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A GIS Assessment of Non- Point Source Pollution Modelling in the Timber Creek Watershed, Cooke County, Texas, USA

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Abstract
In order to improve water quality and restore impaired watersheds, managers need to make decisions using data that are readily available. Due to limited resources as a result of the cost implications of data, modelling approach is considered. The Universal Soil Loss Equation (USLE) is a Geographic Information System (GIS)-based methodology commonly used to estimate sediment yield. The model is appropriate for predicting soil erosion if data and methodical processes involve GIS. However it is not be considered as a final and true depiction to predict erosion. A good understanding of the watershed is needed to validate the model outputs. The model implementation is relatively cheap, cost effective and easy. Existing data and freely available information in the public domain are used for computations. For this study the total sediment in the watershed showed a 48.5% and 60 % difference when the results were compared with the studies of Levine *et al*., 1993 and UNITAR, 2009. The results may not be devoid of uncertainties and errors due to data sources and implementation of the model parameters.
Keywords: sediment yield, watershed, GIS, soil erosion, USLE, modelling

1. INTRODUCTION

The understanding and management of water quality issues ensuing from non- point source pollution involves information and strength of the sources of pollution and the transport of the pollutants from the source to the destination (Novotny and Chester, 1989). Non-point pollution constitutes one of the major dangers to surface and underground sources of drinking water on earth (Corwin et al., 1997). These non-point source pollutants are mainly impurities from surface and underground soil and water bodies which are dispersed naturally and difficult to trace to a particular location hence not easy to estimate (Yoon, 1996; Chowdary et al., 2001). Non- point source pollution results from the transportation of natural and man- made pollutants from sources to destination such as streams, coastal water bodies, rivers and wetlands (Hubbarb, 2007). These non-point source pollutants include sediments, fertilizers, pesticides, herbicides, spilled oil, poisonous chemicals, pharmaceutical waste and salt (Corwin et al., 1997; Hubbarb, 2007; EPA, 2013).

The US Environmental Protection Agency categorised non-point pollution sources as urban runoff, construction, river bank erosion, individual sewage dumping and hydrological modification (Corbitt, 1990). The enormity of the problem arising from the diffused sources of the non-point pollution results in its estimation by simulation method using distributed models. Geographical Information System provides a tool to manipulate, manage, analyse relationships and spatially model processes. This tools help in reducing and locating sources of non-point pollution (Welch et al., 1999; Chowdary et al., 2001; Eisakhani et al., 2009). This project will aim to model sediment load delivery in water shed only with a view. Sediments yield are commonly estimated with the use of "universal soil equation" (USLE) (Levine et al., 1993; Chowdary et al., 2001). Levine et al., 1993 suggested that a water quality model is developed for quantifying non-point source pollution loads and relates statistical modelling of sediment transport with the spatial arrangement of the parameters influencing the model.

2. NON-POINT SOURCE POLLUTION AND SEDIMENT TRANSPORT MODELS

Sediments are loosely packed tiny particles of sand and silt deposit contributing to non-point source pollution due to their ability to be transported over long distances by water or wind thereby causing harm to humans and marine life when deposited in water bodies (Williams et al, 2003)**.** The process of developing an effective erosion management design requires the identification of erosion prone areas (Lim et al., 2005). This is carried out in many places of the world using models (Lim et al., 2005). These models are "Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995), Chemical Runoff and Erosion from Agricultural Management Systems (CREAMS) (Knisel, 1980), European Soil Erosion Model (EUROSEM) (Wischmeier and Smith, 1978; Flanagan and Nearing, 1995; Arnold et al., 1998; Morgan et al., 1998)". The USLE has been widely used and accepted regardless of their characteristic uncertainties (Reckhow, 1979; LaBaugh and Winter, 1984; Kinnell, 2001). The USLE is developed to evaluate the average yearly soil loss in areas having identified crop controlling practice and rangeland (Renard et al., 1997). The processes involved in modelling of non-point source pollution include sediment detachment calculation, overland flow delivery process, stream network delineation, total flow path

delivery ratio and annual sediment loading (Levine et al., 1993; Kinnell, 2001). The detachment and mobilization of sediments are caused by rainfall. Rainfall's impact on the ground detaches sediments and nutrients which are then mobilised and washed away depending on the energy of overland flow (Levine et al., 1993). The USLE is used to calculate erosion within grid cells when the watershed has been demarcated as a sequence of grids (Wischmeier and Smith, 1978). USLE model results from features that influence soil loss through sediment transport like soil type, climate vegetation cover, landscape (Lufafaa et al., 2002). The USLE estimates the possible annual sediment load (Wischmeier and Smith, 1978) and on a time series (Knisel, 1988).
The study aims to implement a spatial model for watershed management in Timber Creek, Cooke County, Texas, USA.

3. METHODOLOGY AND DATA

The area of study is the Timber Creek watershed, in Cooke county of Texas, USA. The area covers different landscape made up of shallow, stony clay loam that influences the growth of oak, juniper and shrubs (Emerson, 2012).

Soil data containing different soil types within a watershed collected by National Soil Conservation Service with each soil type having attributes of permeability and soil erodibility. Land use data composed of 7 land use types within the watershed compiled in raster format from the Centre for Remote Sensing and Land Use Analysis. This was derived by classifying 1986 Multispectral scanner image. A Digital Elevation Model (DEM) of the watershed got from USGS. The DEM was created from digitized 1:24,000 scale 7.5 minute quadrangle colour map.

3.1 THE MODEL

3.1.1 SEDIMENT DETACHMENT

This step involves modelling the total sediment load. It was calculated using the USLE defined as A= R*K*L*S*C*P.
ArcGIS 10.1 tools were used to build the model using spatial analyst tools (slope, flow length, flow direction. The first step involved incorporating the slope and DEM.
The slope was then reclassified to get the slope length (in meters). This was done to reclassify the slope into 3 classes and assigning new values to it.
0.5 show slopes > 4%
0.4 show slopes = 4%
0.3 show slopes < 4%
The reclassify tool in ArcMap is did not support the use of float values therefore, the reclass values were multiplied by 10. The flow direction tool was introduced to aid in estimating the slope length; this was followed by the flow length tool. Both the flow length and flow direction were given appropriate output names and saved.
The reclassified slope, flow length parameters were then used to generate the slope length using the Raster calculator tool in ArcMap. The slope length equation used in is given below:
$\boldsymbol{L = (I / 22)^x}$ (Schwab *et al.,* 1981):
Where; *l* = length of flow (meters), X = slope factor. Here the reclassified slope that was earlier multiplied due to the reclassify tool not supporting float values was divided by 10 to return the values back to float. The raster calculator tool was again useful in estimating the Slope Steepness Factor (S). Using the formula shown below;
$S= (0.43 + 0.30s + 0.043s^2) / 6.574$ (Schwab et al., 1981). Where s = percent slope
The final part of stage one was to estimate the total annual sediment detached using the USLE. USLE is defined as A= R * K * L * S * C * P
R = Rainfall (R equals 616 tons per hectare for this watershed. 1 hectare = $10{,}000m^2$. To convert hectare to square meters (616 / 10,000) =0.0616 tons per m^2. The Cell resolution is 21.21212121 by 21.21212121, the area of each cell is $449.954086m^2$.
Thus, the rainfall per cell = 0.0616 × 449.954086 (27.171717 tons/cell/year).
K = Soil Erodability factor (lookup_K), L = Slope Length factor (Slopelength).
S = Slope Steepness factor (Slopesteepp), C = Cover and Management factor (CL), P = Support Practice factor (conservation practice). The P-factor used is for low range slopes (between 2 and 7%). Since Way Roberts watershed average slope is <2%; hence, P = 0.2 for the entire Timber Creek watershed (Levine et al 1993).

3.1.2 OVERLAND DELIVERY PROCESS

This stage shows the effect of surface conditions such as soil permeability, slope and vegetation cover on the transportation of sediments and nutrients as they are being moved to a river channel (Levine et al., 1993). This was achieved by generating another slope (degree) and a raster calculator was also introduced to the model. The next step involved estimating the Delivery Ratio; this was done by subtracting the trapping efficiency from 1 in the raster calculator.

3.1.3 STREAM NETWORK DELINEATION

This stage involved delineating the streams in the watershed and allocating a delivery ratio of one to the cell in the streams. This was achieved using the flow accumulation tool to delineate permanent streams form temporary streams. Levine et al., 1993 posited that if the threshold of contributing cells is fifteen and above, they are considered as permanent streams but those that have threshold of 14 and below are temporary streams. The flow accumulation tool was introduced to the model at this stage. A conditional tool was added to the model and the condition was expressed as "Value <15 to satisfy for the delineation of temporary streams (<15) from permanent streams (>=15). A second conditional tool was introduced to the model to assign the temporary and permanent streams. This was done to allow the temporary streams continue in the stream network and the permanent streams (cells >= 15) merging to delivery ratio to produce the total delivery ratio of permanent streams in the watershed only.

3.1.4 TOTAL FLOW PATH DELIVERY RATIO

This stage was achieved using the raster calculator to determine the total flow path delivery ratio using the equation, [Cell delivery ratio] * [Flow accumulation] / (watershed maximum flow accumulation).

3.1.5 TOTAL ANNUAL SEDIMENT LOADINGS

Again the raster calculator was introduced to calculate the total annual sediment load conveyed to the watershed. The final stage was to calculate the total annual load in the whole watershed (tonnes/watershed/year). The watershed was initially digitized and saved as a shapefile and a zonal statistics tool was introduced to the model.

4. RESULTS AND DISCUSSION

The Rainfall runoff factor, R is obtained from yearly rainfall dataset of the watershed. It is also known as the erosivity index and is equal to 616 tons per hectare for this watershed by the US Soil Conservation Service. The Cover and Management factor, C shows influence of crop controlling practice related to land use and land cover types and conservation processes (Levine et al., 1993; Renard et al., 1997; Fua et al., 2004). The US Soil Conservation Technical Document gives the C values and their associated land use type ranging from barren land, developed, pasture, rangeland, pasture, water and forest. The soil erodibility factor, K is derived from the local county soil survey tables. It is an empirical index that illustrates the proneness of soil to erosion influenced via some inherent soil characteristics like organic matter, structure and permeability (Fua et al., 2004). The support practice factor, P defines the link between erosion mitigation measures like contour planting, terracing and strip cropping. The P factor value is dependent on the average slope steepness in the watershed (Levine et al., 1993). The Slope Length factor (L) and the Slope Steepness factor (S) is dependent on slope of the topography and the sediment transport within a network of cells depend on overflow upslope, slope length factor (Kinnell, 2010).The predominant flow direction in the image is towards the Northern part of the study. The flow direction values as shown in the image map ranges from 1 to 128. Flow length signifies the distance in which water and pollutants are conveyed through a cell. The flow length out of a cell is equivalent to the cell resolution in the image for horizontal and vertical flows (UNITAR, 2009). Flow accumulation can be used to estimate the number of cells flowing into any one cell, centred on each cell's direction of flow. The flow accumulation ranges from 0 (low) to 249471 (high) in the map above. The total annual sediment loss map shows that the sediment loss is more at the North West portion of the watershed and the total annual sediment detached is 87.755 tons/cell/year which is abysmally low for a watershed compared to estimates of 1032.86 tons/cell/year from Levine et al., 1993. Some errors resulting from uncertainties must have contributed to this. This is discussed extensively in the report stating the Likely reasons for this low value.

Exact figures were not stated in Levine et al., 1993 report detailing if they were for a cell or the total for the whole Timber Creek's water shed. Kinnell, 2010 observed from results obtained using data collected during field experiments based on US natural precipitation and concluded that the USLE was aimed at estimating soil losses. The main advantage of the USLE is the availability of data and its solid empirical background (Levine et al., 1993). The Revised Universal Soil Loss Equation (RUSLE) has been modified detailing how the 6 parameters of USLE are estimated and its application in crop management practice (Kinnell, 2010). The RUSLE model provides a method used in modelling one dimensional hill slope devoid of deposition because of variations in slope gradient (Kinnell, 2010. The advantage of using a RUSLE model is that its data requirements are not difficult or unachievable, it is simple to fathom, apply and most importantly its ability to be integrated in a GIS (Milward and Mersey, 1999). Levine et al., 1993 referred to this stage of the model as "representing the influence of surface conditions such as soil permeability, slope and vegetation density on the transport of sediments and nutrients during movement towards a stream channel. The values here range between 0.00477076 (low): 1 (high). The widely used methods of delineating contributing streams depend on soil properties, vegetation and relief (Levine et al., 1993). The cell delivery ratio doesn't distinguish cells within and outside the stream (Levine et al., 1993). Different densities of network produce different model output because of change in the single cell delivery ratios and the entire flow path delivery ratios. The process of changing the density enables the models to be run repeatedly and the output compared with observed sediment and nutrient loads and finally selecting a drainage density network suitable for the model. Levine et al., 1993 applied this method to adjust the model. The stream network image above shows the number of cells that flows into a cell depending on the direction of flow in each cell. The values will tend to increase from higher elevations in the watershed to the streams. A threshold was applied to delineate the stream network resulting in permanent and temporary streams with the temporary stream a result of storm activity, hence the lower the threshold the higher the network density (UNITAR, 2009). The coloured line shows the stream network and the watershed outlet is in the southern part of the map.

This constitutes the portion of the delivery load that is carried to the watershed channel while the delivery ratio is the load likely to be conveyed to the ensuing cell along the flow path. The model assumes that all sediments conveyed do not get to the watershed therefore the portion that gets to the watershed (Total flow path delivery ratio) is estimated. The values for the total flow delivery ratio range from 0 (low) to 0.999958 (high). There is an observable difference between the estimates of Levine et al 1993, UNITAR, 2009 and the new model estimate each having estimates of 1444.03 tons/year, 1417.408 tons/year and 566.748 tons/year respectively with a percentage difference of 60.8% for Levine et al., 1993 and 60% for UNITAR, 2009 (see table 2). However the strength of the model depends on the comparative spatial variations instead of the exact value got (Hoyos, 2005). The erosivity index for rainfall was given as 616tons/ hectare while the model used cells instead this could be a source of error. Levine et al., 1993 gave the size of the watershed as 10215.20 hectares. The estimates of the total load were observed to be low as compared with Levine et al., 1993 and UNITAR, 2009 estimates; this may be due to the fact that the initial potential load, (A) from the Universal Soil Loss Equation was low as well. Previous research followed when designing the delivery model contained high loads of organic matter that can be conveyed freely than sediment, this entails that that model isn’t suitable for inorganic matter transport that make up most sediments in a watershed.

Levine et al., 1993 also attributed the model’s poor performance based on assumption that 100% stream transport is likely impossible for sediment transport. It normally takes one hundred (100) years for a stream to cleanse its entire sediment (Schumm, 1972). However the quantity of sediment moving in a stream at a particular period of the year is equivalent to the quantity distributed to the stream from neighbouring streams in order to maintain a balance between the sediment distribution and network of deposition and transportation. The USLE has been the extensively used and misrepresented prediction estimator developed to envisage long-term average yearly soil loss. This has been done in some geographical locations efficiently and not properly at other locations.

There are some uncertainties associated with the model which may give a conflicting estimate of model final outputs. This may not be limited to issues of bad pixel in the DEM leading to it being corrected (pre-processing of the DEM), software functionalities used, model limitations and the dataset used (the data used had a low spatial resolution which significantly affects soil loss estimates) (Levine et al 1993; School, 2000). Their joint influence on the model output would be multiplicative (Hoyos, 2005). A National Research Council Ground water Vulnerability Assessment, (1993) stated that uncertainties associated with modelling non- point source modelling are normally derived from; Model related errors (uncertainty arising from insufficient or imperfect implementation of the model processes), data related errors arising from errors during data input, even if model is correct (Logue and Green, 1990) and parameter error. Parameter errors have two likely implications. Most models needing calibration have parameter errors arising from model parameters that are inter-related and vague. While parameter error in models having physically related parameters arise from the failure in representing distributions for inadequate number of point estimations. Burrough and McDonnell (1998) stated that it is possible to enumerate these uncertainties using analytical method or a Monte Carlo model. Practically it is challenging to crudely estimate the errors related to all the individual factors in the USLE (Van der Knijff et al., 2000). Similarly some individual factors are inter-related hence this may cause a great effect on the model outputs.

The accuracy of any meaningful estimate can be influenced by the capability of the model to give a justification for the effect of the physical parameters initiating the final result and the precision in determining the factors (Kinnell, 2010). The USLE model requires a great effort to achieve correct parameters to run (Kinnell, 2010). The USLE as mentioned earlier are used in watershed modelling to observe influence of land use on water quality. They do this by extrapolating data obtained at larger areas than originally designed field sized areas. Therefore the USLE is not entirely suitable for modelling the delivery of sediment. Other models such as the Water Erosion Prediction Project (WEPP), CREAMS, ANSWERS, AGNPS, Soil and Water Assessment Tool (SWAT), European Soil Erosion Model (EUROSEM) and the RUSLE are better suited (Wischmeier and Smith, 1978; Levine et al., 1993; Morgan et al., 1998).

CONCLUSION

The USLE model is appropriate for envisaging erosion if data and methodical processes encompass GIS. However it is not be considered as a final and true depiction to predict erosion (Nyhan and Lane, 1986).

Therefore, the USLE model will possibly be incorporated to model the time-based and spatial distinction in soil erosion in several watersheds in the future and there is advantage in improving the ability of the model in doing this (Kinnell, 2001). Finally results of the model show consequences for water management. Pollutants contributing areas which are areas of high flow delivery ratio can be easily identified due to the spatial character of the model (UNITAR, 1996,2001,2005,2007 and 2009).

REFERENCES

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., (1998). Large area hydrologic modeling and assessment part I: model development. Journal of American Water Resources Association 34 (1), 73–89.

Burrough, P.A. and McDonnell, R.A. (1998): Principles of Geographical Information
Systems. 2nd Edition, Oxford University Press.

Corbitt, R.A., (1990). Standard Handbook of Environmental Engineering, McGraw-Hill, New York, New York, pp. 7.50-7.57.

Corwin, D. L., Vaughan, P. J. and Loague K. (1997). Modelling Nonpoint Source Pollutants in the vadose Zone with GIS. Environmental Science and Technology. 31; 8, 1997.

Eisakhani, M., Pauzi, A., Karim, O., Malakahmad, A., Kutty, S. R., and Isa, M. H. (2009). GIS-based Non-point Sources of Pollution Simulation in Cameron Highlands, Malaysia. International Journal of Civil and Environmental Engineering 1:3 2009.

Emerson, T. L. (2012). "TIMBER CREEK (COOKE COUNTY)," *Handbook of Texas Online*. The Texas State Historical Association. Available at [http://www.tshaonline.org/handbook/online/articles/rbt52] Accessed 25th March, 2013.

Environmental Protection Agency (2013). What is Nonpoint Source Pollution
Available at [http://water.epa.gov/polwaste/nps/whatis.cfm] Accessed on 4th May, 2013.

Flanagan, D.C., Nearing, M.A., (1995). USDA Water Erosion Prediction Project:
Hillslope Profile and Watershed Model Documentation. NSERL Report No. 10,USDA-ARS National Soil Erosion Research Laboratory

Fua, G., Chena, S. and McCoolb, D. K. (2004). Modeling the impacts of no-till practice on soil erosion and sediment yield with RUSLE, SEDD, and ArcView GIS Elsevier Science B.V. Soil & Tillage Research 85 (2006) 38–49

Hoyos, N., (2005). Spatial modelling of soil erosion potential in a tropical watershed of the Colombian Andes. Elsevier Science Catena 63(2005) 85-108

Hubbard, M. (2007). Nonpoint Source Pollution and Geographic Information Systems http://dusk.geo.orst.edu/gis/student_bibs/hubbard.html

Kinnell, P. I. (2001). Slope length factor for applying the USLE-M to erosion in grid cells. Soil & Tillage Research 58 (2001) 11-17. 2001 Elsevier Science B.V.

Kinnell, P. I. (2010). Event soil loss, runoff and the Universal Soil Loss Equation family of models. Journal of Hydrology, Elsevier Science B.V. 385, 384–397. www.elsevier.com/locate/jhydrol

Knisel, W. G. (ed.). (1980). CREAMS: A Field-scale model for chemicals, runoff and erosion from agricultural management systems. Conservation Research Report *20.* U.S. Department of Agriculture, Washington, D.C.

LaBaugh, J.W. and Winter, T.C. (1984). The impact of uncertainties in hydrologic measurement on phosphorus budgets and empirical models for two Colorado reservoirs. Limnol. Oceanogr. 29(2):322-39.

Levine, D. A., Husaker, C. T., Timmins, S. P. and Beauchamp, J. J. (1993). A Geographic Information System approach to modelling nutrient and sediment transport. Oak ridge national laboratory, Environmental science Division, Publication No 3993. Oak Ridge, TN: Oak Ridge national Laboratory.

Lim, J. K., Sagong, M., Engel, B. A., Tang, Z., Choi, J. and Kim, K. (2005). GIS-based sediment assessment tools. Elsevier.

Loague, K. and Green, C.C.K. (1990). Criteria for evaluating pesticide leaching models. In Field-scale Water and Solute Flux in Soils, Roth, K., Fluhler, H., Jury, W. A. and Parker, J. C. eds. Basel, Switzerland: Birkhauser Verlag.

Lufafaa, A., Tenywaa, M. M., Isabiryeb, M., Majaliwaa, M. J and Woomerc, P. L. (2002). Prediction of soil erosion in a Lake Victoria basin catchment using a GIS-based Universal Soil Loss model. Agricultural Systems 76 (2003) 883–894.

Millward A. A., Mersey J. E. (1999). Adapting the RUSLE to model Soil erosion potential in a mountainous tropical watershed. Catena, 1999; 38: 109－129.

Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D., Styczen, M.E., 1998. The European soil erosion model (EUROSEM): a dynamic approach for predicting sediment transport from fields and small catchments. Earth Surface Processes and

Landforms 23, 527–544.
National Research Council, (1993). Ground Water Vulnerability Assessment: Contamination Potential under Conditions of Uncertainty. Committee on Techinques for Assessing Ground Water Vulnerability (242), Water Science and Technology Board Commission on Geosciences, Environment and Resources National Research Council. National Academic Press Washington, D.C. p.80
Novotnoy, V. and *G.* Chesters. 1989. Delivery of sediment and pollutants from nonpoint sources: A water quality perspective. J. Soil Water Conser. 44(6):5
Nylan, J. W. and Lane, L.J. (1986). Erosion Technology: A User's Guide to the Use of the Universal Soil Loss Equation at Waste Burial Facilities. Los Alamos National Laboratory Los Alamos, New Mexico 87545.
Reckhow, K.H. (1979). Empirical lake models for phosphorus: development, applications, limitations and uncertainty: A manual and compilation of export coefficients. EPA 440/5-80-011. U.S. Environmental Protection Agency, Washington, D.C.
Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). USDA-Agriculture Handbook No. 703.
Schoorl, J.M., Sonneveld, M.P.W., Veldkamp, A. (2000). Three-dimensional landscape process modelling: the effect of DEM resolution. Earth Surface Processes and Landforms 25 (9), 1025– 1034
Schumm, ***S.*** A. (1972). Fluvial geomorphology. In Dowden, Hutchinson, and **Ross** (eds.), River Morphologyy. Dowden Publishing *Co.,* Stroudshurg, Pa.
Schwab, G.O., Frevert, R.K., Ediminster, T.W and Bamcs, K.K. (1981). Soil and water conservation Engineering. 3rd ed. John Wiley, New York.
United Nations Institute for Training and Research (2009): Applications of Hazard Assessment and Management: Non-Point Source Pollution Modelling. Exploration in Geographical Information Technology Volume 6, Eds Srinivas Emani and Clark Labs. Clarks University, Worchester, MA 01610 USA
Van der Knijff, J. M., Jones, R. J. A., and Montanarella, L. (2000). Soil Erosion Risk Assessment in Europe. European Commission Directorate General jrc Joint Research Centre Space applications institute (EUR 19044 EN). http://eusoils.jrc.ec.europa.eu/ESDB_Archive/pesera/pesera_cd/pdf/ereurnew2.pdf
Welch, R., Fernandes, N. and Jordan, T. (1993). GIS modelling of nonpoint source pollution with remotely sensed data. *Proceedings of the* 1993 *Georgia Water Resources Conference,* Institute of Natural Resources, University of Georgia.
Williams, J. D., Tilt, K. and Barrett, P. (2003). Reducing Nonpoint Source Pollution in Residential Landscapes. Alabama Cooperative Extension System.
Wischmeier, W.H., Smith, D.D. (1978). Predicting rainfall erosion losses. A guide to conservation planning. The USDA Agricultural Handbook No. 537.
Yoon, J. (1996) Watershed-Scale Nonpoint Source Pollution Modelling and Decision Support System Based on a Model-GIS-RDBMS Linkage. http://www.awra.org/proceedings/gis32/jyoon/.

Table 1: Total annual potential sediment load calculated

	Total Sediment (Kg/year)	Total sediment (Tons/cell/year)
Observed Estimated	937000 6230000	1032.86 6867.39
New Estimate	79609.99	87.755

Table 4: Total Annual Sediment in the Watershed

	Total Sediment (Kg/year)	Total sediment (Tons/year)	Percentage difference
(Levine et al., 1993) Observed Estimated	 9.37×10^5 1.31×10^6	 1032.87 1444.03	 28.5 %
UNITAR, 2009 Estimate	1.286×10^6	1417.408	With Levine et al., 1993 estimated value (1444.03 tons/year) 1.83 %
New Estimate	5.66748×10^5	566.748	With Levine *et al 1993,* Observed 45 %, *estimated 60.8 %. With UNITAR, 2009 estimated(1417.408 tons/year) = 60 %*

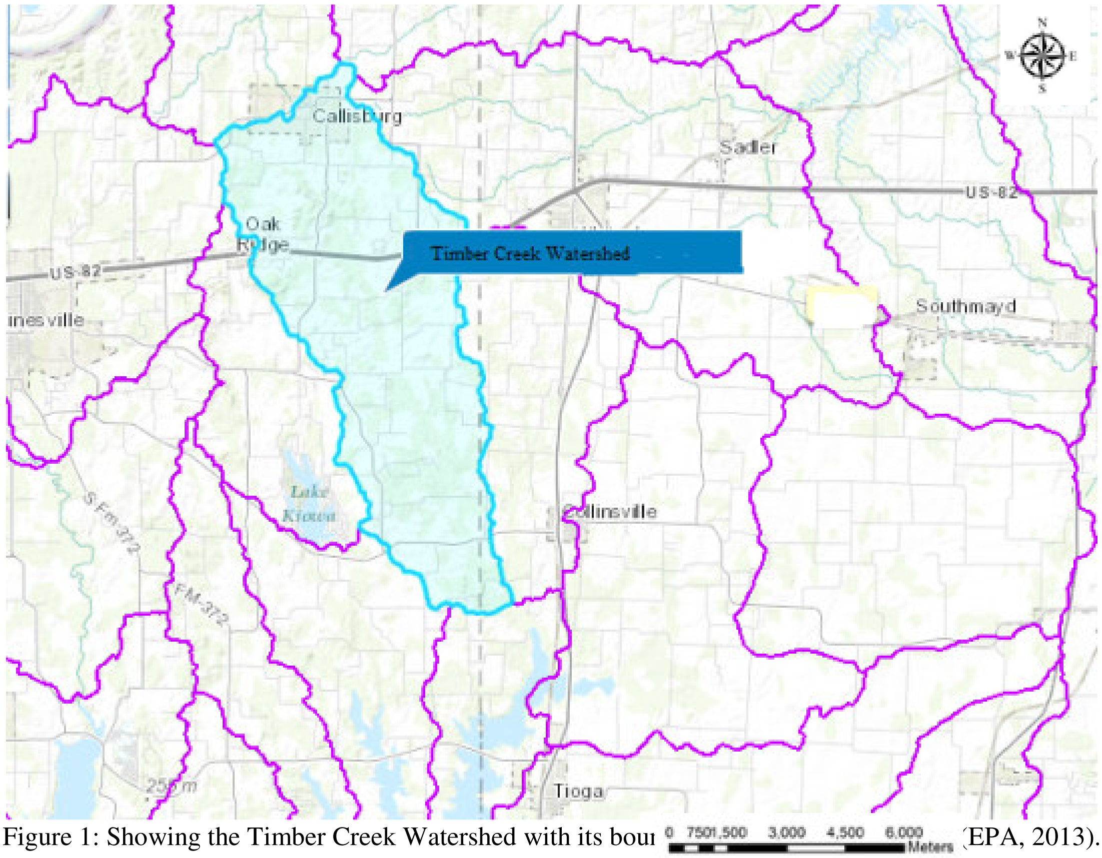

Figure 1: Showing the Timber Creek Watershed with its bour (EPA, 2013).

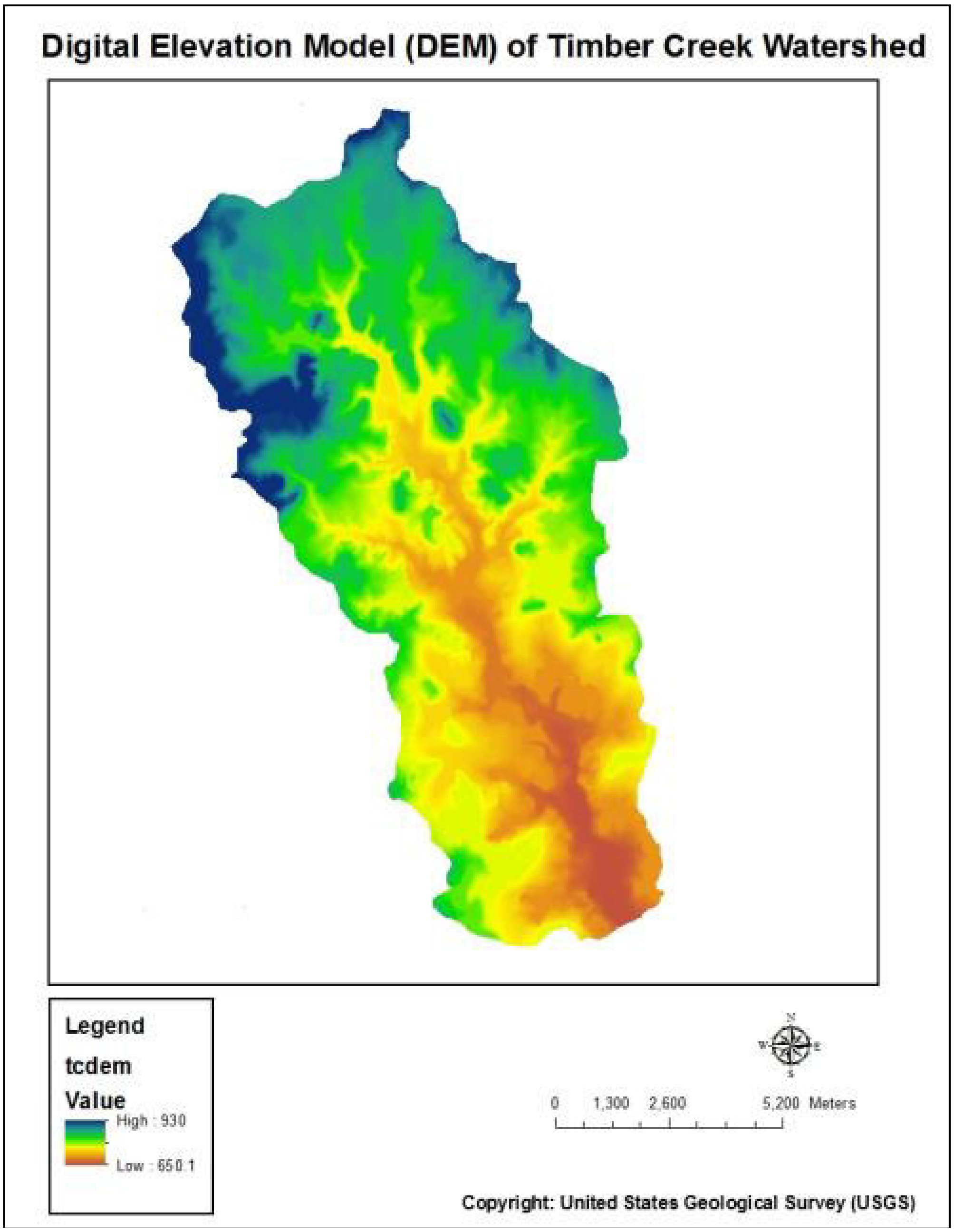

Figure 2: Digital Elevation Model (DEM) of Timber Creek watershed.

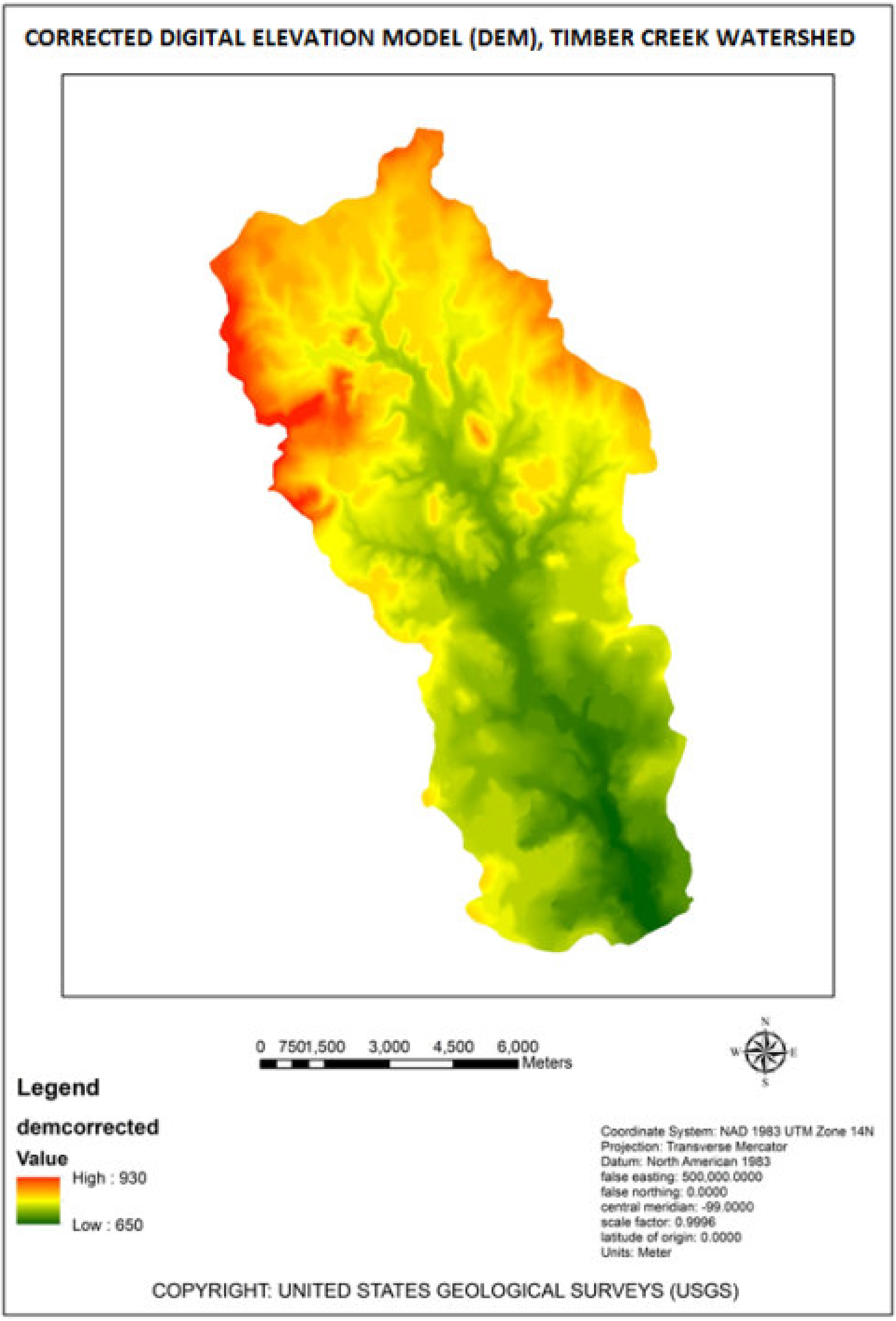

Figure 3: Corrected Digital Elevation Model (DEM) of Timber Creek watershed.

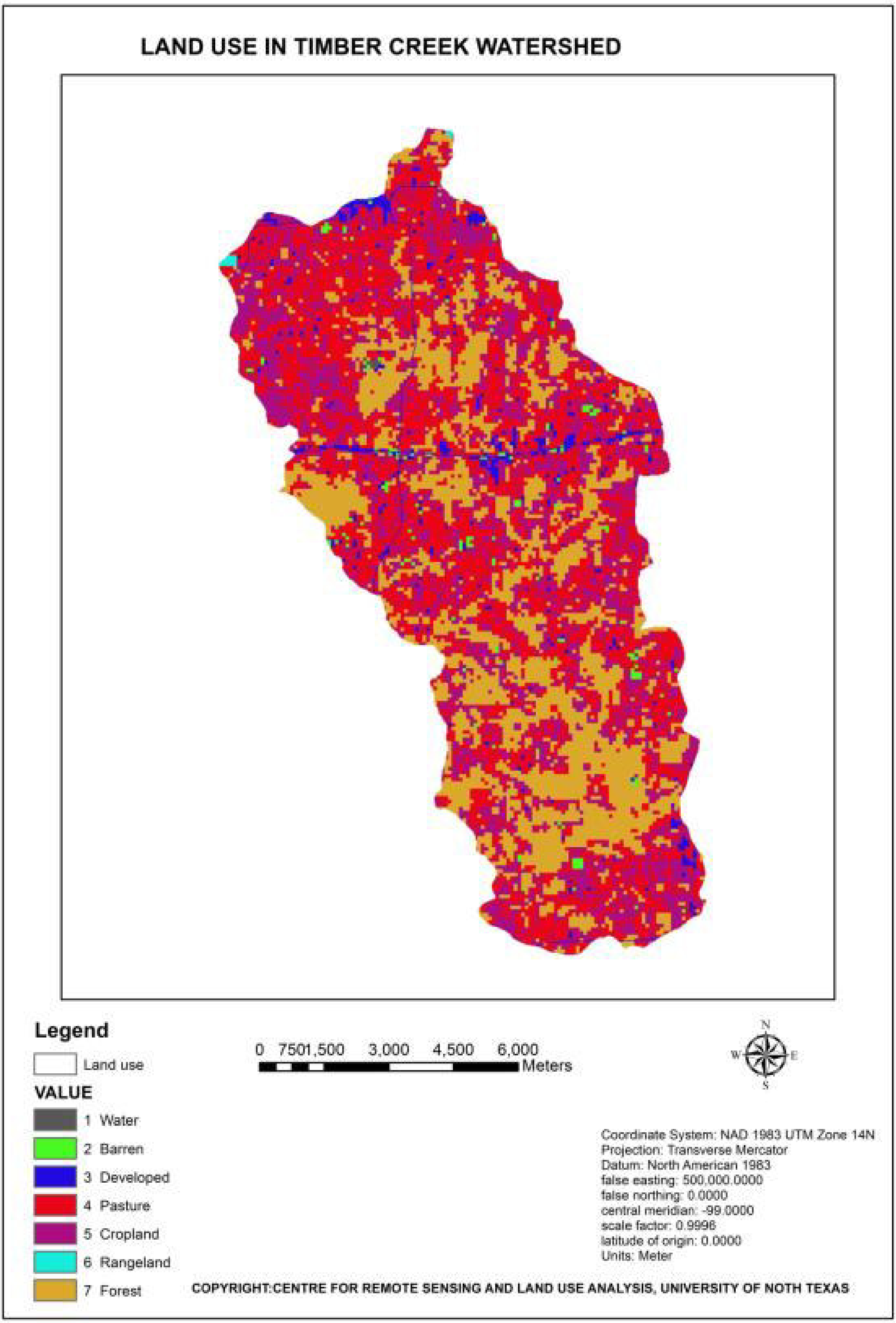

Figure 4: Land Use map of Timber Creek watershed.

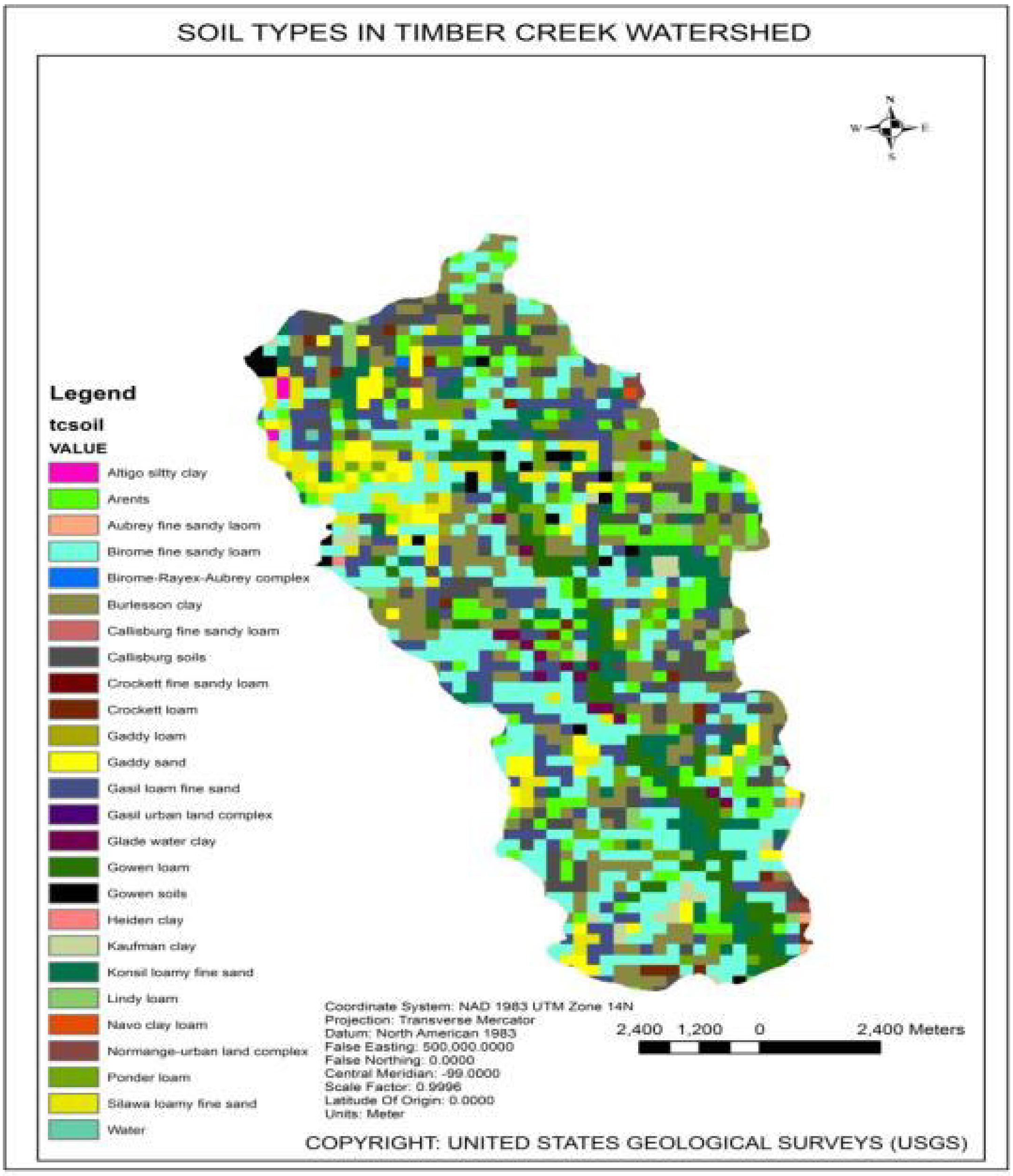

Figure 5: Map showing the different soil types in Timber Creek watershed.

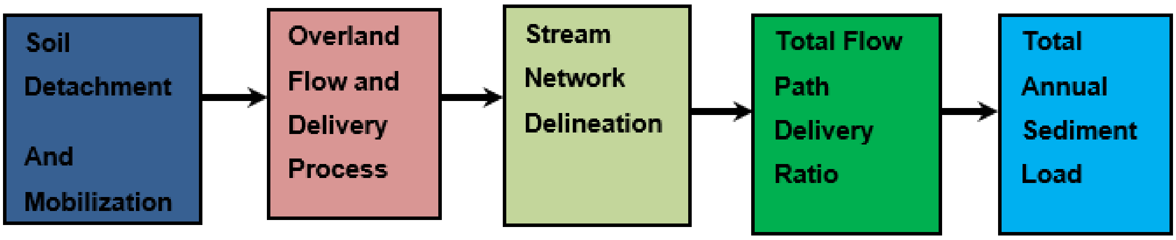

Figure 6: Methodological flow chart (After Levine *et al.,* 1993)

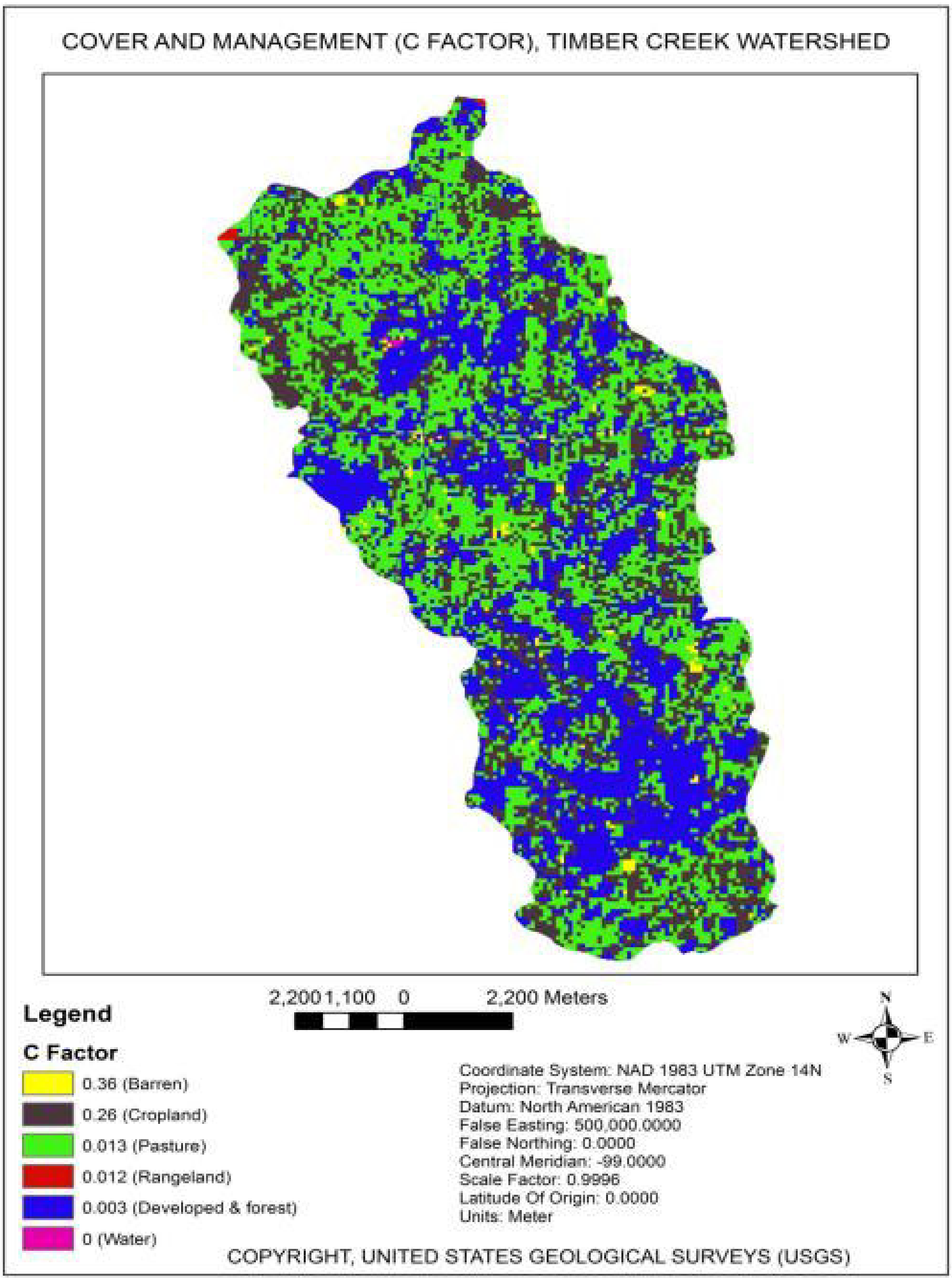

Figure 7: Spatial distribution of Cover Management (C Factor) in Timber Creek watershed.

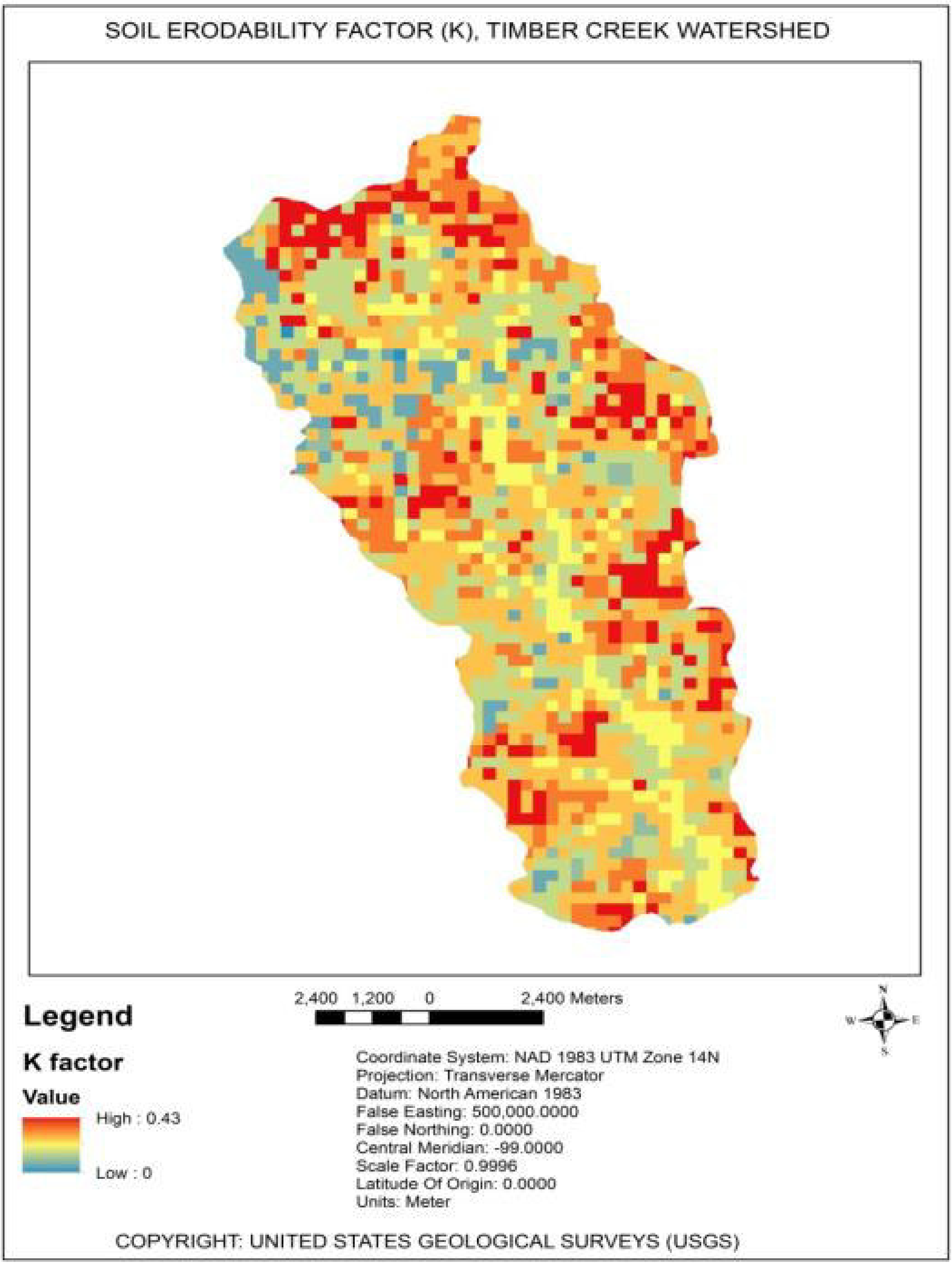

Figure 8: Spatial distribution of Soil Erodability factor in Timber Creek Watershed.

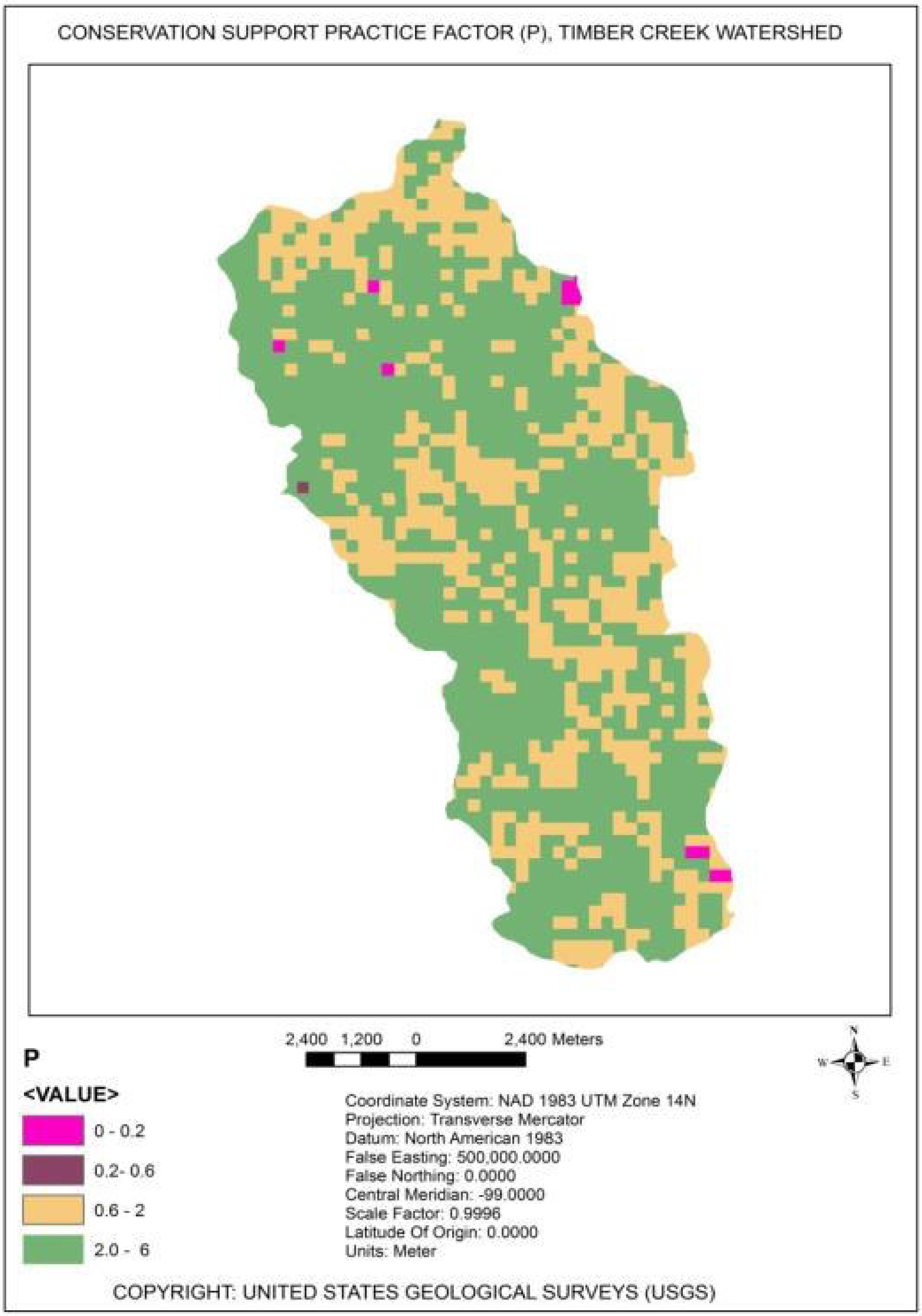

Figure 9: Spatial distribution of Conservation Practice in Timber Creek Watershed

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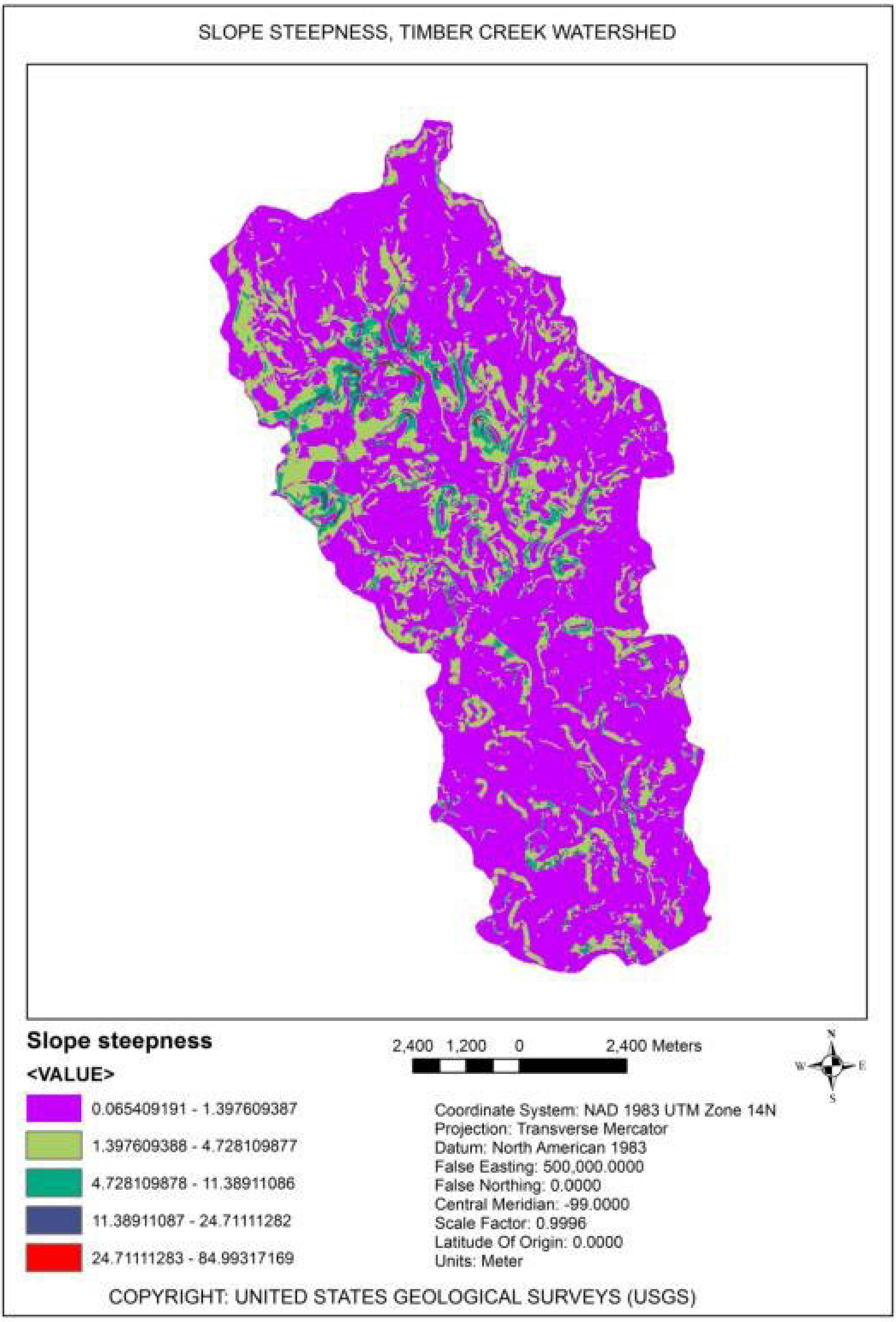

Figure 10: Slope steepness in Timber Creek Watershed

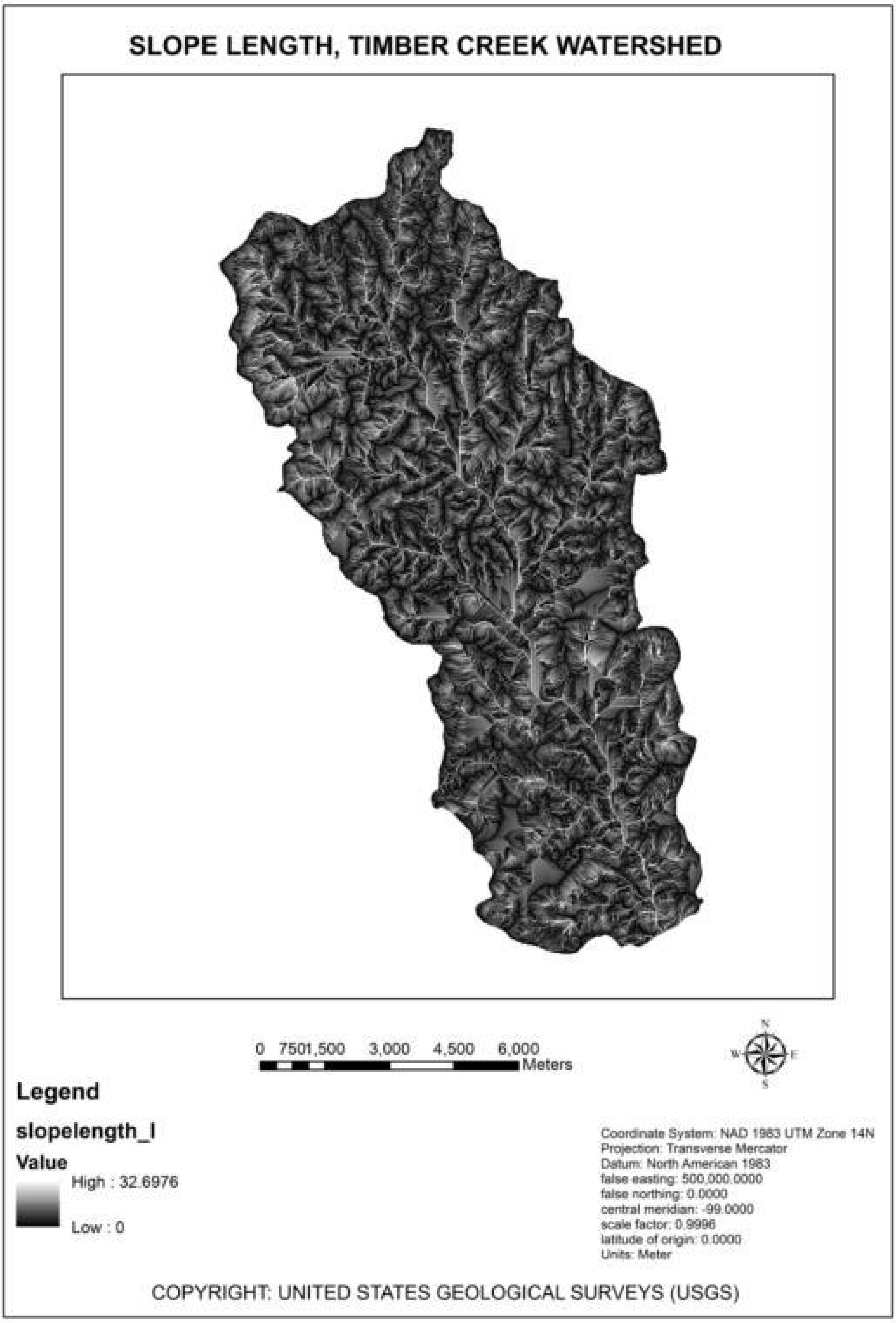

Figure 11: Slope Length map of Timber Creek watershed.

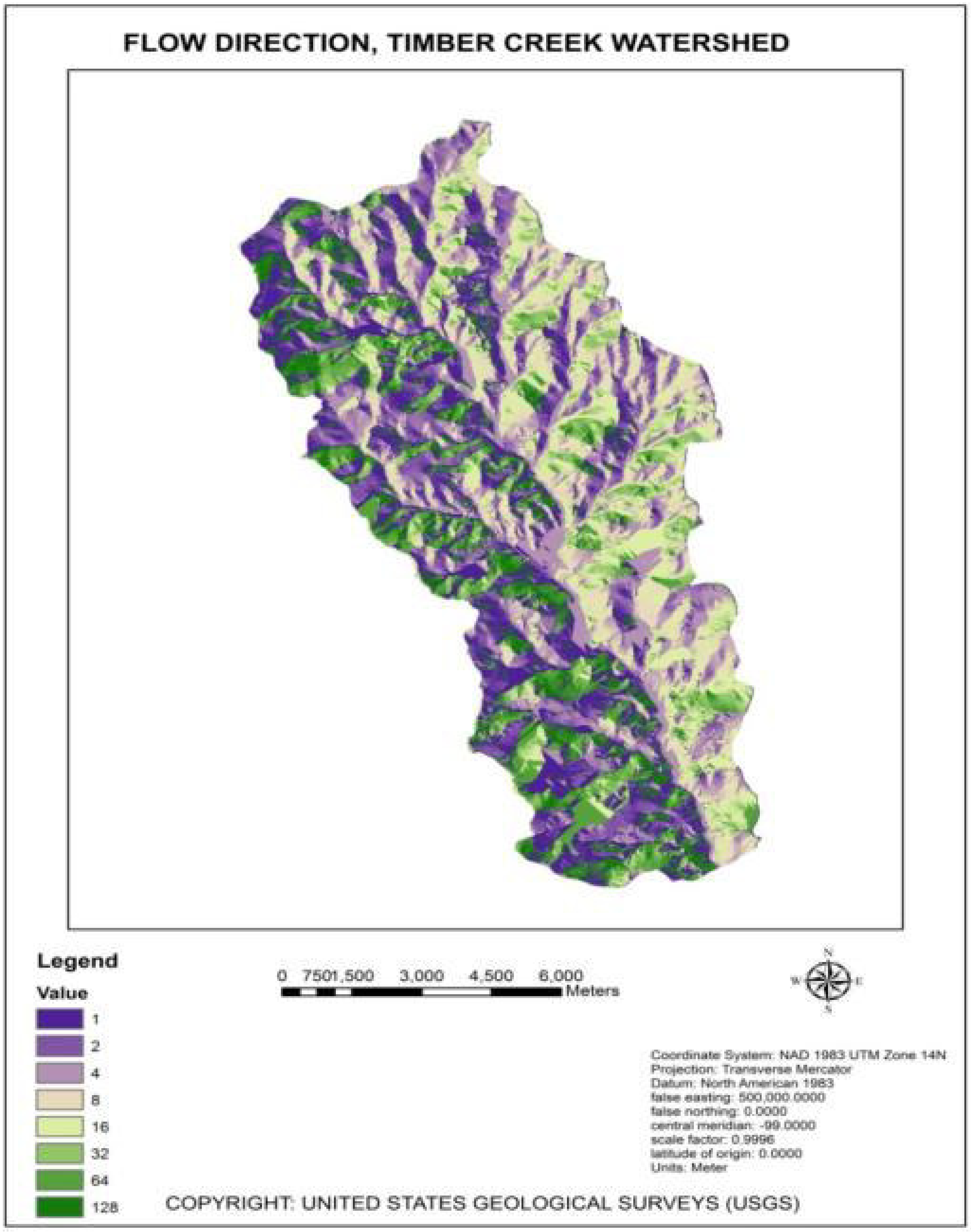

Figure 12: Flow Direction map of Timber Creek watershed.

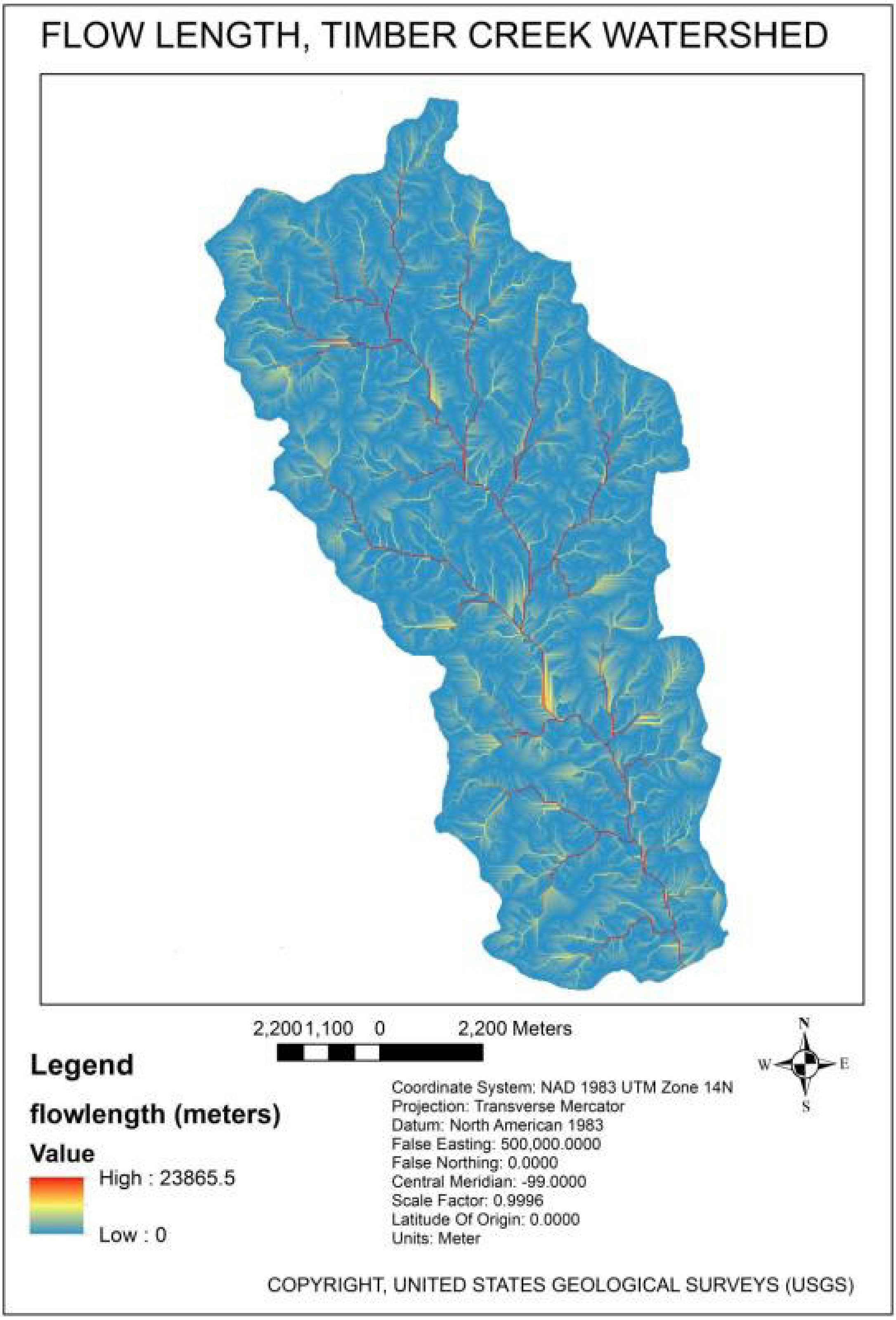

Figure 13: Flow Length map of Timber Creek watershed.

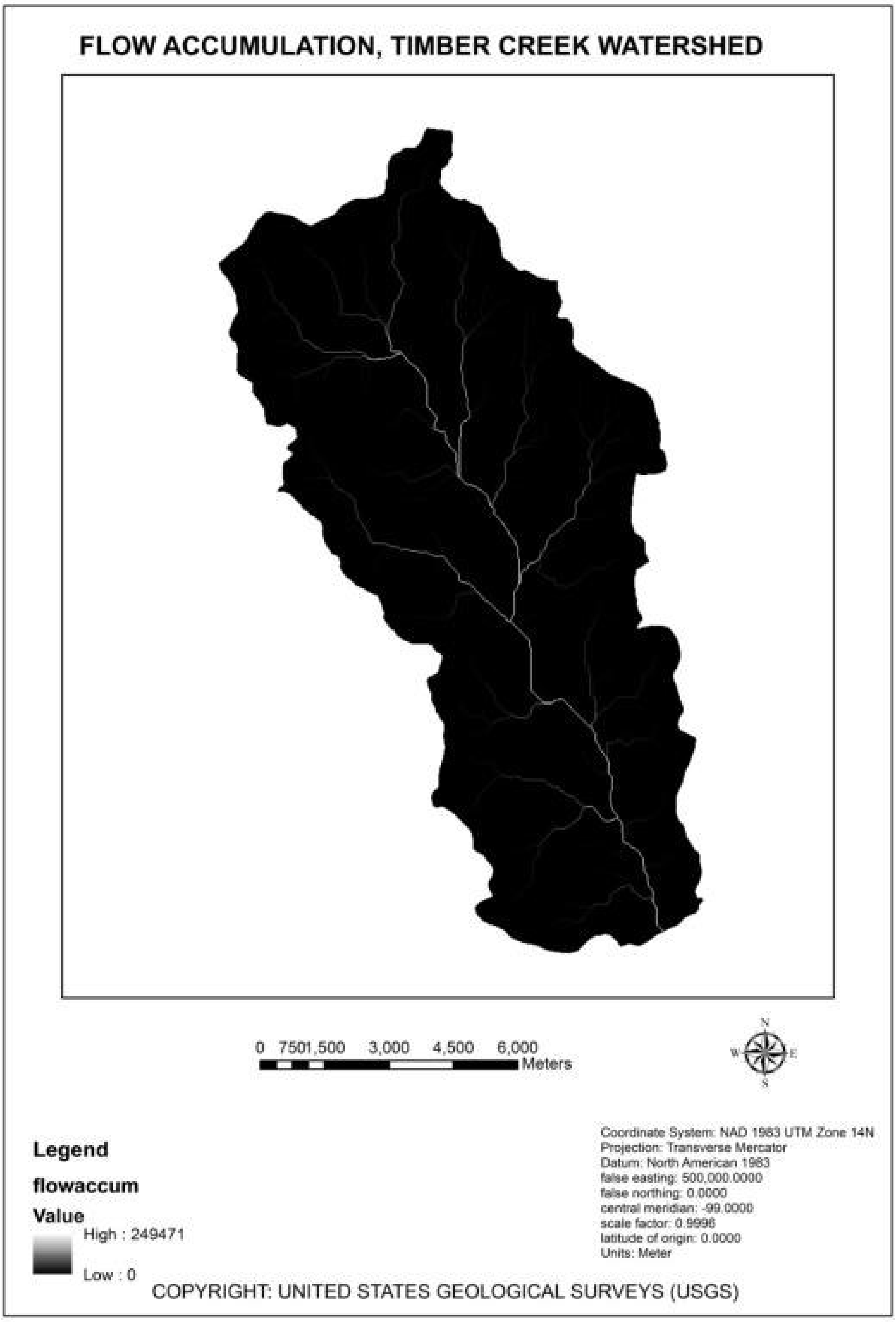

Figure 14: Flow Accumulation map of Timber Creek watershed.

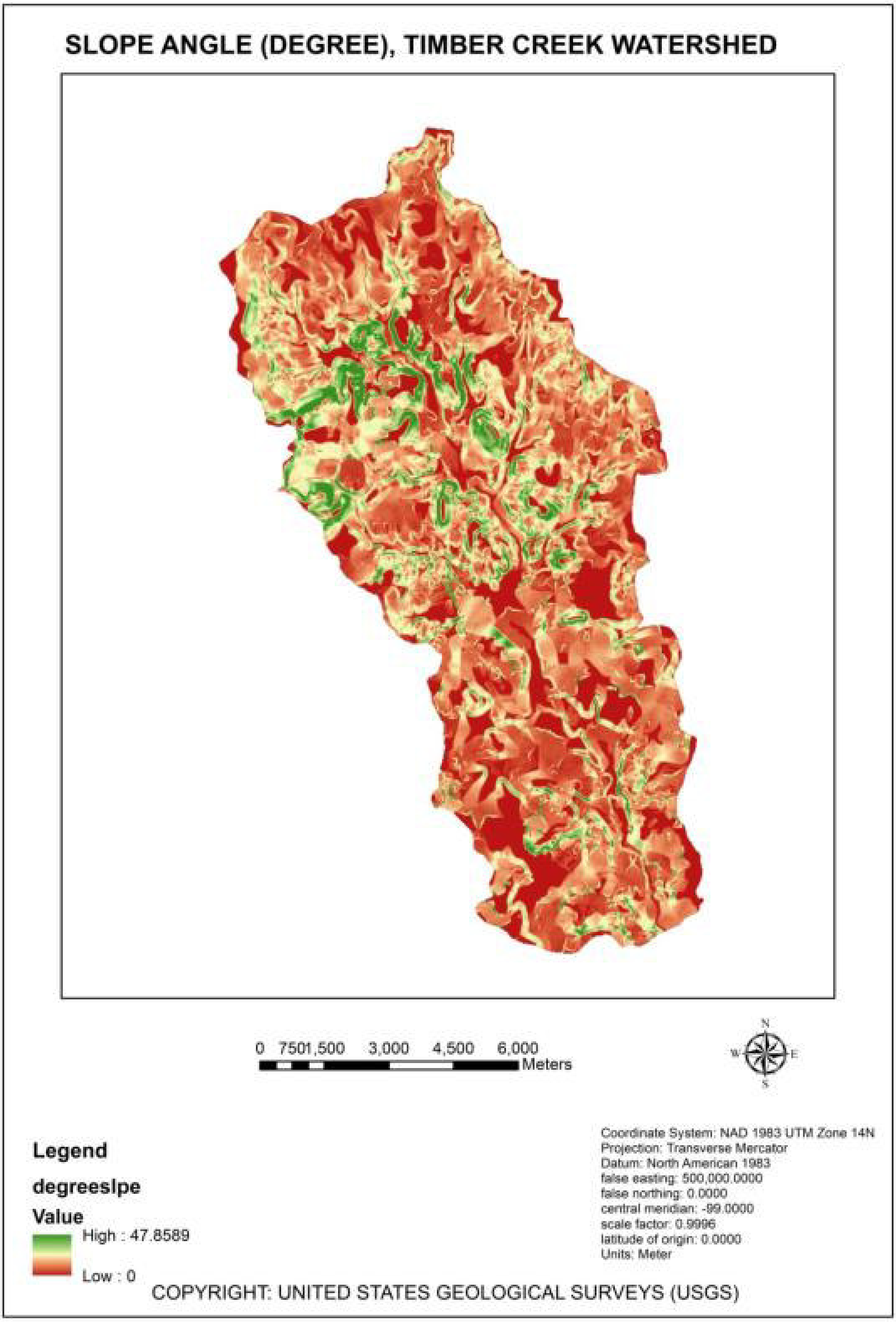

Figure 15: Slope Angle (degree) map of Timber Creek watershed.

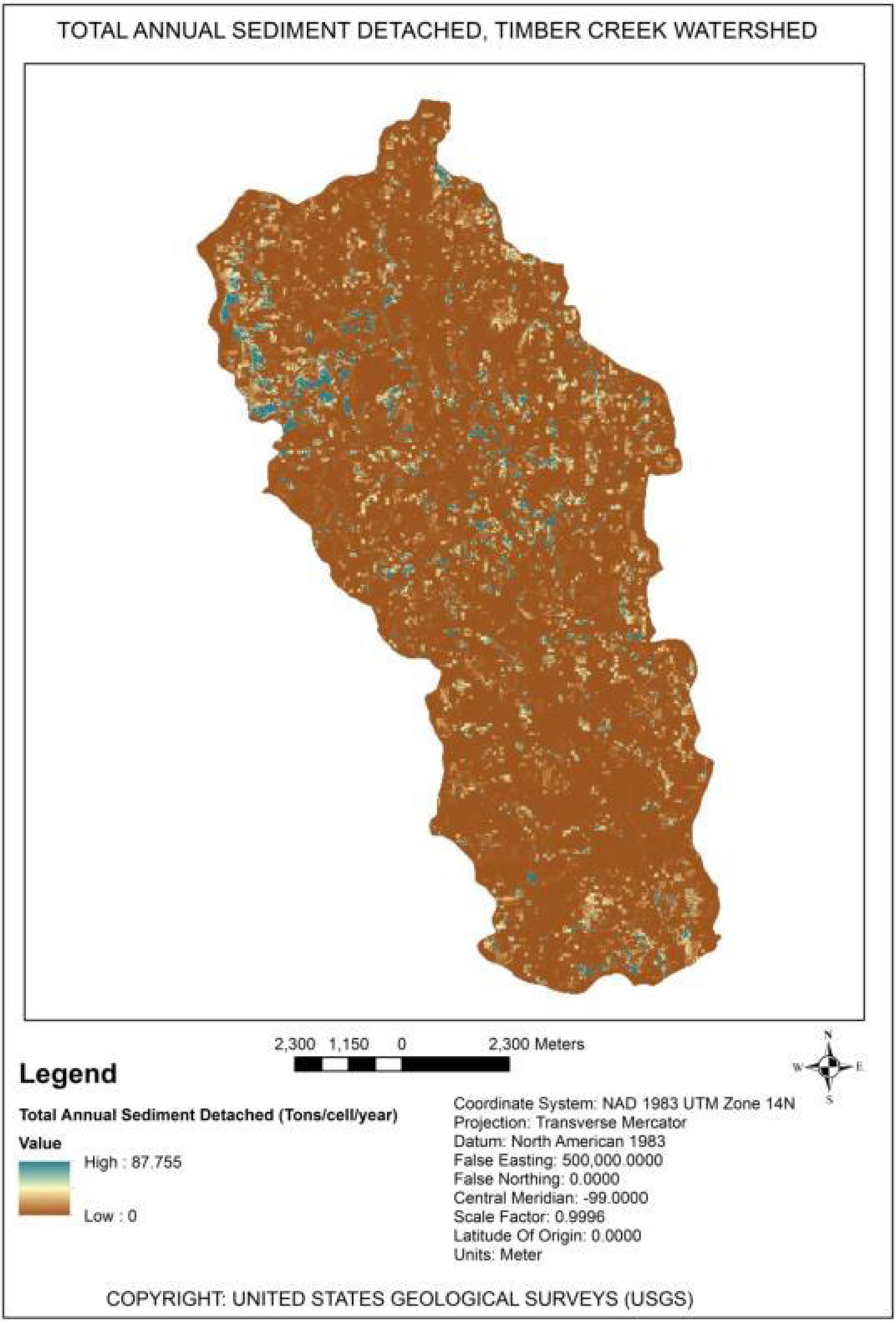

Figure 16: Total Annual Sediment Detached (A) map in Timber Creek watershed.

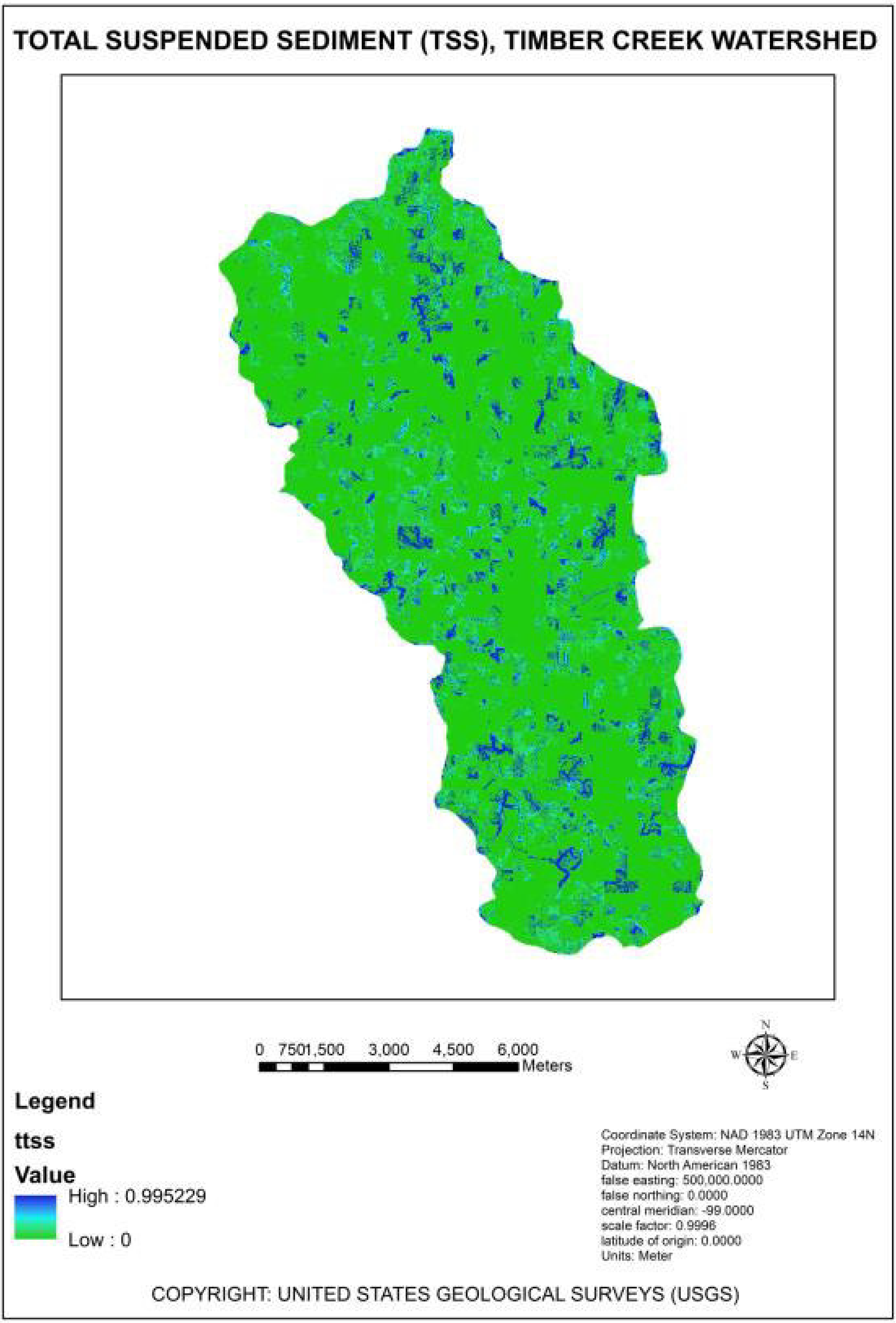

Figure 17: Total Suspended Sediment map of Timber Creek watershed.

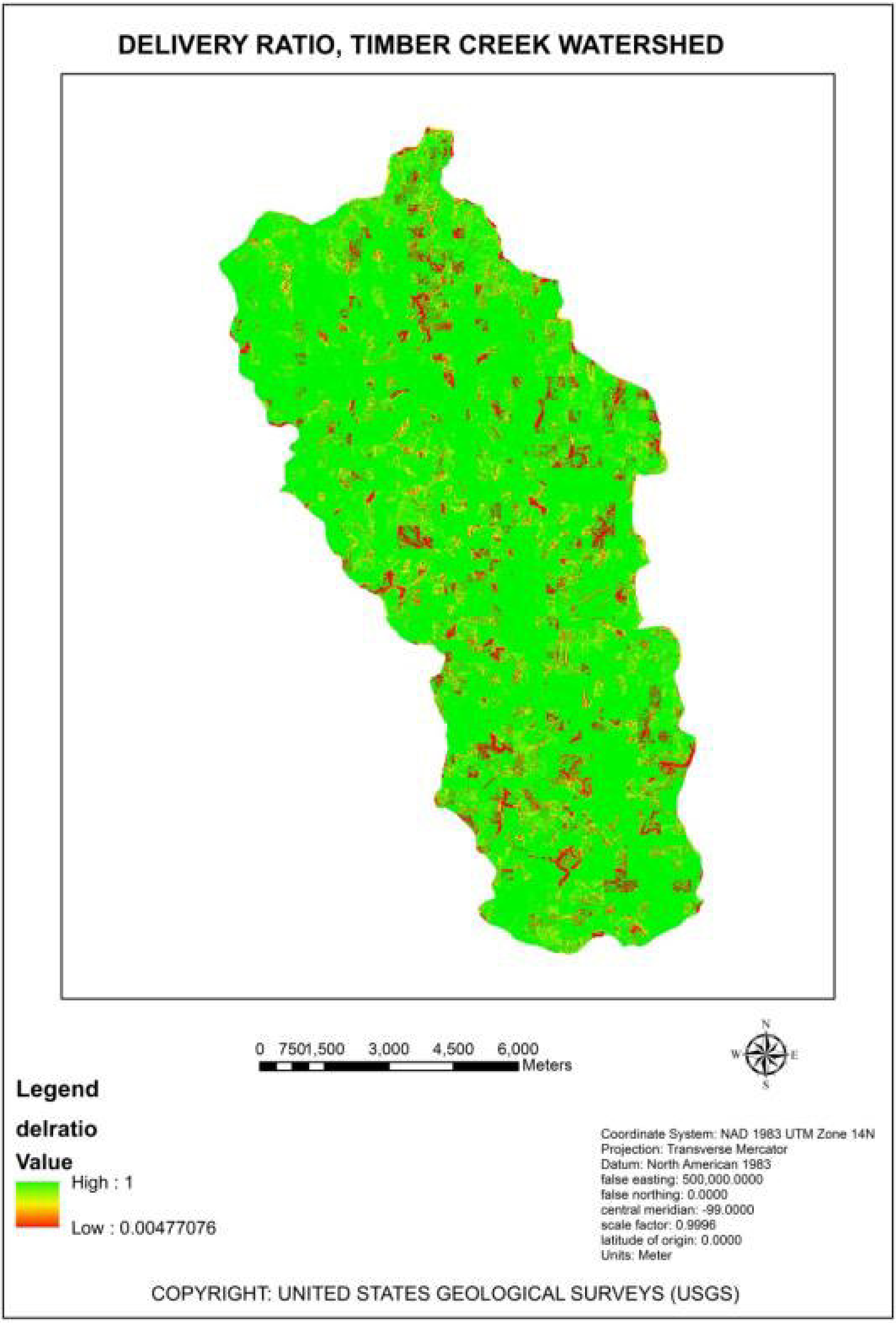

Figure 18: Delivery ratio map of Timber Creek watershed.

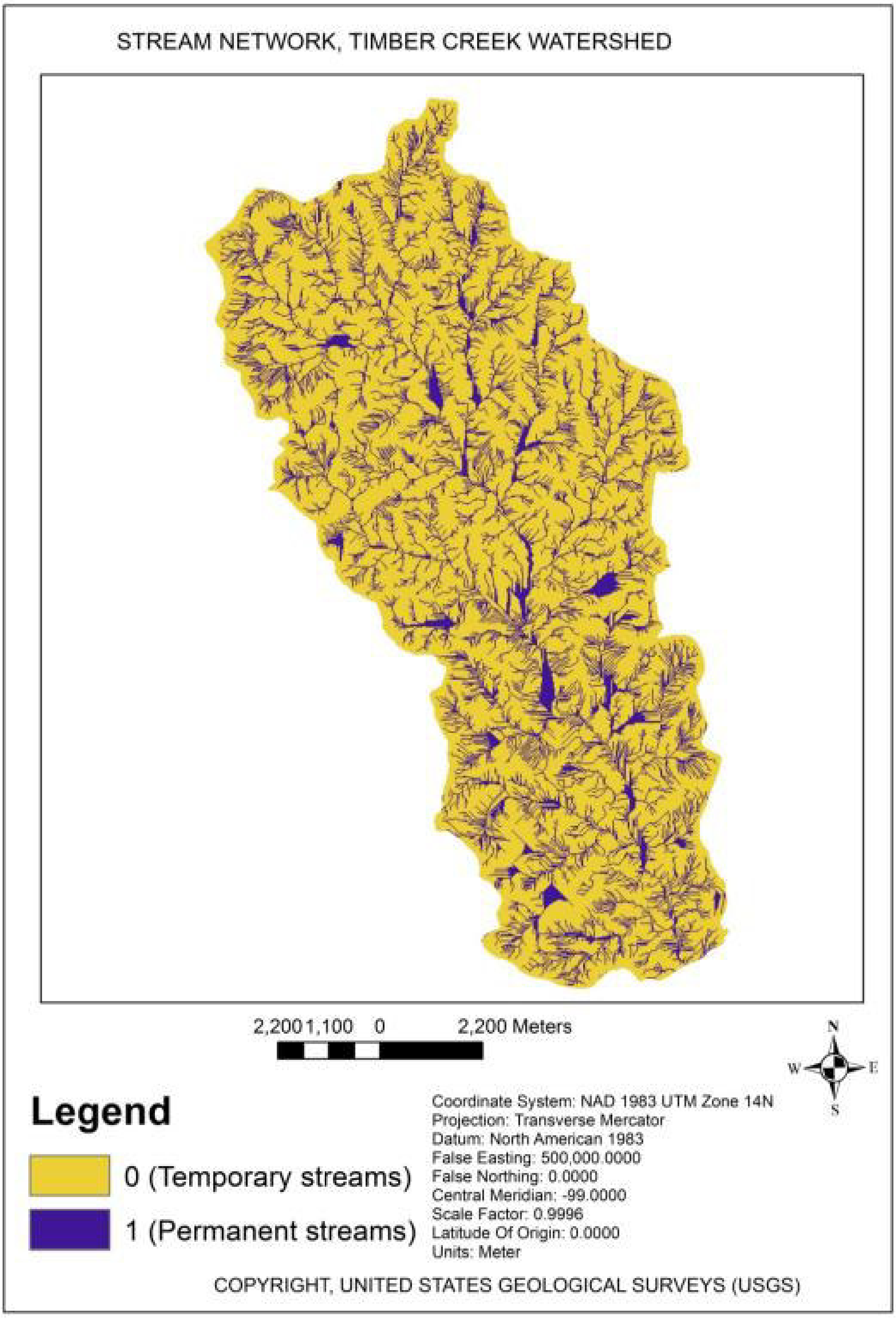

Figure 19: Stream Network map of Timber Creek watershed.

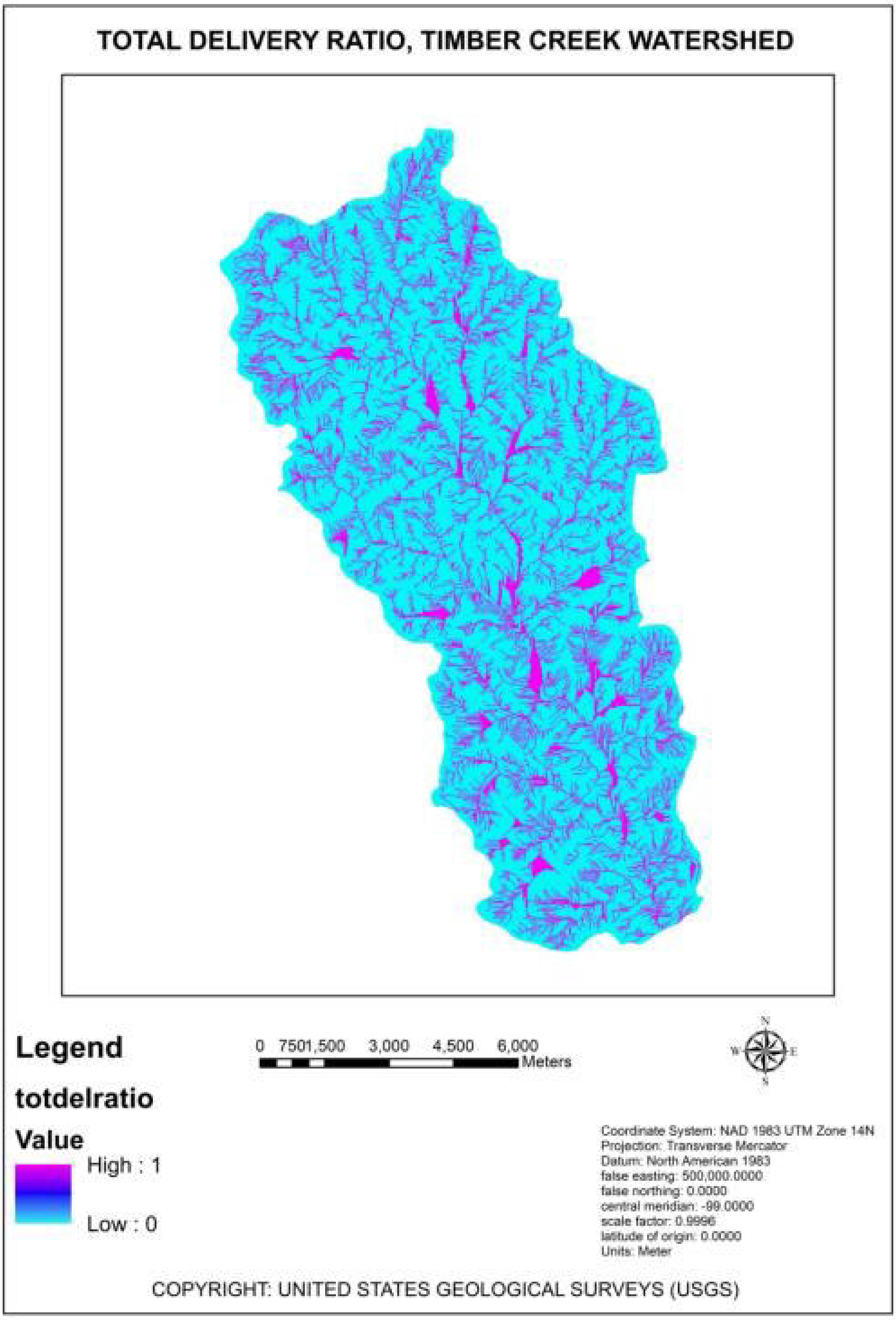

Figure 20: Total Delivery ratio map of Timber Creek watershed.

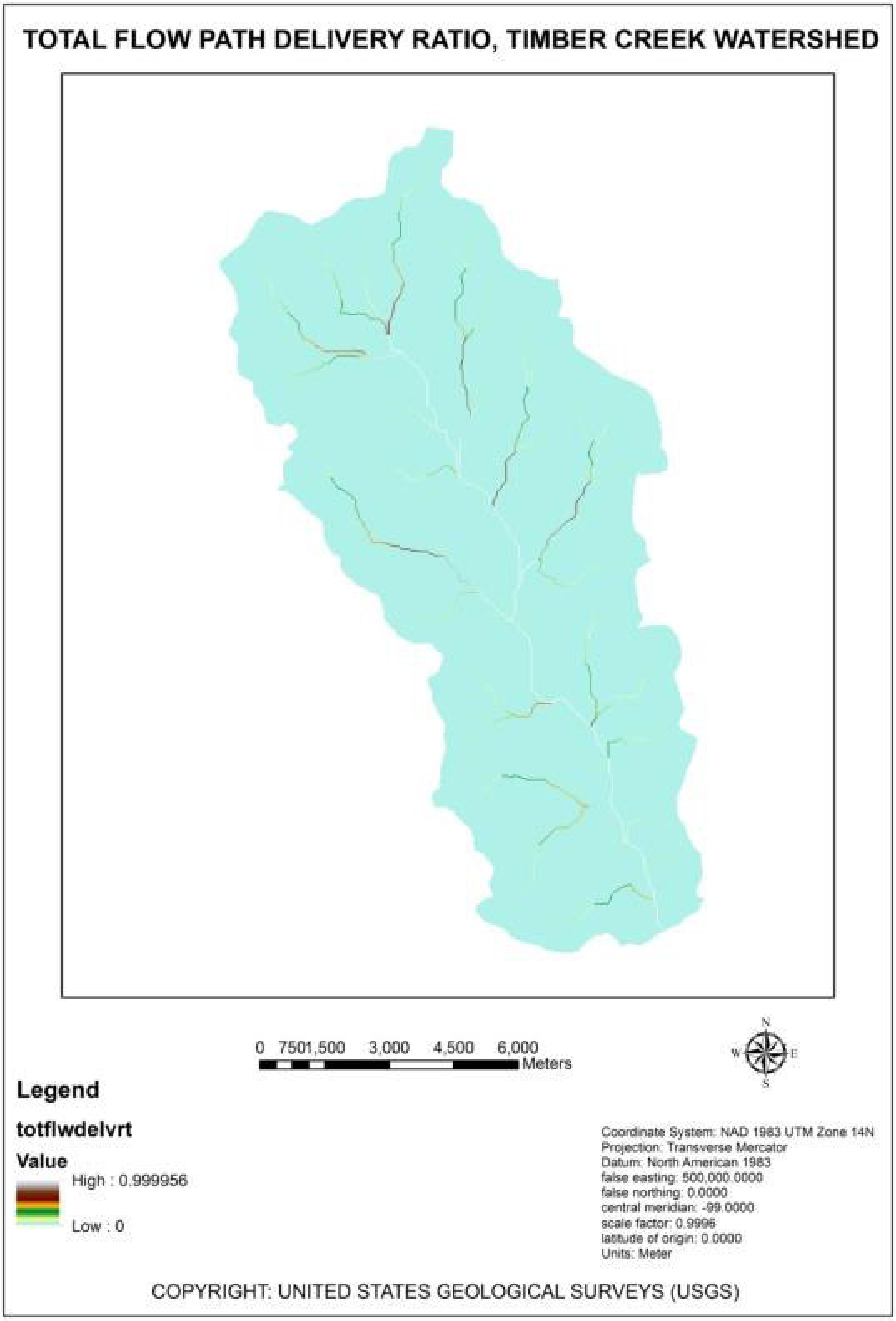

Figure 21: Total Flow Path Delivery Ratio map of Timber Creek watershed.

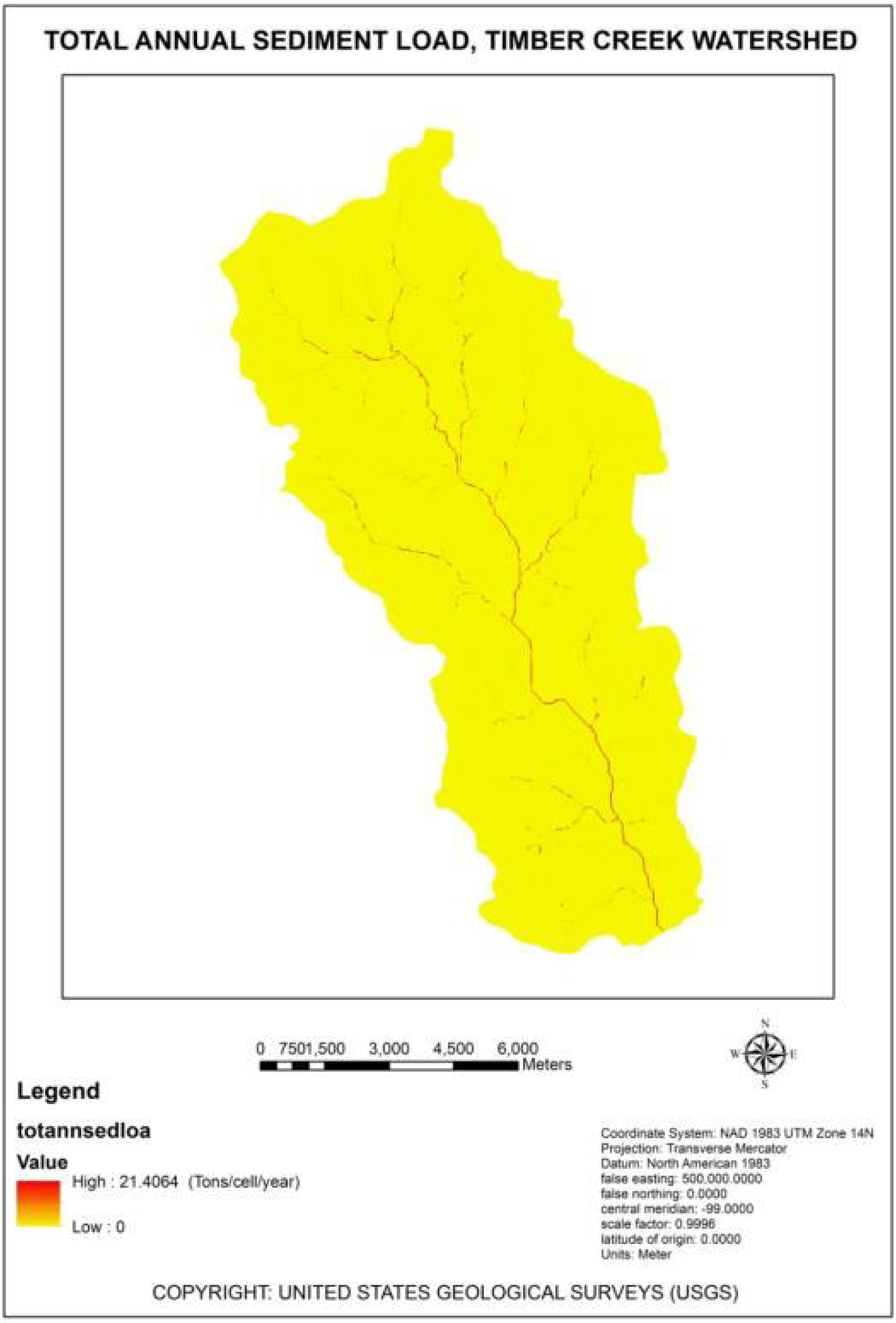

Figure 22: Total Annual Sediment Load map of Timber Creek watershed.

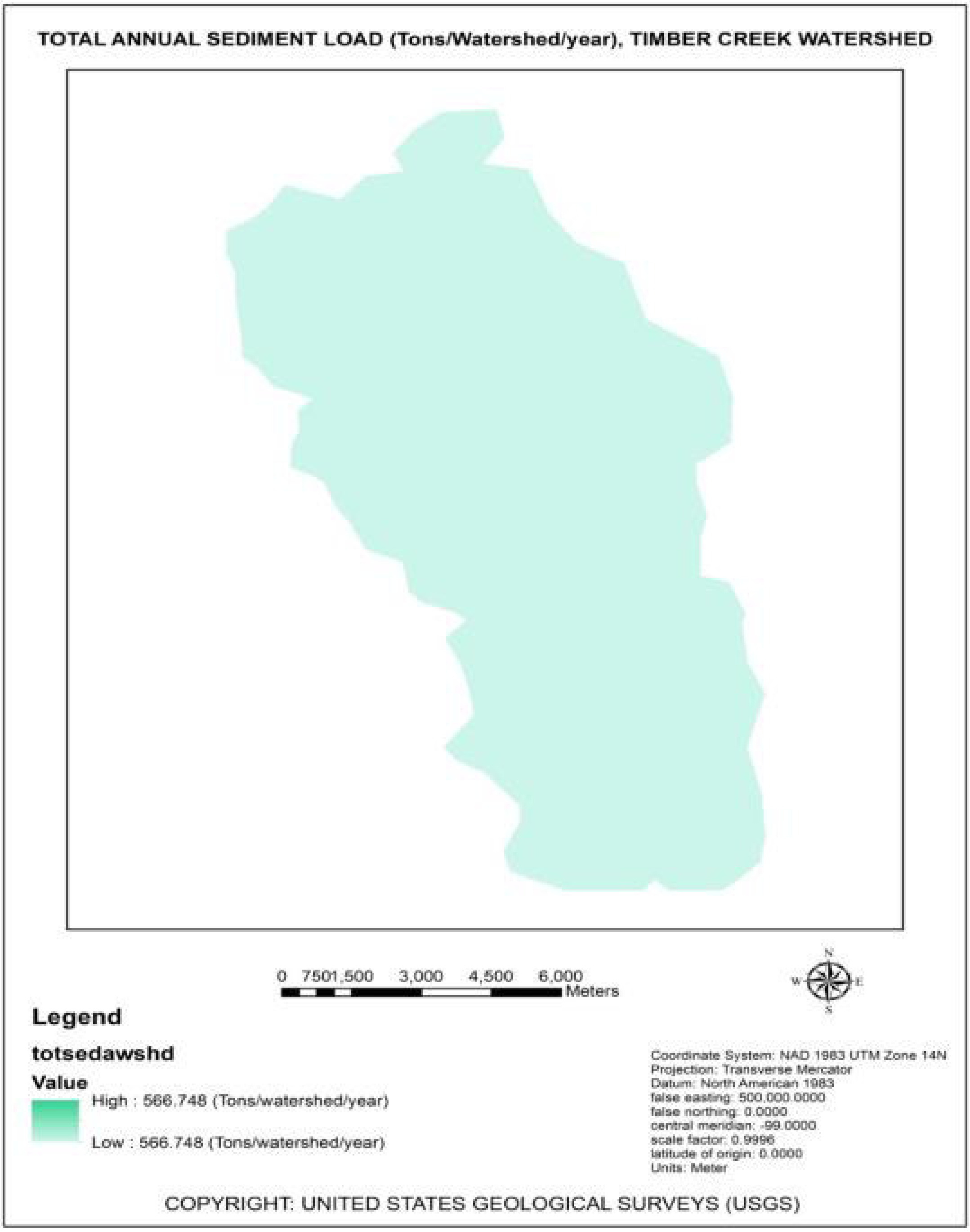

Figure 23: Total Annual Sediment Load in the watershed in Timber Creek.

Figure 24: Bad pixel in the DEM before it was corrected.

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