CHAPTER 7

GENERAL CONCLUSIONS AND RECOMENDATIONS

7.1 Soil erodibility

The inherent susceptibility of soils to detachment and transport by the various erosive agents is a function of soil properties including among others, texture, aggregate size and stability, organic matter content, clay mineralogy and electrolyte concentrations. The extent of each of these soil properties is different in different soils thereby influencing the degree of vulnerability of a given soil to destructive forces. These are in turn influenced by the interactive effects of the topographic, cover and rainfall factors.

Soil erodibility assessment using simulated rainfall on the three different textured soils revealed that runoff and sediment yield increased with increasing slope gradient for silt and clay dominated soils and was not significant for the sandy soils. Sandy soils were the least erodible. Despite a slight tendency of greater sediment yield on silt than clay soils at low slope gradients, the difference was not significant on higher slope gradients. This research also revealed that higher rainfall intensity (60 mm hr^{-1}) was more erosive than lower rainfall intensity (30 mm hr^{-1}) regardless of slope gradient and soil texture.

In another experiment where erodibilities of soils form 15 different locations in Harerge were evaluated using laboratory rainfall simulation, the soils showed different degrees of vulnerability to surface sealing, runoff and sediment yield which were associated with various soil properties. It was found that aggregate stability was the main determinant factor to the susceptibility of the soils to sealing, runoff and soil loss on these soils. The aggregate stability was in turn affected by organic carbon content, percent clay and ESP. Soils with relatively high ESP such as Babile (13.85) and Gelemso (7.18) were among the lowest in their aggregate stability (percent water stable aggregates 33.7 and 42.2 respectively); have highest runoff and sediment yield as compared to other soils in the study. Similarly, most of those soils with relatively low ESP, high C% and WSA such as Hamaressa, AU Vertisol and AU regosol are among the least susceptible to sealing and interrill erosion. Nevertheless, some exceptions include soils like those of Hirna where high runoff was recorded whilst having relatively high C%, low ESP and high water stable aggregates.

The soils considered in the study were placed into five categories based on the degree of their susceptibility to runoff and sediment yield. In the first category are Babile and Gelemso, which have high runoff and high sediment yield. The possible explanations for their high runoff is due to high rate of surface sealing that in turn resulted from low aggregate stability owing to high ESP, low % C and low clay content. However, the seals that are formed from the less coherent coarse particles are too weak to resist the shearing force of surface flow resulting in high sediment yield but strong enough to inhibit infiltration. Soils with high to medium runoff and low sediment yield such as Hirna, Lange, Amadle and Adele were considered in the second category. Despite the high runoff, the soils are more resistant to detachment and transport by overland flow. This could be associated with the soil properties as most of them have high clay and C % that keeps the seals coherent enough to withstand detachment.

The soils of Diredawa and AU Alluvial are composed of coarse and loose particles with low aggregate stability (%WSA =35.5 and 48.9 respectively) that resulted in medium runoff (about 35% of the applied rainfall) but high sediment yield. Despite the low aggregate stability, these soils had a better infiltration rate due to the composition of the coarse particle sizes. But these soils are susceptible to high detachment as the particles are too loose to resist the shearing force of the overland flow.

The fourth category includes Chiro, Chinaksen and Karamara soils whose composition of water stable aggregates (0.25 –2.0mm in diameter) range from 59 – 79%. The runoff and sediment yield of these soils is intermediate as compared to other soils in the study areas.

On the other hand, Hamaresa, AU regosol, Bedessa and AU vertisol have relatively low runoff and sediment yield. This can be attributed to the relatively high clay and organic carbon contents and low ESP that resulted in high aggregate stability (62 to 71% water stable aggregates) which in turn resulted in less susceptibility to sealing and high infiltration rate. Therefore, the low sediment yield in these soils could be attributed to two reasons: Firstly, the aggregates are strong enough to resist detachment and secondly, due to the high infiltration rate, the overland flow is too weak to transport the sediments.

It is important to note that the terminologies such as high, medium or low that have been used to compare the various erosion parameters in this text, were only in reference to the soils considered in the study and not to any other standard reference. Besides, extrapolating the laboratory erodibility values to a large field scale conditions may also be misleading as the sediment yield values obtained under the rainfall simulation are very much underestimated due to the short slope length. Therefore, the sediment yield values should only be considered as relative indices for qualitative assessment of the particular soils.

7.2 Soil loss modelling

The estimated soil loss obtained for the different study sites considered in this study by using SLEMSA and USLE was correlated to the laboratory soil erodibility values (sediment yield) with correlation coefficients of r=0.61 and 0.33 respectively. The low correlation between the soil loss estimated by USLE and sediment yield could be ascribed to the less sensitivity of the model to the soil erodibility factor. Both SLEMSA and USLE enabled to identify the potential erosion hazards for the study sites. Despite the differences in the procedures used in the two models, both estimated higher soil loss for Gelemso, Babile, Karamara and Hamaressa. Soil loss was lower for Diredawa, AU-vertisol and AU-Alluvial all of which occur on a relatively level topography. The high soil loss for Babile and Gelemso conforms with the relative soil erodibility values obtained under rainfall simulation suggesting that soil erodibility, among others, is the main factor contributing to high soil loss for these soils.

The difference in the estimated soil losses for the different sites was a function of the interaction of the various factors involved in calculating the soil loss. For instance, although the laboratory scale soil erodibility values were low to medium for Hamaressa and Karamara, the estimated soil loss was higher due to the field topographic situations such as high slope gradient. On the other hand, for the Diredawa and AU alluvial soils, despite the high sediment yield obtained under the laboratory study, the estimated soil loss was low due to their occurrence on relatively level topography.

The two models that were used to estimate soil loss in the study sites showed different degrees of sensitivities to their input variables. SLEMSA was highly sensitive to changes in rainfall kinetic energy (E) and soil erosdibility (F) and less sensitive to slope length and vegetal cover. The highly significant correlation between sediment yield determined in the lab and estimated soil loss by SLEMSA (r=0.61) can somehow explain this relationship. USLE was highly sensitive to slope gradient and cover but less so to slope length as compared to the other input factors.

Qualitative comparison of the soil loss values estimated by using the USLE and SLEMSA models with that obtained under laboratory rainfall simulation revealed that although some discrepancies are observed that indicate the risk of using laboratory values to validate soil loss models, these values give some indications of the soils' inherent susceptibility to erosion and are valuable especially for comparison of different treatment effects under well controlled condition at limited cost.

7.3 Soil conservation

This study indicated that under the current management situations, about 70% of the soils of Harerghe would lose the productive top 15cm of their soils in less than hundred years exposing the infertile subsoils and converting most of the agricultural lands into marginal lands. Therefore, it is imperative that appropriate management practices be designed and implemented to sustain soil productivity and reduce erosion to at least tolerable levels. It is advisable that the two approaches of soil conservation namely mechanical and biological conservation measures be designed and implemented based on the level of severity of erosion. The fact that mechanical soil conservation measures such as terraces, diversions, and bunds are costly and time consuming necessitate use of easily available farm products such as crop residue for soil and water conservation. The question is ‘how much residue should be applied and how?’ To answer this question, this study evaluated various rates and application patterns of wheat residue on runoff and soil loss both in the laboratory rainfall simulation and under field natural rainfall conditions. Both experiments revealed that surface application of crop residue is more effective in reducing soil loss and runoff than incorporating the same amount of the residue into the soil. Likewise, for a particular residue application pattern, runoff and soil loss decreased with increasing application rate of the mulch. However, the difference was not significant between 4 Mg ha^{-1} and 8 Mg ha^{-1} wheat straw application rates suggesting that the former can effectively control soil loss and can be used in areas where there is limitation of crop residues due to their preferential use for various other purposes provided that other conditions are similar to that of study site (AU Regosols). Yet, under the traditional low input farming, this amount of residue is usually unattainable due to low productivity. The conventional average residue production rate of 1.65t ha^{-1}, may reduce soil loss by about 50% as compared to the bare soils if it is left on the soil surface. It should however be noted that the effectiveness of mulching in controlling soils loss and runoff can vary under various slope gradients, rainfall characteristics and cover types. On steep slopes and /or higher rainfall events, the mulching material can easily be removed by concentrated overland flow. Therefore, in such cases, mulching should be supplemented with the mechanical soil conservation measures and vise versa. Research is required to evaluate the effectiveness of residue rates of less than 4 t ha^{-1}.

7.4 General remarks

One of the main factors contributing to severe soil degradation by accelerated soil erosion in Ethiopia is related to the ever-growing population pressure that led to shortage of arable lands and forced the farmers to clean and cultivate marginal areas. Moreover, the lack of adequate land use policy added to the mountainous and rugged topography as well as erratic rainfall exacerbate the problem. Therefore, the following general points need due consideration if further human induced land degradation is to be resolved.

- Create awareness among the farmers about short-term and long-term impacts of land degradation and the possible methods of reducing it which may involve family planning issues.
- Educate and support the farmer towards teaching his family so that job diversification can be possible to reduce the pressure on a given piece of land.
- Conduct farmer based research to the interest of the farmer.
- Develop, test and implement appropriate land use strategy
- Evaluate and validate indigenous and exotic soil and water management technologies based on farmer-oriented research.

Note that the above remarks are not specific outputs of this study but can provide some idea towards reducing human induced environmental degradation thereby contributing to environmental protection and its sustainability.

7.5. Research needs

Detailed process based soil loss estimation shall be made in order to get a more accurate estimate of soil loss from a particular area so that site specific management options can be executed with better confidence. Furthermore, integrated soil conservation research is required to develop a comprehensive database for modeling of the various soil erosion parameters as well as to design and implement appropriate soil conservation measures. The following broad indicators are only few of the many and diversified research needs that would be worth mentioning in relation to soil erosion and conservation:

- Conducting intensive research related to the effect of soil properties on soil erodibility under various site-specific conditions with emphasis to aggregate stability and size distribution, clay mineralogy, ionic composition, texture and organic matter.

- Assessing the relative importance of the various soil erosion parameters that are most responsible to degradation in a given area.

- Developing comprehensive database in order to develop sound erosion models which are relevant to the specific conditions of a given site. This may include accumulation of more detailed data on climate (including rainfall, temperature, evapo-transpiration, etc); soil; canopy and surface cover; topography; geology and hydrology; land management, economic and social aspects.

- Studying the effectiveness of various types and rates crop residues under different climatic, soil and topographic conditions in controlling soil erosion.

- Assessing the influence of various cropping (such as crop rotation, strip cropping) and tillage systems on erosion for various site-specific conditions.

- Evaluating the effectiveness of single and combined effects of the different mechanical and biological soil conservation measures for various soil conditions.

- Validation of the most accepted erosion models and soil conservation measures with reference to the existing situations in a given study site.