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EROSION IN ANDEAN HILLSIDE FARMING

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SUMMARY

Rapid growth of population in the climatically favourable tropical mountain regions in combination with ecologically non adapted patterns of land use have caused a dramatic increase in soil erosion by water. In order to avoid the destruction of agricultural land it is necessary to develop cultivation systems allowing a sustainable agricultural utilization of endangered areas. This goal requires knowledge of the causes and the processes of soil erosion in the tropics. The best known model to estimate soil loss by water erosion is the Universal Soil Loss Equation (USLE) which was developed by WISCHMEIER and SMITH (1978)

$$A = R * K * L * S * C * P$$

where A is the soil loss in $t \cdot ha^{-1}$ and year, R (or EI_{30}) is the rainfall and runoff factor, K is the soil erodibility factor, LS is the topographic factor, C is the cover and management factor, and P is the support practice factor.

The research reported here aimed to collect basic information on the characteristics of erosion processes in a defined area of the Andean zone of Colombia. This should allow to make conclusions about the applicability of the USLE. Furthermore, conventional and improved cassava cropping systems adapted to local smallholder conditions were to be tested to obtain knowledge based on the influence of management practices on erosion processes. To this end, erosion trials were established on slopes with a gradient of 7 - 20 % at two locations in Southern Colombia. The trials were started in the beginning of 1987 and continued during two growing seasons until the beginning of 1989. The trials were established with three repetitions in Santander de Quilichao and with two repetitions in Mondomo. The cultivation systems were: treatment 1 - clean tilled fallow (standard plots), treatment 2 - cassava flat without ridges, treatment 3 - cassava planted on contour ridges, treatment 4 - cassava planted on ridges down the slope, treatment 5 - cassava intercropped with grain legumes, treatment 6 - cassava planted between contour strips of grass, treatment 7 - cassava planted in a traditional minimum tillage system. The size of the standard plots was 22 m x 11 m, whereas all other plots were 16 m long and 8 m wide. A detailed registration of the erosion processes was ensured by installing collecting channels for eroded soil material at the lower end of the plots and a connected runoff measuring device which consisted of a splitter and a collecting tank. To determine the individual factors of the USLE, nutrient losses and some chemical and physical soil properties, numerous soil analyses were carried out (e.g. grain size distribution, organic matter content, distribution and stability of aggregates, plasticity and consistency limits, soil water content at field capacity and at wilting point, total N, exchangeable cations, trace elements). Also plant growth and ground cover were measured regularly (factor C). Information on the erosivity of the climate was

obtained by evaluating the records of rain gauges. The soils of the study area were acidic and infertile Inceptisols with favourable physical characteristics such as high structural stability and high infiltration rate.

The kinetic energy of rainfall was 21.3 J · m^{-2} in Santander de Quilichao and 20.4 J · m^{-2} in Mondomo. Most of the rain fell with intensities of more than 10 mm. The correlation of 17 erosivity indices with the soil loss of the standard plots was calculated. These Indices were the rainfall amount A, the kinetic energy E, the maximum 30 minute intensity (I_{30}), 15 minute intensity (I_{15}), the 7.5 minute intensity ($I_{7.5}$) of erosive rains and products of two or more of these indices. While no significant correlations were found 1987/88, the correlation coefficients of almost all tested indices were significant in 1988/89. The highest correlation coefficients were found for the compound indices.

The greater erosivity 1988/89 caused significantly higher soil losses in the second growing season. In the standard plots which were kept free of vegetation, up to 310.6 t · ha^{-1} per year of dry soil was lost. In treatment 4, the greatest soil loss of all cropping systems was measured with up to 68.0 t · ha^{-1} per year. Greatest soil losses were measured in both years, with rill erosion being predominant. A ground cover of mulch, grass or weeds was more effective in controlling erosion than the equivalent percentages of ground cover provided by the canopy of standing plants. Minimum tillage (treatment 7), contour ridges (treatment 3) and also contour strips of grass (treatment 6) in Mondomo showed the best erosion control effect and caused soil losses within the limits of 1 - 5 t · ha^{-1} per year, being identified as the tolerable limit of soil loss for the study area.

In general, selected soil fertility parameters in the top soils of the test plots, such as nutrient contents, acidity, and organic matter, did not show significant changes during the test period. Recognizable changes were mainly caused by fertilizer applications. Nutrient losses were dependant on the concentration of respective elements in the eroded soil material and the runoff, and also on the amounts of soil loss and runoff. Selected parameters of top soil properties such as grain size distribution, stability and distribution of aggregates, bulk density, infiltration rate, plasticity and consistency, water retention and moisture regime did not change noticeably during the two years test period, either.

Average cassava fresh root yields of the best treatments were 28 - 32 t · ha^{-1} in Santander de Quilichao and 15 - 20 t · ha^{-1} in Mondomo. Smaller yields of 7 - 20 t · ha^{-1} fresh roots were produced by the intercropping system of cassava and grain legumes, and the minimum tillage system. A simple economic analysis produced the highest gross margin for treatments 2 and 6 at both test sites, and also for treatment 3 in Santander de Quilichao.

Based on the data of rainfall erosivity, soil structure, topography and management practices, we tried to apply the USLE under the test conditions. Applying the procedure of WISCHMEIER and SMITH K values of 0.08 were found for both trial sites and test years. Calculating the K values as a quotient of the soil loss of treatment 1 and the rainfall erosivity EI_{30}, K values of 0.04 (Santander de Quilichao) and 0.03 (Mondomo) were found in 1987/88, in 1988/89 0.13 (Santander de Quilichao) and 0.10 (Mondomo). Individual values did fluctuate within a wide range. Based on the data of slope length and slope gradient, LS values of 0.63 to 2.99 were calculated. Data of plant heights, percentage of ground cover provided by the canopy of standing plants, mulch, grass and weeds were used to calculate C values for the cropping systems which ranged from 0.01 to 1.00. Results obtained by a multiple regression analysis showed that the rainfall erosivity, expressed as EI_{30}, explained soil loss best. In general, soil losses which were calculated with the USLE (without factor P) exceeded the actually measured soil losses in the field.

At both sites, the statistical analysis of field data on soil erosion produced highly significant differences between test years and treatments, but no significant differences between the trial sites. Though environmental characteristics of the two test sites such as elevation, rainfall, soil properties and slope gradient were different, these did not result in significantly different soil losses. The results suggest that management practices such as planting on contour ridges or contour strips markedly reduce soil loss while producing optimum cassava yields. Regarding the applicability of the USLE no definite conclusions were possible due to the short test period of only two years. However, the data suggest that the USLE did not provide a realistic description of the erosivity of the rainfall (factor R). Also the erodibility (K factor) based on the USLE-calculations was clearly smaller than K values calculated on the basis of field data. The question of USLE applicability under the given conditions therefore requires the continuation of this research for an extended period.

5. CONCLUSIONS

Erosion trials were carried out at two locations in the southern Central Cordillera of Colombia. Six different cassava cropping systems were tested during two years. The objectives of this research were to obtain basic information on erosion processes under Andean highland conditions and to verify the effect of cassava cultivation practices on process and amount of erosion. This should allow the identification of erosion-reducing cropping practices for cassava. Furthermore, the applicability of the Universal Soil Loss Equation (USLE) to the tropical highland conditions of the Andes was to be tested using the calculation procedures described by WISCHMEIER and SMITH (1978) and comparing calculated with actually measured soil loss.

Influences of management practices on erosion processes were similar for most of the tested cultivation systems in both locations and years. Basic erosion patterns in connection with specific management practices were not affected by the changing rainfall erosivity, which was significantly greater in the second than in the first year. As expected, the greatest soil losses were found in the clean tilled fallow system. However, at the beginning of the growing period the greatest soil losses were measured where rill erosion was predominant. This was especially evident in plots with treatment 4 (cassava on ridges down the slope) where greater soil losses were recorded during the first months after planting than in the plots with clean tilled fallow. These results show that soil conservation measures must be directed especially towards the reduction of surface runoff during the first months after planting. In this context those cropping systems were the most efficient which reduced the velocity and the quantity of runoff by physical barriers. This is especially evident for the contour ridges (treatment 3) and to a limited extent also for the contour grass strips (treatment 6). Also, a high initial percentage of ground cover (treatment 7) reduced effectively the shear stress of the surface runoff and prevented rill erosion.

The soils were very acidic, deeply weathered Inceptisols. Nutrients and organic matter (O.M.) were concentrated in the top soil, the O.M. being the main source of subsequent delivery of plant available nutrients. Therefore, the soil layer which could be utilized by agricultural crops, i.e. the profoundness of the soil, was restricted mainly to the A-horizon. Based on these site characteristics, a tolerable amount of a yearly soil loss of 1 - 5 t · ha^{-1} was calculated. Applying this threshold level to actual soil losses found in different cropping systems, treatments 3 and 7 and in Mondomo also treatment 6 were found to be sustainable cultivation systems.

Apparently, the first two years of this investigation were too short to identify any noticeable changes in concentrations of plant available nutrients and other parameters of the soil fertility. Also, due to the excellent structure of the soils, no essential changes of the physical properties occurred during the test period. The influence of soil tillage practices were best reflected by the aggregate size distribution, where minimum tillage produced the highest Mean Weighted Diameter (MWD) of the aggregates, whereas the smallest MWD was measured in the clean tilled fallow plots. Intensity and time of soil tillage had a strong influence on aggregate sizes and bulk density.

Altogether the analyses of soil chemical properties reflect the low natural soil fertility of the two locations. The tested management practices and cropping systems did not produce any noticeable changes during the two test years. However, when comparing the non-fertilized plots of treatment 1 (clean tilled fallow) with the fertilized cropping systems (treatments 2 - 7), an increased soil pH and a higher level of plant available nutrients was noticed. Simultaneously, the Al saturation decreased in the top soil of all plots where dolomitic lime was applied. Soil amendments and fertilizers could thus, at least on a short term basis, compensate the nutrient losses caused by erosion.

Nutrient losses were closely related to the amount of soil loss, the quantity of surface runoff and the respective nutrient concentrations in the eroded soil and the runoff. Greater amounts of nutrients went lost by the runoff than by the soil loss. Therefore, erosion control measures have to focus not only on the reduction of soil loss but also on diminishing runoff. In the case of several nutrients (Ca, Mg, K) an enrichment in the eroded soil material compared to the field soil was found. No definite relations were found between the concentration of organic matter and nutrients in the eroded soil and the amount of eroded soil. In this case longer-term investigations are necessary.

Under the test conditions the cropping systems with solecropped cassava (treatments 2, 3 and 4) and cassava planted between contour strips of grass (treatment 6) produced relatively high yields. Low yields were found for intercropping of cassava and grain legumes (treatment 5) and cassava in minimum tillage (treatment 7). However, location and variety were of great importance.

Therefore, these yielding patterns of cassava may not necessarily be verified under different environmental conditions.

When assessing the extent of soil erosion and the economic performance of the tested cropping systems, cassava planted on contour ridges (treatment 3) can be recommended for Santander de Quilichao whereas cassava planted between contour strips of grass (treatment 6) was the best in Mondomo. This conclusion is based on the relatively high financial yields and the soil conserving effect of these cropping systems.

The time limits of the test period must be considered as the most important factor restricting the possibilities to assess the applicability of the USLE in our study. Furthermore, it was assumed that the hypotheses on which the USLE model is based were also valid for Andean hillside conditions in Colombia, however, no proof for this assumption has as yet been given . As a rule, soil losses calculated with the USLE (excluding the P factor) were markedly greater than the actually measured amounts of eroded soil. This is contrary to the common supposition that the USLE frequently underestimates the erosivity of tropical rainfall, and therefore would provide lower estimates for soil loss than the amount directly measured.

These results allow the conclusions that under our conditions the erosivity of the rainfall explained most of the variation in soil loss, whereas the soil erodibility was low. The influence of management practices was more pronounced where the rain factor R (EI_{30}) was not strongly correlated with soil loss. No definite answer can so far be given to the question whether the USLE-equation can be applied to the conditions of the study area or not. However, the basic factors which determine the processes of water induced soil erosion presumably are also important in this climatic zone.