand for consumption products that are currently imported from regional and international markets. Examples of crops that can be introduced in the north-central regions of Rwanda are: Vanilla seeds, apricot saplings, and macadamia plants. Other potential products include under-utilised crops such as the high-yielding fodder crop Russian comfrey, and indigenous African vegetables, which are in high demand and are particularly suited to small-scale farms, as they require low external inputs and are resistant to local pest and climatic conditions. To optimize the earnings of farmers, the concept of water productivity is recommended to be applied. Through an assessment of water requirements per crop in comparison to crop value, the most profitable crop per litre of water will be identified. This assessment must consider the local situation for post-harvest processing. Water efficiency is boosted through the applied agroecology techniques, and 'Push-Pull' strategy that will improve the water retention potential of the soils, which is essential for rainfed agriculture.	

Figure 2: Integrated climate resilient agricultural soils intervention visualized