Selection of Best Management Practices for Sustainable Control of Soil Erosion in a Reservoir Watershed: Evaluation of Water Conservation Measures based on Environmental and Economic Effectiveness

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Abstract of Thesis

Thesis Title: Selection of Best Management Practices for Sustainable Control of Soil Erosion in a Reservoir Watershed: Evaluation of Water Conservation Measures based on Environmental and Economic Effectiveness
(貯水池流域における土壌侵食の持続可能な制御のための最適管理施業の選択法：環境と経済性の効果に立脚した水保全手法の評価)

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Abstract of Thesis

Dams and reservoirs constructed in watersheds have yielded various economic benefits. To date, the Tunisian government built more than 30 reservoirs to supply water for drinking and irrigation purposes. However, many of those hydraulic structures are providing reduced benefits because of pressing environmental issues such as sedimentation and water quality degradation. The Joumine reservoir, located northern Tunisia, has experienced recently such matters. To date, the reservoir has lost about 15 % of its initial storage capacity because of sedimentation. Additionally, due to the intensive agricultural activities in its watershed area, the Joumine reservoir has recently experienced a degradation in its water quality. These issues, related to soil erosion by water, are responsible for severe restriction in water uses. These externalities have usually been limited by a strategic selection and placement of best management practices (BMPs) in the watershed area. Because of budget constraints, watershed managers are always seeking to achieve the maximum of sediment reduction with the minimum cost. Therefore, BMPs should be implemented in the critical source areas (CSAs) for sediment generation, and the environmental and economic effectiveness of various BMPs scenarios should be assessed before in-field implementation to select the most cost-effective management scenario. Contrary to the global progress on this subject, these assessments have not yet been addressed in studies of Tunisian Regions.

The current Ph.D. thesis aims at determining the most cost-effective management scenario for controlling sediment yield in the Joumine watershed. To achieve this objective, a combination of Geographic Information System (GIS), remote sensing, biophysical modeling (Soil and Water Assessment Tool SWAT model), and economic approach (Cost-Benefit Analysis CBA) has been used. GIS and remote sensing have been employed to develop a detailed land cover map for our study area based on information about the vegetation phenology. The SWAT model was used to identify CSAs for sediment and investigate the effectiveness of various BMPs scenarios in reducing sediment yield. The CBA was used to evaluate the cost-effectiveness of different BMPs scenarios.

The present doctoral thesis contains seven chapters: The first chapter presents the research objectives after stating the research problems. The second chapter provides a literature review of the watershed models developed for soil erosion prediction and the different approaches used for assessing the impacts and cost-effectiveness of BMPs. The third chapter outlines the problem of soil erosion and sedimentation in Tunisia and summarizes the efforts of the Tunisian government to deal with such issues. The fourth chapter focuses on the development of a new approach for land cover mapping. This method was used for mapping land cover in our study area, which is required for modeling the soil erosion. The fifth chapter highlights the usefulness of the SWAT model to assess the soil erosion and determine the CSAs for sediment in the Joumine watershed. The sixth chapter studies the environmental and economic effectiveness of various BMPs scenarios and identifies the most cost-effective one to be applied for sustainable control of sediment yield in reservoir watersheds in Tunisia. The seventh chapter concludes the research findings, summarizes the study limitations and gives directions for future work.

Here, we summarized the findings of the present research: In chapter four, the overall accuracy of the proposed approach for land cover mapping (86 %) was found to outperform the conventional supervised approach using multi-date images (76 %) and single date images (54 – 55 %). This approach provides reliable information on the spatial distribution of land-use and can lead to enhance the accuracy of soil erosion prediction using the SWAT model. In chapter five, the SWAT model was employed and calibrated at a single site (outlet of the Joumine watershed) because of limitation in observed data. Its performance was good for streamflow (NSE = 0.87) and satisfactory for sediment (NSE = 0.55) simulation. The model indicated that the soil erosion intensity in the Joumine watershed is mostly related to the vegetation cover and surface runoff intensity. Most of the sediment was originated from the

cultivated upland area. About 34 % of the catchment area consisted of CSAs that were affected by high to very high soil erosion risk (sediment yield > 10 t/ha/year). These areas yielded about 70 % of the total sediment load in the Joumine watershed. BMPs projects should be mainly implemented in these areas to limit the erosion intensity in the watershed area and the sediment load to the Joumine reservoir (downstream of the watershed). In chapter six, the effectiveness of BMPs in reducing sediment yield was found to be dependent on the slope angle of the target area: e.g., grass strip cropping and contour ridges practices were more effective when introduced in gentle slope areas than in steep slope areas. At the watershed level, the ordinal effectiveness of individual BMPs in reducing sediment yield was as follows: contour ridges > 20-m buffer strips > no-till farming with residue management > 15-m buffer strips > grass strip cropping > 10-m buffer strips > 5-m buffer strips > land use management > detention/sediment ponds. Combinations of BMPs were found to be more effective than individual BMPs. Combining 5-m buffer strips with other BMPs depending on the land slope (> 20 % slope: conversion to olive orchard; 10 – 20 % slope: contour ridges; 5 – 10 % slope: grass strip cropping) was the most effective BMP scenario regarding sediment yield reduction and cost-effectiveness. It reduced the sediment yield by 61.84 % with a Benefit/Cost ratio of 1.61. Adoption of this approach by local farmers has great potential to increase farm yields and income, reduce soil erosion impacts, and improve the water quality in the Joumine reservoir. Additionally, BMPs scenarios were found to be more cost-effective than dredging for sediment removal in the Joumine reservoir. Furthermore, they may extend the lifetime of the reservoir and delay the need for dredging operations.

The findings of the present research may contribute to ensuring the sustainability of future conservation programs in Tunisian watersheds. However, our results should be interpreted with caution because various assumptions were made for modeling and economic assessment.

Keywords: *Joumine Watershed, Best Management Practices, Sustainable Control of Sediment Yield, Integrated Environmental and Economic Approach, SWAT model, Cost-Benefit Analysis*