^{137}Cs and ^{210}Pb profiles in North Morrocan soils: Inventories and erosion rate estimates

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Abstract. Various studies have been conducted during the last decade onto atmospheric deposited ^{210}Pb and caesium isotopes in soils in order to quantify soil erosion rates. In North Morocco (Tangier area), erosion is a real problem leading to silting up of artificial lakes. Soil profiles were collected in cultivated areas from the catchment basin of one of this lake in order to quantify the erosion. ^{137}Cs and ^{210}Pb concentrations and inventories were measured and their spatial distribution was studied in relation with other parameters: granulometry, pH, organic matter content. Mean ^{137}Cs inventory in stable soils was found to be 2582 Bq.m^{-2} in 1999, in agreement with literature data for Spanish and Portuguese soils. Depth profiles were usual, showing an exponential decrease with depth for ^{210}Pb and a subsurface peak for ^{137}Cs in reference soils where it was found until 30 cm depth. No clear relations appeared with organic matter content or pH and the distribution of the inventories is probably linked to erosion process. Estimated erosion rates varied from 5 to 66 t.ha^{-1}y^{-1}, but the use of different models for such estimation led to important differences.

1. INTRODUCTION

Numerous studies have been conducted during the last decade onto atmospheric deposited ^{210}Pb and caesium isotopes in soils in order to quantify soil erosion rates. Inventories of these nuclides in eroded soils are compared with those from adjacent reference soils (neither eroded nor accumulated) and the difference is introduced into models to calculate mass erosion rates. In North Morocco (Tangier area), erosion is a real problem leading to silting up of artificial lakes. Soil profiles were collected in cultivated and non-cultivated areas from the catchment basin of one of this lake in order to quantify the erosion. ^{137}Cs and ^{210}Pb concentrations and inventories were measured and their spatial distribution was studied in relation with other parameters: granulometry, pH, organic matter content.

2. STUDY AREA AND METHODS

The studied area is a small basin catchment (80 km^2) 30 km South of Tangier feeding an artificial reservoir created in 1996 : the El Hachef dam (Figure 1). The basin is dominated by a series of sandstone-pelitic hills under plant cover of mattoral. Lower altitudes correspond to marly-clayey deposits and terraces mainly used for agriculture. Soils are brown soils on stone wares and vertisoils developed on the marly soft cliff. Climate is Mediterranean type sub-humid characterized by winter rains and long dry summers. Annual average precipitation is about 800 mm.

Twenty-four soil profiles were collected along four transects on cultivated and uncultivated fields. They were sliced each 2, 5 or 10 cm depth until 20 or 40 cm depth. 20 g were homogenized for a non-destructive gamma spectrometry analyses on a semi-planar germanium detector at the Cerege Laboratory, and the gamma spectra were analyzed for ^{137}Cs, ^{210}Pb and ^{226}Ra.

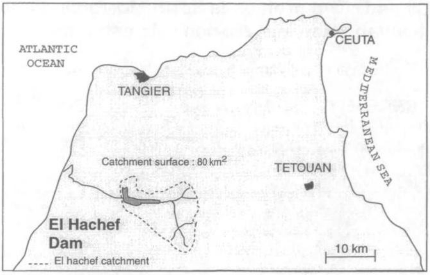

Figure 1: Location of the basin catchment.

3. REFERENCE PROFILES

Three reference profiles supposed nor eroded nor accumulated were collected in different areas and different soils. REF 1 is developed on sandstone rock (pH = 6; organic matter content = 3%, fraction > 50µm = 65%) whereas REF 2 and REF 3 are vertisoils (pH = 7.5; organic matter content = 3%, fraction > 50µm = 35 %) collected on top-hill. Only B horizons were observed in each soil.

^{137}Cs concentrations decreased with depth until 30 cm showing subsurface peaks (Figure 2).The three ^{137}Cs inventories are in good agreement with a mean of 2582 ± 70 Bq.m^{-2}. This value compares well with soils inventories in Portugal (500 to 2430 Bq.m^{-2} [1]) and is lower than the estimation for north hemisphere based on values reported by [2] : 3083 Bq.m^{-2} corrected to year 2000 and not including the Chernobyl deposit. Chernobyl fallout on Morocco was probably very low to non-existent regarding the radioactive cloud trajectory.

Total ^{210}Pb concentrations exhibited usual decay with depth (Figure 3). Excess ^{210}Pb is around 10 Bq.kg^{-1} and is reached at 10 or 15 cm, which are usual observed penetration depths. Mean excess ^{210}Pb inventory is 1174 ± 52 Bq.m^{-2}, similar to values for soils in South Portugal [1]. Calculated penetration rates of ^{137}Cs and ^{210}Pb are respectively 0.7 and 0.1-0.15 cm.y^{-1} (assuming first caesium input in 1958).

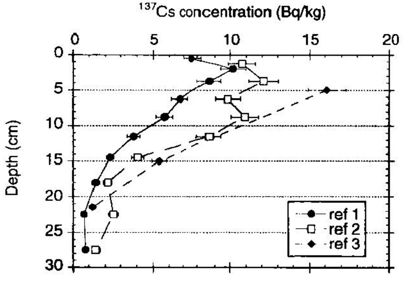

Figure 2: ^{137}Cs **concentrations vs depth in the three reference soil profiles.**

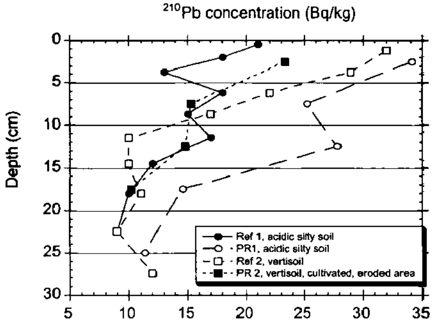

Figure 3: Total ^{210}Pb concentrations from two reference soil profiles and two other soils collected in the basin catchment.

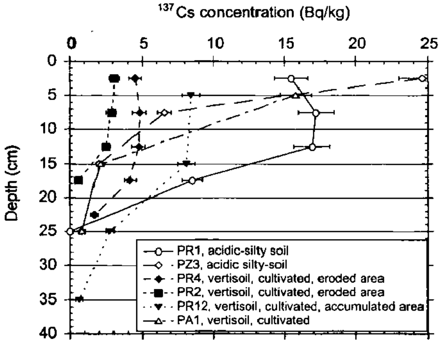

Figure 4: ^{137}Cs concentrations profiles in various soils from the basin catchment.

4. EROSION RATES

Erosion rates were estimated from ^{137}Cs inventories (derived from the soil profiles, examples are given in figure 4) using the proportional model for cultivated soil (Walling and He, 1997). Such estimation corresponds to the surface soil redistribution and do not take into account gullies sometimes well developed. 13 profiles exhibited inventories higher than reference indicating accumulation processes. They correspond to uncultivated field or were located at the base of hill-slope. For the other soils, more than 75% of the inventory is found in the first 15 cm corresponding to the plough layer. Erosion rates varied greatly from 5 to 66 t ha^{-1} y^{-1}, the most important value corresponding to a very steep slope gradient. Excepting this last value, **mean erosion rate is 24 t ha^{-1} y^{-1}**. No relations appeared between erosion rate and slope gradient, organic matter content or granulometry.

Errors are associated to this calculation. First, the proportional model is dependent on the depth assumed for the plough layer that is difficult to evaluate. Using 20 cm instead of 15 cm induces a difference of 30%. Second, other empirical models exist (Mass balance model 1 and 2, Walling and He, 1997) that give higher erosion rate for the same ^{137}Cs inventory. The difference is accentuated for low inventory. Third, the caesium-uptake by plants is never taken into account. It will have no influence for ^{137}Cs soil-plant transfer factor around 0.01 (Bq kg-1 plant/Bq kg-1 soil) but this factor is not well known and could reach values higher than 0.1, that will lead to an important overestimation of the erosion rate. These problems demonstrate the necessity of a new approach and new models for such study.

Acknowledgments

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