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Full Length Research Paper

Soil loss prediction using universal soil loss equation (USLE) simulation model in a mountainous area in Ağlasun district, Turkey

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Land degradation and soil loss is a global event. Human induced pressures on the natural ecosystems are still in progress as well as conservation efforts. The need for sufficient knowledge and data for decision makers is obvious hence the present study was carried out. The study area, the Ağlasun district, is in the middle west of Turkey and is characterized by a cold and sub-humid Mediterranean climate. The mountainous area is mostly covered with average low canopy closure of 11 - 40% of different forest species (52% of the study area). Universal soil loss equation (USLE) simulation model was used to predict the soil loss amounts in the study area. The results show that the predicted average soil loss amount is 7.38 (ton/ha/year). The average soil depth is about 35 cm and the soil loss tolerance limit is widely exceeded in the study area.

Key words: Soil erosion, soil loss tolerance, canopy closure, isparta.

INTRODUCTION

For thousands of years, the Anatolian region (Boydak, 2003; Özkan et al., 2009; Özkan, 2009, Toksoy et al., 2008) and more in particular, the region around the ancient city of Sagalassos, has been on the theatre of nonstop human activity, embracing a continuous quest for fuel wood and timber going hand in hand with an ever expanding grazing area. This uninterrupted and long lasting human disturbance has lead to an important decrease in forest area (Özkan et al, 2010; Fontaine et al, 2007; Özkan 2008a; Gumus and Acar, 2010). Natural or geological soil erosions do not occur at constant or consistent rates. Semi-arid and arid soils, which lack protective plant covers, may erode naturally at rates averaging 10-50 times greater than those for humid climate soils (Miller and Donahue, 1990). The natural progress of soil erosion can be increased horrendously by human activities, such as over-cultivating depleted soils until the protective ground covers are gone and accelerated erosion takes place. Soil erosion, for whatever cause, destroys man-made structures, fills reservoirs, lakes and rivers with washed soil sediment, and dramatically damages the land. Whether it is called mud, silt or sediment, it is all soil material that should have been kept in place, on top of the land where it can support plant growth and plants can, in turn, stabilize the soil. Erosion sediment is the richest part of the soil, the nutritive topsoil containing most of the organic matter. The cost of dredging the several billion tons of sediment from rivers and harbors each year is about 15 times more than that of holding the soil on the land from which it eroded (Miller and Donahue, 1990; Hacisalihoglu et al, 2006, Özkan 2008b).

Soil loss has social, economical, cultural etc. aspects. These aspects have to be studied and cleared to understand soil erosion event rightly. According to the International Soil Reference and Information Centre (ISRIS), very high water or wind erosion takes place in Turkey (Oldemann et al., 1991). Although the extents of soil loss and runoff rates in different regions and areas of

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Abbreviations: asl, Altitude above sea level; **HL,** heat load; **T,** soil loss tolerance; **GPS,** global positioning system.

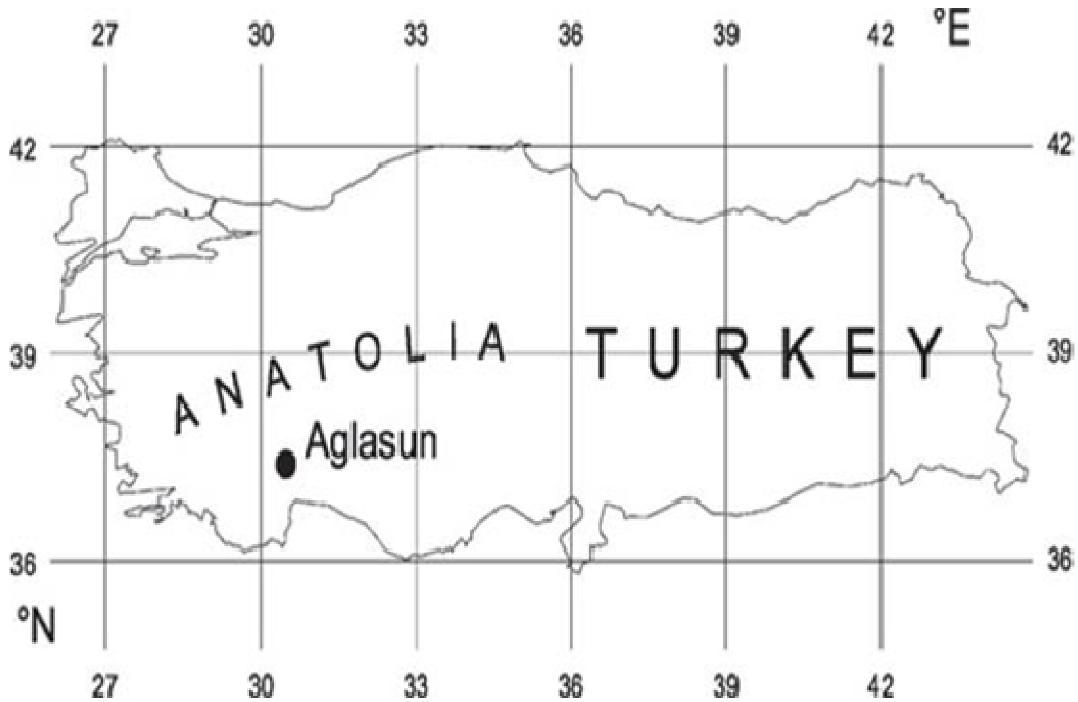

Figure 1. Study district (Ağlasun) in Turkey.

Turkey have not been studied extensively (Sariyildiz and Gemci, 2004; Aydemir, 1973), very few studies have been carried out to determine the effects (social, economical, cultural etc.) of different land-use types and slope classes on soil loss and runoff (Hacisalihoglu et al, 2010). The aim of the present study was to determine the soil loss and degradation ratio in a cold to sub-humid Mediterranean climatic conditions using the most popular soil erosion predicting method named the universal soil loss equation (USLE) simulation model in different land use types, slope classes, etc. in the study site (Ağlasun, Turkey).

MATERIALS AND METHODS

Study sites

Ağlasun district (37° 33' N - 30° 32' E, elevation: between 350 m and 2200 m altitude above sea level (asl)) is located in 40 km NW of the regional capital Isparta in southern Anatolia (Figure 1). It is a mountainous, calcareous area of approximately 55000 ha covered for 52% by Oro-Mediterranean pine forests, mainly composed of *Pinus brutia* (19500 ha) and *Pinus nigra* ssp. pallsiana (2500 ha). Some areas are covered by relics of *Cedrus libani* forests (Toros cedar). The area has a long history of human disturbance including a high livestock grazing pressure.

The area is characterized by a cold and sub humid Mediterranean climate with pronounced winter precipitation and summer drought (Paulissen et al., 1993). From 1963 to 1990 the mean annual temperature at Ağlasun (1100 m asl) ranged from -2.1℃ (January) to 28.7℃ (August) and the mean annual precipitation was approximately 990 mm year^{-1} (Librecht et al., 2000). Above 1450m asl an Oro-Mediterranean climate prevails. It is characterized by a higher precipitation than in the valleys below. The predominating parent rock in the area was limestone, though conglomerate and sandstone are present. Soil depth, moisture content and stoniness varied with topography. Most soils could be classified as leptosols, regosols or cambisols, depending on shallowness and stoniness (FAO et al., 1998).

Data collection

To maximize spatial variation in the dataset, stratified random sampling was used to lay out 20 transects, mostly oriented from valley to ridge. Along those transects, 153 plots of 20 x 20 m were sampled at intervals of at least 90 m and mean plot distance of 658 m (Figure 2). Each plot was mapped using a global positioning system (GPS). Altitude above sea level (asl) was assessed with an altimeter and the bedrock was derived from existing maps. Landscape position, surface roughness and landform were recorded at sight. Surface stoniness (%) and slope (%) were assessed by stabbing the soil at 10 random locations with a steel probe and clinometers, respectively. The slope exposition, measured in degrees relative to north (N), was transformed to a relative measure of heat load (HL) using the formula described by McCune and Keon (2002), $HL = [1 - \cos\theta] / 2$. Species (woody and herbaceous) presence and absence and the canopy closure (0: 0-10 %, 1: 11 - 40 %, 2: 41 - 70 %, 3: 71 -100 %) were determined and recorded. The depth of the litter layer was measured and divided in three sub-layers if present (litter - fermentation - humus). Aggregate classes (BK., 1994), Permeability (Saxton et al., 1986) and soil depth was measured at 10 random places in every plot and the values were averaged. In every plot, soil samples were taken and pooled for further analysis. Soil texture (Bouyoucos hydrometer method (Bouyoucos, 1962), pH (pH 1/2.5 with glazing electro Ph meter in pure water), total lime content (Shiebler calcimeter method (Allison and Moodie, 1965) and organic matter content (Walkley-Black wet oxidation method (Allison, 1965), etc. were determined in the

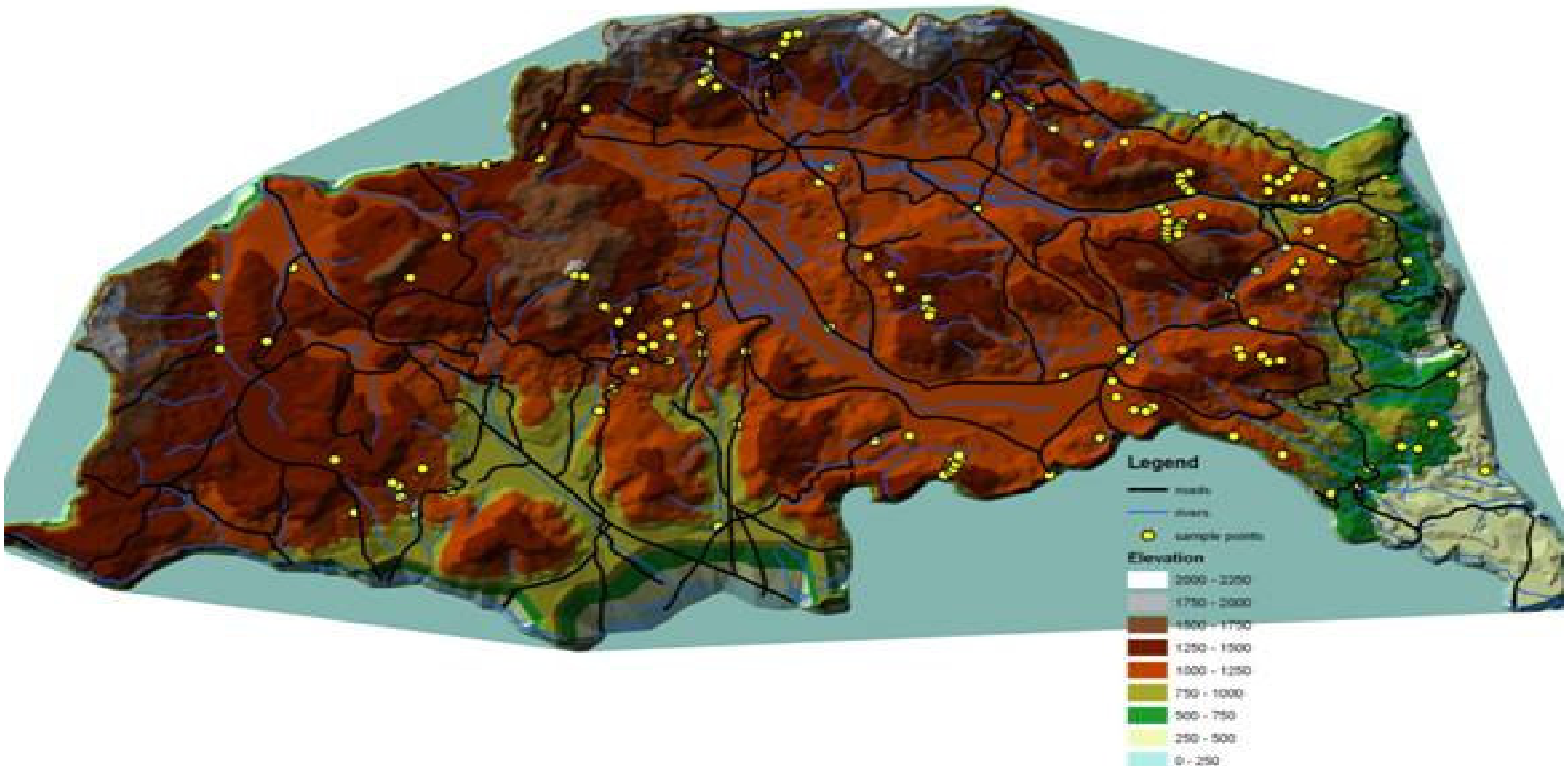

Figure 2. Sample plots in different elevation zones in the study site.

laboratory.

Soil loss predicting with the USLE

The international version (where the values are turned in to metric system and adapted to the European conditions) of the simulation model USLE was used to determine the soil loss amounts according to Schwertmann et al. (1990). Most of the erosion assessments performed in North America during the past two decades have used the USLE. This model was derived empirically from approximately 10,000 plot-years of data (Wischmeier and Smith, 1978) and may be used to calculate erosion at any point in a watershed that experiences net erosion. The USLE is written as follows:

$$A = R.K.L.S.C.P \quad (1)$$

Where, A is the average annual soil loss (t/ha per year), R the rainfall erosivity factor, K the soil erodibility factor, L the slope length factor, S the slope steepness factor, C the cover management factor and P is the supporting practice factor.

Climate erosivity is represented by R and can be estimated from the rainfall intensity and amounts data which were taken from Dogan and Gücer (1976). The soil erodibility monograph can be used to predict the K value (Schwertmann et al. 1990). The topography and hydrology effects on soil loss are characterized by the L and S factors. For direct USLE applications, a combined LS factor was evaluated for each land cell as Wischmeier and Smith (1978). Land use and management are represented by P

Table 1. Average amounts of some variables used in USLE

Variables	Minimum	Maximum	Mean	Std. deviation	Variance
Slope gradient (%)	5.00	95.00	41.9281	21.39851	457.896
Organic matter (%)	.99	33.11	7.5905	4.81992	23.232
Hydrolic conductivity (mm/hr)	1.40	63.00	6.1196	10.21304	104.306
Surface stoniness (%)	.00	90.00	46.2418	29.07726	845.487
Soil depth (cm)	7.00	94.00	34.9412	24.79713	614.898
Sand (%)	3.19	85.08	41.2441	15.65488	245.075
Loam (%)	8.18	42.03	24.1202	5.96082	35.531
Clay (%)	5.41	78.69	34.6342	13.79120	190.197
Canopy closure classes (0 to 3)	0	3	1.12	1.143	1.307
Soil loss amount (ton/ha/year)	.08	37.80	7.3814	6.85417	46.980
Tolerance classes (1 to 6)	1.00	6.00	4.5359	1.83900	3.382

Valid N (list wise) =153.

Table 2. Correlation between soil loss amounts and the other variables.

Variables		Slope	Organic	Permea	Surface	Sand	Loam	Clay
Soil loss (ton/ha/year)	Pearson Correlation	.530(**)	-.054	.025	-.175(*)	.112	-.071	-.096
	Sig. (2-tailed)	.000	.509	.761	.030	.168	.382	.237
	N	153	153	153	153	153	153	153

**Correlation is significant at the 0.01 level (2-tailed); *correlation is significant at the 0.05 level (2-tailed).

and can, with some difficulty, be inferred using remote sensing combined with ground-trusting.

Soil loss tolerance (T)

" T" is the soil loss tolerance factor. It is defined as the maximum amount of erosion at which the quality of a soil as a medium for plant growth can be maintained. This includes maintaining (1) The surface soil as a seedbed for plants; (2) the interface between the air and the soil that allows the entry of air and water into the soil and still protect the underlying soil from wind and water erosion; and (3) the total soil volume as a reservoir for water and plant nutrients, which is preserved by minimizing soil loss. Erosion losses are estimated by the universal soil loss equation and the revised universal soil loss equation. The T factor is assigned to soils without respect to land use or cover. T factors are assigned to compare soils and do not directly relate to vegetation response. However, many of the factors used to define a T factor are important to vegetation response, but the T factor itself is not. The classes of T factor are 1 (0 -1 ton/ha/year), 2 (1 - 2 ton/ha/year), 3 (2 - 3 ton/ ha/ year), 4 (3 - 4 ton/ha/year), and 5 (4 - 5 ton/ha/year). The five classes range from 1 ton per acre per year for very shallow soil to 5 tons per acre per year for very deep soil that can more easily sustain productivity (NRCS, 1999). T factor class 6 indicates that the soil loss amount is more than 5 ton per acre per year.

Statistical methods

For the evaluation of the research results, statistical package for the social sciences (SPSS) was used to determine the averages and correlation between some of the variables.

RESULTS AND DISCUSSION

The research area is mountainous, partly forested (52% forest) and mostly historically human disturbed. The negative effects of the human activities on the soil loss event (Bermudez et al., 1998; Lasanta et al., 2000) are still in progress in the area. Many different variables have been measured and determined to obtain the requirements of the used predicting model (USLE). Some of these variables and their average values are given in Table 1. According to this measurement results, the average slope gradient is very high and almost 42% (about 18.9 degree) in the sample plots. It is well known that a positive and strong correlation between the slope gradient and soil loss exists (Wischmeier and Smith, 1978; Aydemir, 1973; Hacisalihoglu, 2004). The very significant and positive correlation (Table 2) between the predicted soil loss amounts and slope gradients in the sample plots supports this general knowledge. Organic matter contents of the sample plots soils are in average 7.59% where the minimum amount 0.99% and the maximum amount 33.11% is. Organic matter content of the top soils have a very positive effect on the physical, chemical, hydrological etc. soil characteristics which absorbs the infiltrated surface water and reduces in this way the soil loss (Singer and Bissonnais, 1998). The minimum and maximum hydraulic conductivity (permeability) amounts of the top soils in the study area varies in

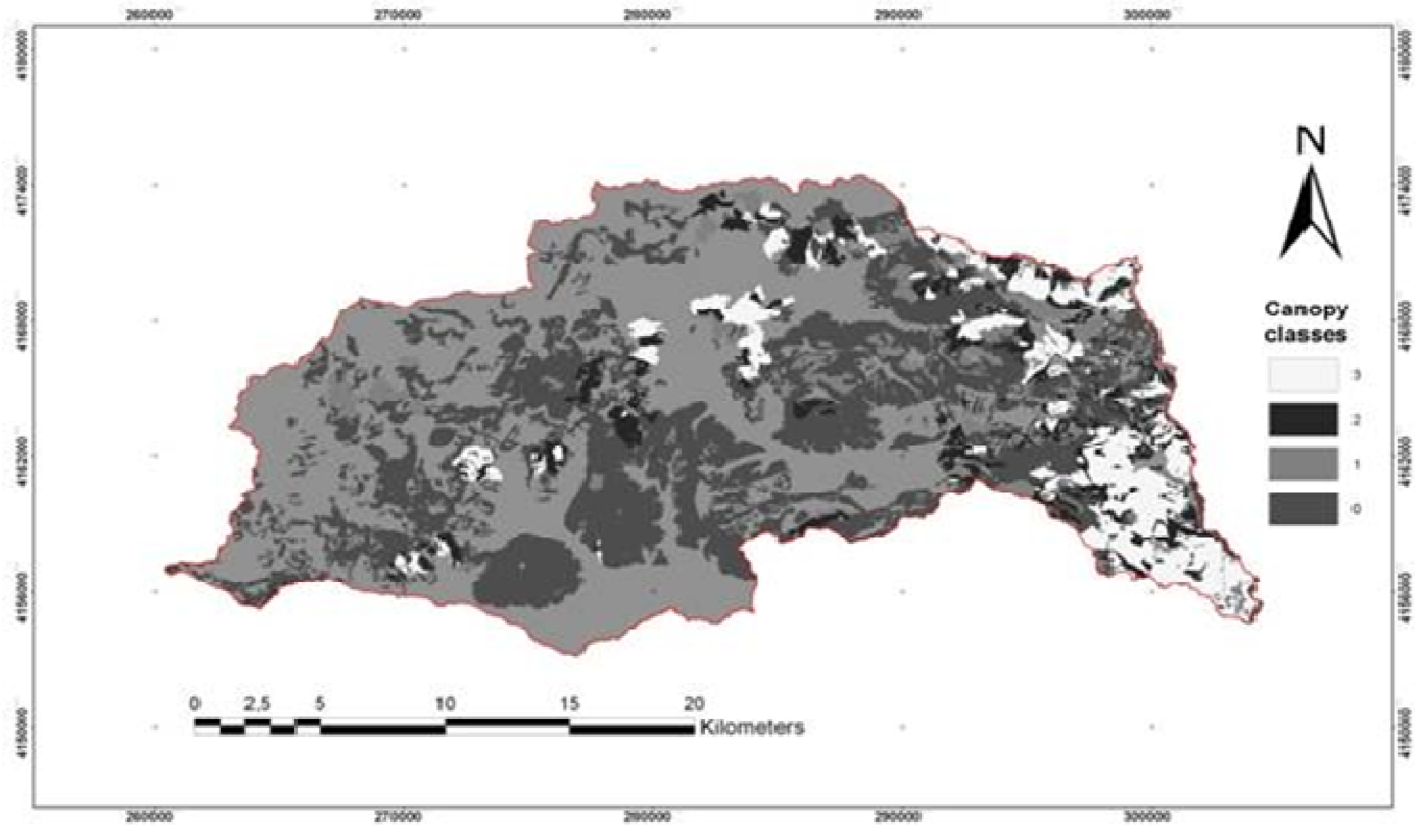

Figure 3. Canopy closure classes in the sampling plots.

big intervals where the minimum amount 1.40 (mm/hr), maximum amount 63 (mm/hr) and the average amount about 6.12 (mm/hr) is. Surface stoniness (soil fractions bigger than 2 mm diameter) increases the infiltration ratio of the soils, helps to decrease the surface flow and so reduce the soil loss (Descroix et al., 2001). The average surface stoniness in the study sites are about 46% which could be considered as a high value. The minimum and maximum surface stoniness amounts vary from 0 to 90% in the measurement plots. The forest Canopy closures in the study sites (Figure 3) are quite fallen and are in average about 11 - 40 % (class 1) which could be considered as low.

The study results shows that the predicted soil loss amounts in the sample plots are quite high. Average soil loss amount is about 7.38 (ton/ha/year). The minimum soil loss amount is 0.08 (ton/ha/year) and the maximum 37.80 (ton/ha/year). Average soil depth in the study area is about 35 cm and this could be considered as very low. Soil loss tolerance concept is closely related with soil depth. According to the average soil depth in the sample plots, it is clear that the soil loss tolerance in the study area is the class 1 (0 to 1 ton/ha/year). The study results shows that the average soil loss tolerance class is about 5, this indicates that soil loss tolerance was exceeded in almost all of the sample plots.

Conclusion

The very high average slope gradient and guide low canopy closure in the sample plots increased the predicted soil loss amounts while the high surface stoniness and the organic matter contents of the top soil decreased the soil loss amount; although, the predicted soil loss amounts are quite high (7.38 ton/ha/year in average) and the soil loss tolerance were exceeded in the study area. The still continuing human induced negative effect on the different land use types (agriculture, pasture, forest etc.) and vegetation resources are increasing land degradation. Social, economic, cultural etc. precautions must be undertaken to decrease land degradation and soil loss and reaching in this way to sustainable resources management understanding (Toksoy and Hacisalihoglu, 2008). This kind of studies has to be increased to fulfill the general knowledge and data absence in this subject which is necessary for decision makers.

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