Relative efficacy of two biophysical approaches to assess soil loss tolerance for Doon Valley soils of India

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Abstract: One of the major factors in favor of soil conservation measures is the prevention of top fertile soil removal, which adversely affects the crop productivity, depending upon the type of crop, soil, and erosion intensity. This reasoning has generally been assigned qualitatively and has rarely been supported through a quantitative relationship between soil loss and crop productivity. The soil loss tolerance limit (*T* value) is one of the several indicators to properly explain this phenomenon. The *T* value can be used as a guide to decide the maximum soil loss that can be removed before the long-term soil productivity is adversely affected. In this paper, two methods have been compared in determining *T* value on a regional scale for Doon Valley conditions in India. The first approach is based on assessment of the productivity index (*PI*) that considers permissible soil productivity loss rate (δ) and planning horizon (H) for sustainable land use. Productivity index is assessed and then related with tolerable rate of soil loss. The second approach is based on a quantitative weighted additive model, which has been used to define the current state of the soil resource. Both methods have been found to be good indices of soil loss tolerance value. However, the *PI*-based approach requires a complicated depth-wise dataset, including available water capacity, bulk density, and pH, which at present is not available for most of the ecological regions of India. Generating such a database may require long time and large investment. On the other hand, the weighted additive model requires a minimum data set of six soil attributes, which are readily available. Using the sensitivity index, the different *T* value at each of the study sites was separately compared. The overall mean of the sensitivity index was statistically insignificant at $p < 0.05$ for each location. Both methods were able to provide a reliable estimate of *T* value at different locations. However, the weighted additive model proved to be more reasonable as it requires a readily available dataset.

Key words: Doon valley—India environmental sustainability—erosion tolerance—productivity index (*PI*)—quantitative weighted additive model

Soil erosion resulting mainly from agricultural land use is associated with environmental impacts (Clark II et al. 1985) and crop productivity loss (Lal 1995; Pimentel et al. 1995; Bakker et al. 2004). It is, therefore, imperative to properly understand the erosion tolerance of a given soil to ensure food (Daily et al. 1998) and environmental security (Matson et al. 1997). Soil conservation programs need to be justified in terms of productivity and environmental sustainability (Tiwari 1991; Ponzi 1993). Soil scientists assign soil loss tolerance limits (*T* value) to a soil based on the soil's properties and the potential for the soil to lose productivity over time from erosion. Erosion depletes or eliminates root-explorable soil depth and crop-available water, selectively decreases the soil nutrients and organic matter content, and exposes soil layers having unsuitable characteristics for crop growth. Crop yield is thus a function of root growth, which in turn is affected by soil environment. Though loss of any amount of soil by erosion is generally not considered beneficial, years of field experience and scientific research indicate that some loss can be tolerated without affecting crop production significantly (Schertz 1983). This acceptable rate of erosion is known as Soil Loss Tolerance (SLT) (Wischmeier and Smith 1978; McCormack et al. 1982; Soil Conservation Society of America 1982; Lal 1988; Beach and Gersmehl 1993; ISSS 1996) or permissible soil loss (Kok et al. 1995). In this study, two different approaches (models) have been adopted to determine soil loss tolerances. These modeling approaches involve estimation of SLT by relating erosion-induced change in soil quality.

The first approach is a widely known index that relates total soil depth and soil quality with the productivity index (*PI*). The *PI* model has been widely used under diverse soils and agroecological regions. The basic assumption in the *PI* model is that crop yield is a function of root development, which in turn is governed by soil quality. It is, in fact, a depth-weighted soil quality index. The *PI* model can be used to characterize the soil erosion/productivity relationship for a specific site (Lal 1998; Liu et al. 2009). Soil loss tolerance could be based on explicit losses in productivity judged over a specific planning horizon. This has already been advocated by Delgado (2003) using a 10% allowable decline in yield over 100 years.

The second approach is based on current functional state and structural integrity of a soil resource. A quantitative, weighted additive model was used to define the current state of soil resource. Soils were categorized as soil group 1, 2, or 3, depending upon their overall aggregated score. A two-way matrix, developed by USDA Natural Resources Conservation Service, was then followed with specific soil group and soil depth to determine the *T* value of a given soil. In both methods, two sets of indicators were used as minimum data set (MDS).

The main objective of this study was to examine the relative variation in the two methods generally employed to determine Soil Loss Tolerance Limit (SLTL) for Doon Valley soils of India. The region experiences soil erosion on a moderate to severe scale (Dhruva Narayana and Rambabu 1983), and it may be as high as 53 Mg ha^{-1} y^{-1} (23.66 tn ac^{-1} yr^{-1}) (Khola and Sastry 2005). In order to assess future risks of soil erosion, more precise and quantitative information

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