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Prioritizing rainwater management strategies in the Blue Nile basin

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Abstract: Most farmers in the Blue Nile Basin depend on unreliable rainfed agriculture and are vulnerable to climate variability. Lack of appropriate rain water management in these areas prevents smallholders from addressing the consequences of flooding during the rainy season and droughts during the dry season. This is in turn a major contributory factor to food insecurity and poverty. Addressing these issues entails designing, targeting and prioritizing rain water management strategies. In support of this, we developed a generic methodology for out-scaling and prioritizing interventions in agricultural systems. The methodology entails a multi-stage and iterative process of (1) diagnosis and selection of options, (2) characterization of the options, (3) identification of the recommendation domains and out-scaling potential of these options, (4) assessing the impacts along different dimensions and on different groups of people. This paper describes how we applied this methodology in the Blue Nile Basin. We consulted several national stakeholders and identified the 'best-bet' options as they are currently being promoted by the SLM program. A next step entailed the description and characterization of the options. Previous knowledge about bio-physical and socio-economic conditions influencing suitability was collated, while field studies were undertaken to increase our understanding of adoption of these options. Matching this characterization data with a spatial database allowed us to map the suitability and feasibility of rainwater management options and strategies. For the last stage, the impact assessment, we identified the most-likely-to-be-adopted strategy for each of the watersheds based on the feasibility maps. We translated this into maps compatible with the SWAT model. Results from the impact assessment should eventually feed back into the assessment of alternative options. The framework is applicable in many different forms and settings. The steps can be gone through qualitatively in a multi-stakeholder setting while the process can also be done quantitatively. It has a wide applicability beyond the Blue Nile Basin.

Media grab: When designing rainwater management strategies, it is important to combine multiple practices across the landscape and look at their potential impacts beyond the local level.

Introduction

Most farmers in the Blue Nile Basin depend on unreliable rainfed agriculture. Lack of appropriate rain water management in these areas prevents smallholders from addressing the consequences of flooding during the rainy season and droughts during the dry season (Johnston and McCartney 2010). As a result, farmers and livestock keepers in the Blue Nile basin face a wide variety of challenges. Amongst others, they have to deal with widespread food insecurity, high poverty levels, land degradation and declining soil fertility, low and variable yields (de Fraiture et al. 2010). Some of these challenges are limited in their geographical spread while others are common to many smallholders in the region.

A wide variety of rainwater management practices (RWPs), ranging from soil and water conservation structures and biological measures over forestry and agroforestry to area enclosures, have been developed and promoted by the Ethiopian Government and NGOs (Merrey and Gebreselassie 2011). Many of these RMPs have been promoted with relatively low success. Too often, practices did not suit the socio-economic and institutional context of the communities resulting in high dis-adoption rates (Merrey and Gebreselassie 2011). In addition, implementing single rainwater management practices might not lead to the expected overall benefits. Indeed, some practices might have positive or negative impacts on downstream farmers. In order to takes these synergies or trade-offs into account, rainwater management should be optimized at landscape scale. They need to be matched to the local context and combined across the landscape so that together they reach the overall objective of sustainable landscape productivity while also addressing water depletion, land degradation and profitability.

Addressing the multitude of challenges thus entails designing, targeting and prioritizing location-specific rainwater management strategies (RMSs). A strategy is therein defined as a combination of different practices across the landscape. This paper describes a generic methodology supporting this process, with an example application in the Blue Nile basin.

Methods

Deciding which rainwater management practice to implement where entails a multi-stage and iterative process including the following four steps.

A first step involves the diagnosis and selection of options. Depending on the local environment, land use and current problems encountered in the landscape, different RWPs are needed. We consulted several national stakeholders and identified the 'best-bet' RWPs that are currently being promoted by the SLM program. In different landscape zones, different objectives need to be met and therefore different RMPs are required. In the uplands, the objective is mainly to increase water infiltration, while in the midlands erosion control and soil moisture maintenance is more important. In the lowlands, the focus is often on more efficient use of surface water. Regardless of the landscape zone, fodder quantity and quality need to be improved on grassland, whereas on heavily degraded land, rehabilitation is the major objective. By maximizing the potential synergies and minimizing negative trade-offs between these individual RMPs the aim is then to optimize the multiple objectives at the landscape scale. Each landscape has different characteristics and therefore the water productivity or water availability maximization might call for different combinations of RMPs. We therefore combined or 'mixed and matched' different practices and came up with a variety of potential strategies at the landscape scale.

A next step entailed the description and characterization of the options. A comprehensive database describing the selected practices in terms of their purpose and the bio-physical, socio-economic and institutional conditions that influence their suitability, adoption and success was compiled. Previous knowledge about bio-physical and socio-economic conditions influencing suitability was collated. This was mainly based on the 'Community Based Participatory Watershed Development' (CBPWD) guidelines from the Ministry of Agriculture and Rural Development produced in 2005, but complemented with livestock-based interventions. In addition, adoption studies, which responded to the knowledge gap around socio-economic factors influencing applicability of RMPs were carried out. The adoption model used was of the following form: $P(Y = 1) = \Phi(X'\beta)P(Y = 1) = \Phi(X'\beta)$ where Y is the binary variable that captures the adoption of a given RMP, Φ is the cumulative normal distribution, X the vector of explanatory variable and β the regression coefficient. The estimation of the econometric model results into an estimated coefficient $\hat{\beta}\hat{\beta}$ that can be used to predict the model:

$$\hat{y} = \Phi(X'\hat{\beta})\hat{y} = \Phi(X'\hat{\beta}).$$

A third step entails the delineation of recommendation domains and out-scaling potential. Based on the characterization of options, areas where the options are likely to be applicable can be identified. It is however important to note that the impact of a technology intervention is not only dependent on the suitability of the technology to the bio-physical environment, but also to the adoption pathway of this technology (Thornton et al. 2006). We therefore applied 3 consecutive sub-steps to produce feasibility maps for the selected RMSs:

a. Creation of suitability maps: we matched the conditions favouring the successful implementation of an option, identified in step 2, to a spatially referenced database. This involved transforming the previously identified characteristics for a technology into variables for which spatial data exists or can be collected. The application of GIS overlays then results in the delineation of geographical areas where this specific strategy is likely to have a positive impact.

b. The suitability maps are made on the basis of the bio-physical characteristics. This, however, doesn't give any information about where they are likely going to be adopted. We therefore used small-area estimation to come up with watershed level 'willingness to adopt' maps, i.e. maps that predict locations where the socio-economic criteria are more in favour of adoption of a given technology or practice. The small-area estimation technique is a technique that is usually applied for poverty mapping (Davis 2003; Hyman et al. 2005). It uses the output from the adoption studies and extrapolates results from the linear econometric model based on a farm household survey to broader scales by predicting the model with full coverage census data. We therefore made use of the IFPRI rural economic survey based on the census data, which constitutes of data at *woreda* (district) level. For market access, a zonal statistic was performed on the GIS layer with travel time to markets (Nelson 2008) to get an average at *woreda* level. Three promising RMPs for the Ethiopian Blue Nile have been chosen to illustrate the approach, namely, orchards, terraces and river diversions. These three RMPs are amongst the most promoted RMPs by GIZ and are also commonly chosen by stakeholders and communities in participatory processes.

c. A simple multiplication of suitability with willingness-to-adopt yields practice-specific feasibility. The resulting feasibility maps indicate the likely adoption rates of the practice in suitable areas only. A geographical information system (GIS) was then used to overlay the practice-specific suitability maps with a landscape delineation layer. This allowed us to compute the total suitable area for each practice within the landscape. For a landscape to be considered suitable for a given RMP, a certain minimum threshold of suitable area needs to be met. As such suitable landscapes can be identified for single RMPs as well as combinations of RMPs, i.e. 'strategies'. The feasibility of the strategy in a suitable landscape is defined by the lowest practice-specific willingness-to-adopt.

A last step involves assessing potential impacts of alternative strategies. It is thereby important to assess the impacts (i) for different stakeholders, (ii) at different spatial and temporal scales and (iii) in terms of different metrics, such as yield increases, economic returns, food security and income, environmental sustainability, social and cultural acceptability. In order to do so, scenarios of alternative options need to be constructed and compared in reference to a baseline. For this paper, we demonstrate this by the construction of a 'most likely to be adopted SLM practices' scenario that was fed into a SWAT modelling exercise.

Results and discussion

The database describing 83 different RMPs can be found on http://nilebdc.wikispaces.com/rainwater+management+practices. It describes each RMP in terms of their purpose and therefore indirectly links them to a specific landscape zone and an envisioned impact there. In addition, factors influencing their bio-physical suitability and likeliness to be adopted are included. Based on this information bio-physical suitability maps were constructed. A few examples are shown in Figure 1.

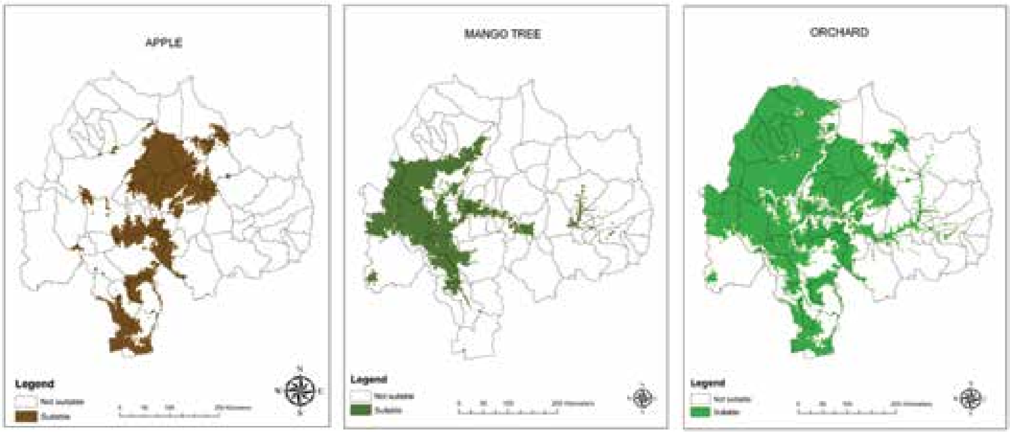

Figure 1. Suitability maps for apple trees (a), mango trees (b) and orchards (c)

The adoption studies indicated that the willingness to adopt orchards, soil and water conservation structures and irrigation from the river are influenced by very different factors. Farmers who have bigger plots size, who hire labour and have access to advise are more likely to adopt orchards. Orchards are also found further away from markets. Soil and water conservation seems to be adopted by smallholders with smaller holdings, with off-farm jobs and who hire labour. Also access to advice through the extension services increases their adoption rate. Farmers with more but smaller plots and bigger land pressure (household size / landholding) are more likely to irrigate from the river. Female headed households are less probable to irrigate from the river. As travelling time to markets increases, the adoption of irrigation from the river decreases. Figure 2 shows how these adoption factors are expressed geographically through applying the factor weights to spatially-explicit census data. An example for orchards is shown. In addition it shows the associated feasibility map, which is the result of multiplying suitability and willingness-to-adopt.

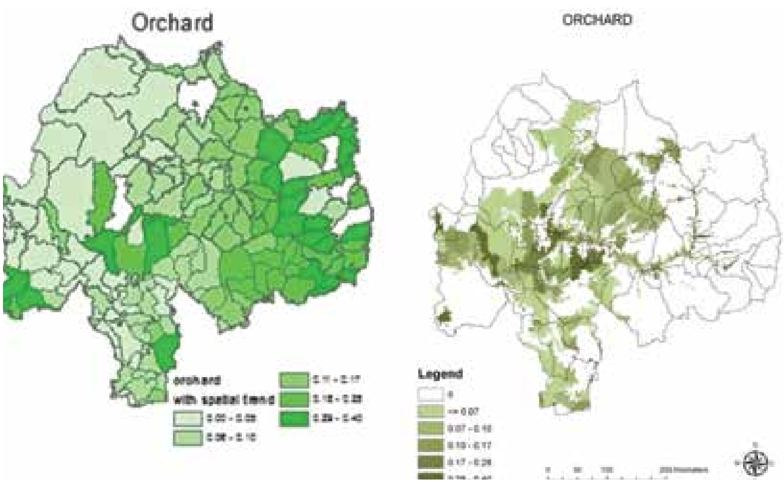

Figure 2. Willingness-to-adopt (a) and feasibility (b) maps for orchards

Based on such feasibility maps for the RMPs, the likely-to-be-adopted RMS was identified for each watershed. For more than half of the watersheds, not a single strategy, combining practices for the 3 zones, was found suitable. In the other watersheds, one of the following strategies was possible. Their location is shown in Figure 3.

1 Orchard, multipurpose tree, strip, river diversion, well, gully rehabilitation, water harvesting
2 Orchard, multipurpose tree, strip, river diversion, gully rehabilitation, water harvesting
3 Multipurpose tree, terraces, strip, river diversion, gully rehabilitation, water harvesting
4 Multipurpose tree, strip, wells, water harvesting
5 Multipurpose tree, strip, river diversion, gully rehabilitation, water harvesting
6 Multipurpose trees, orchard, terraces, strips, river diversion, gully rehabilitation, water harvesting
7 Orchards, multipurpose tree, strip, well, grazing land management, gully rehabilitation, water harvesting
8 Multipurpose tree, strip, river diversion, well, grazing land management, gully rehabilitation, water harvesting
9 Orchards, multipurpose tree, strip, river diversion, well, grazing land management, gully rehabilitation, water harvesting
10 Multipurpose tree, terraces, strip, river diversion, well, grazing land management, gully rehabilitation, water harvesting

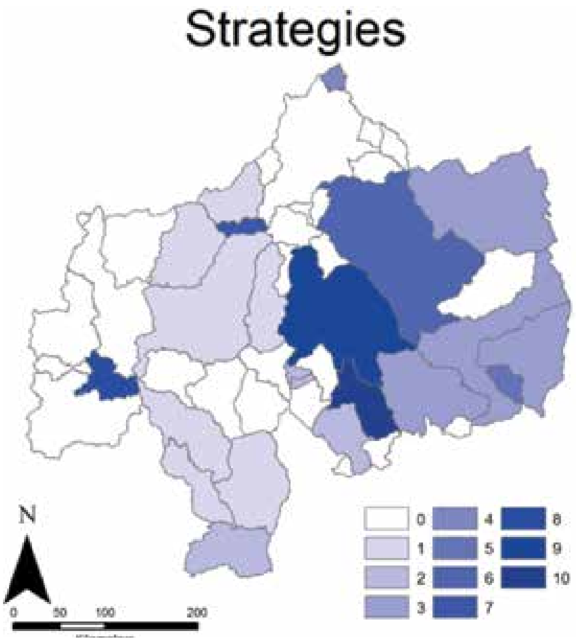

Figure 3. Map showing the likely-to-be-adopted strategies

These strategies were then fed into the SWAT model with the aim of assessing the likely impact of full implementation of SLM-promoted landscape level strategies. The assessment will go beyond the local scale and cover potential basin-wide impacts. It will look at both short- and long-term impacts. This will provide an important piece of information to take into account for further planning. In principle, different scenarios of potentially useful practices and strategies can be taken through this process. The projected impacts of different strategies at different timescales, on different stakeholders, locally, upstream, downstream and in the overall basin can then feed into discussions about the prioritization and final design of RWM interventions.

Conclusion

In this paper, we demonstrated the application of a generic four-step framework that explicitly links the prioritization of rainwater management interventions with impact assessment, targeting and out-scaling. We've shown a quantitative implementation of the framework. The same four steps can, however, also be run through with several stakeholder groups and in either qualitative or semi-quantitative fashion. Also, the framework has an application domain far beyond rainwater management. The same generic steps of (i) diagnosis and selection of alternative options, (ii) characterization of the options, (3) identification of the recommendation domains and (4) impact assessment are important in any prioritization exercise. As such the framework provides a comprehensive step-by-step guide for designing and planning rural development interventions.

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