Published in Proceedings of the 5th International SWAT Conference
Boulder, CO. Aug. 5-7, 2009.

# ArcMap Tool for Pre-processing SSURGO Soil Database for ArcSWAT

**Aleksey Sheshukov**
Biological and Agricultural Engineering, Kansas State University,
49 Seaton Hall, Manhattan, KS 66506, ashesh@ksu.edu

**Prasad Daggupati**
Biological and Agricultural Engineering, Kansas State University,
30A Seaton Hall, Manhattan, KS 66506, prasad9@ksu.edu

**Ming-Chieh Lee**
Biological and Agricultural Engineering, Kansas State University,
30A Seaton Hall, Manhattan, KS 66506, mclee@ksu.edu

**Kyle Douglas-Mankin**
Biological and Agricultural Engineering, Kansas State University,
48 Seaton Hall, Manhattan, KS 66506, kmankin@ksu.edu

**Abstract**

*The Soil Survey Geographic (SSURGO) database provides the highest resolution for a county-wide soil database in the United States. AvSWAT and ArcSWAT are developed for using soil input prepared in a format of the State Soil and Geographic (STATSGO) database. The available SSURGO processing extension tool currently works only with AvSWAT but not with ArcSWAT. The purpose of this study is to develop an extension tool for ArcMap GIS that is capable of processing the SSURGO soils into a modified STATSGO format that is readable by ArcSWAT. This process consists of the following steps: preparing a SSURGO soil dataset in a format compatible with ArcSWAT, appending it to a user soil dataset, building a watershed specific soil lookup table, and creation of a soil GIS layer for SWAT input. All these steps are automated and incorporated in a user-friendly interface programmed as an Extension to ArcMap GIS. A comparison of using STATSGO versus SSURGO soil input datasets to the SWAT model was conducted on a Black Kettle Creek Watershed in South-Central Kansas.*

**Keywords:** ArcSWAT, SSURGO, ArcMap, GIS, Soil, ArcObjects

## Introduction

Several soil databases are available for use in watershed modeling exercises:

- The State Soil Geographic Database (STATSGO) was developed by the National Cooperative Soil Survey and published in 1994. It consists of a broad-based inventory of soils and non-soil areas that occur in a repeatable pattern on the landscape. The dataset was created by generalizing soil survey maps in 1- by 2-degree topographic quadrangle units and its attributes were determined by expanding the data statistics of whole map unit.
- In 2006 the STATSGO spatial and tabular data were revised and renamed to the U.S. General Soil Map (GSM) or STATSGO2 (NRCS, 2009b). Several modifications were made and the coverage was updated. At the present time, STATSGO dataset is considered obsolete due to introduction of STATSGO2.
- The Soil Survey Geographic Database (SSURGO) database is the most detailed soil survey database currently available in the U.S (NRCS, 2009a). It is structured on the county basis and consists of sets of multiple spatial and tabular data files.

Typical spatial resolution of the SSURGO database is 10 to 20 times higher than STATSGO2. This makes the use of SSURGO soils preferable for smaller scale projects, such as modeling small watersheds, catchments, or even individual fields. For larger scale projects the use of SSURGO can be beneficial as it provides more soil groups and gives better representation of the soil spatial distribution. However, it also significantly increases number of unique soil-slope-landuse combinations thus making the watershed representation more complex. The difference in spatial resolution between STATSGO2 and SSURGO soil datasets is shown in Fig. 1 for five soil characteristics. Both the STASGO2 and the SSURGO soil data are available for download at USDA/NRCS website http://soils.usda.gov/survey/geography.

SWAT uses STATSGO2 as the default soil data format. An ArcSWAT soil database file (*Swat_US_Soils.mdb*) is used to store the soil properties for the United States. To use SSURGO soils, an independent procedure outside of the SWAT GIS module needs to be developed to convert the soil dataset into an ArcSWAT compatible format and add it to a user soil table in *Swat2005.mdb* database file. A currently available SSURGO processing tool was developed to work with the previous version of SWAT, AvSWAT (Di Luzio *et al.*, 2004, Peschel *et al.*, 2006). The tool can be downloaded at http://lcluc.tamu.edu/ssurgo.

An upgrade from AvSWAT to ArcSWAT changed the soil data storage approach along with many other essential improvements and made the current SSURGO processing tool incompatible with ArcSWAT. The study of SSURGO soils in the Kansas and Missouri States revealed that many soils in the database had missing values for several soils attributes that are used by ArcSWAT. Hence, adjustments of SSURGO soils need to be performed before proceeding with SWAT calculations. The objectives of this study are (1) to design an approach for processing SSURGO soils in a format compatible with ArcSWAT, and (2) to develop a set of tools in a form of extension to ArcMap GIS application that allows the user to seamlessly integrate SSURGO soils in ArcSWAT.

(a)
(b)
(c)
(d)
(e)

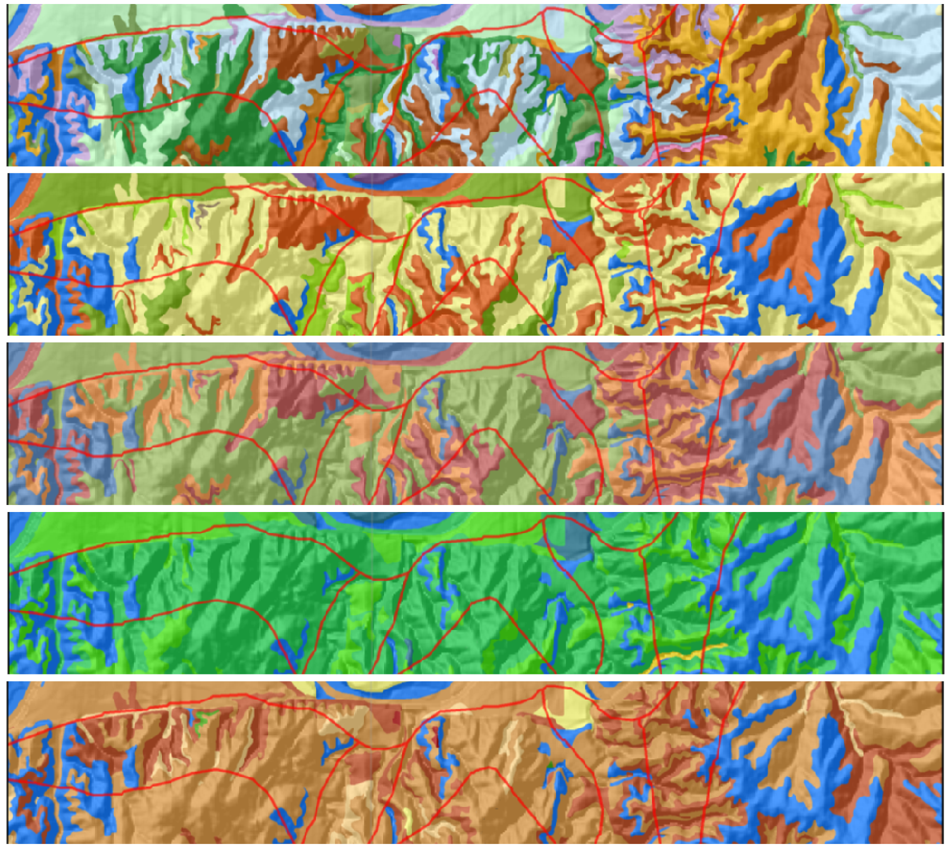

Figure 1. Soil properties in SSURGO and STATSGO databases: (a) soil component, (b) major texture, (c) hydrologic soil group, (d) saturated hydraulic conductivity, and (e) USLE soil erodibility K factor. STATSGO soils are outlined with a solid line, while SSURGO soils are shown as a background.

## Methodology

The county-based SSURGO data files downloaded from the USDA/NRCS website are split into two groups. The first group contains GIS-based graphical vector shapefiles that provide spatial soil coverage and can be viewed in ArcMap GIS. The soil coverage is formed by the continuous network of polygons presented in the shapefile. Each soil type has a unique key identifier `mukey` and may exist in more than one polygon. All files for this group are stored in '*spatial*' folder. The second group is tabular source data files in an ASCII text format stored in '*tabular*' folder. The tabular files contain information about the extended properties of the soils found in the spatial soil coverage. Table 1 lists the five tabular files that contain valuable information for preparing the SSURGO files into the ArcSWAT format.

The tables within the five files have a relationship one to another via unique key identifiers or primary keys. Fig. 2 provides an example of *one-to-many* relationships between the tables presented in a Relationship window of Microsoft Access application. The primary key fields identified in the tables are `chkey`, `cokey`, `mukey`, and `lkey`. For each soil in the soil coverage shapefile a query created based on the soil `mukey` value will cascade through the map unit table to the other tables and retrieve the required soil information. Repeating the same procedure many times, all the SSURGO soils can be processed and collected in one database file. The fields in the database file are prepared according to ArcSWAT requirements and presented in Table 2. The values for some fields are composed with individual SSURGO variables and may require additional calculations.

Table 1. Tabular source data files that are used in the processing tool.

| **Tabular file** | **Logical Name** | **Description** |
|---|---|---|
| Mapunit.txt | Map Unit | The Map Unit table identifies the map units included in the referenced legend |
| Legend.txt | Legend | The Legend table identifies the soil survey area that the legend is related to |
| Chorizon.txt | Horizon | The Horizon table lists the horizon(s) and related data for the referenced map unit component |
| Chfrags.txt | Horizon Fragments | The Horizon Fragments table lists the mineral and organic fragments that generally occur in the referenced horizon |
| Comp.txt | Component | The Component table lists the map unit components identified in the referenced map unit, and selected properties of each component |

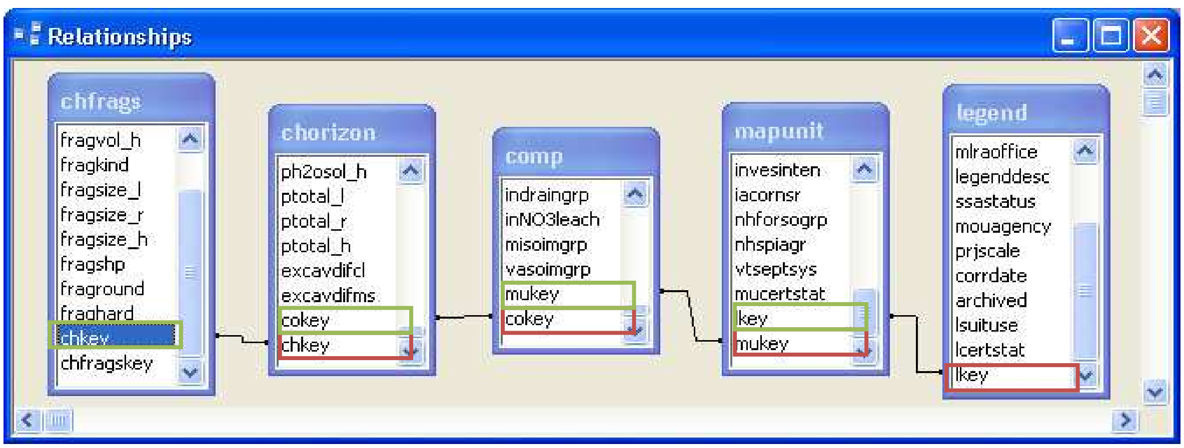

Figure 2. *One-to-many* relationships between the key fields in five SSURGO tables.

For AvSWAT a dedicated SSURGO folder is created in AvSWAT installation directory. In the SSURGO folder each county has its own subfolder where the spatial coverage and the created database file in dBASE format are located. During the soil processing procedure AvSWAT scans this user soil directory, selects the soil coverage and clips it to the watershed. In ArcSWAT the user soil data management is different. After processing of SSURGO soils the created dataset must be added to the list of user soils in 'usersoil' table in *Swat2005.mdb* file. To link the soils in the user table with the soils in the spatial coverage file the lookup table must also be created with `snam` and `mukey` fields used as a link. The SWAT field `snam` is a concatenated string composed with two SSURGO fields, Areasymb and Musym, and one SWAT field, `seqn`. The `snam` field uniquely identifies the soil in the created SSURGO dataset. At the soil processing step during the SWAT project setup, the created lookup table is substituted when asked to recognize the soils in the soil coverage and clip them to the watershed.

Table 2. ArcSWAT and SSURGO variables.

| ArcSWAT Variable | Description | SSURGO Variable | SSURGO Table |
|---|---|---|---|
| MUID | Mapping Unit Identifier | Areasymb | Legend |
| SEQN | Record Counter | ** | – |
| SNAM | Soil Identifying Name (concatenated key) | Areasymb Musym | Legend Mapunit |
| S5ID | Soil interpretation record | *** | – |
| CMPPCT | Percent of Soil component | Comppct_r | Comp |
| NLAYERS | Number of soil layers, not more than 10 | ** | – |
| HYDGRP | Soil hydrologic group | Hydgrp* | Comp |
| ANION_EXCL | Fraction of porosity for which anions are excluded | *** | – |
| SOL_CRK | Potential or maximum crack volume of soil profile expressed as fraction of total volume | *** | – |
| TEXTURE | Texture of soil layer – not required by ArcSWAT | Taxpartsz | Comp |
| SOL_Z | Depth from soil surface to bottom of layer (mm) | Hzdepb_r* | Chorizon |
| SOL_ZMX | Maximum rooting depth of sol profile (mm) | ** | – |
| SOL_BD | Moist bulk density (g/cm3) | Db3bar_r* | Chorizon |
| SOL_AWC | Available water capacity of sol layer (mm H20/mm soil) | Awc_r* | Chorizon |
| SOL_K | Saturated hydraulic conductivity (mm/hr) | Ksat_r* | Chorizon |
| SOL_CBN | Organic carbon content (percent of soil weight) | Om_r | Chorizon |
| CLAY | Clay content (percent of soil weight) | Claytot_r* | Chorizon |
| SILT | Silt content (percent of soil weight) | Silttot_r* | Chorizon |
| SAND | Sand content (percent of soil weight) | Sandtot_r* | Chorizon |
| ROCK | Rock fragment content (percent of soil weight) | Fragvol_r* | Chfrags |
| SOL_ALB | Moist soil albedo | Albedody_r* | Chorizon |
| USLE_K | USLE soil erodibility K factor (0.013 metric ton m2 hr/m3 metric ton cm) | Kffact* | Chorizon |
| SOL_EC | Electrical conductivity (dS/m) | Ec_r | Chorizon |

* Value may be missing for certain soils, substitute with the educated guesses
** ArcSWAT variable requires additional calculation
*** ArcSWAT does not require the value to be specified

For certain soils some fields of the SSURGO soil data are not defined. Working with the SSURGO soils in Kansas and Missouri it was found that soils named Aquentos, Arents, Psamments, Fluvents, Orthents, Pits, Aqualls, Quarry, and others were missing the attribute values for the variables denoted with the star in Table 2. After processing these soils the corresponding ArcSWAT variables become undefined and create errors during the SWAT GIS processing. The extension tool developed in this study indentifies soils with the missing values, correct the problem by retrieving the values from a table specially-prepared with the use of SSURGO metadata files, soil survey books, and other appropriate sources.

For automating a process of converting a SSURGO soil database into the ArcSWAT format, a set of Visual Basic scripts were written within the ArcGIS framework. The ArcGIS framework enables the conversion process to be assembled within ArcMap GIS with a user-friendly interface. For each step of the process a custom class was created and ICommand interface was implemented. All commands were hosted on a custom toolbar using IToolbar interface. An extension to ArcGIS was developed to maintain the state of individual items in the toolbar. Once registered with the ArcGIS application, the extension provides an easy access to the SSURGO conversion tools and can be used with ArcSWAT project at any time.

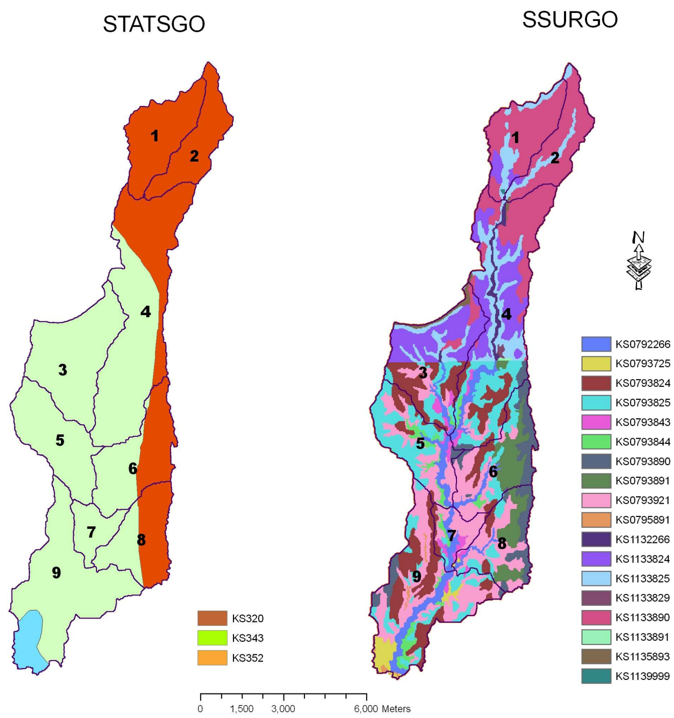


Figure 3. STATSGO and SSURGO soil types for Black Kettle Creek Watershed.

## Application and Results

The developed tool was tested in the Black Kettle Creek Watershed in Central Kansas to examine the effects of higher soil resolution on sediment and overland flows. Black Kettle Creek Watershed is a 7,818 ha (19,295 ac) subwatershed of Little Arkansas River Watershed (Hydrologic Unit Code 11030012) located within McPherson and Harvey Counties in south-central Kansas. Primary land use in the watershed is cropland (84% of total area). The watershed is delineated into nine subwatersheds ranging from 265 to

1845 hectares (see Fig. 3). STATSGO soil database has three soils in the watershed, while SSURGO soil database shows 18 soils. The prevailed soils are of C and D hydrologic groups (see Fig. 4). Contrary to STATSGO, SSURGO soils in the watershed have low percentage of A and B groups. NLCD2001 land cover dataset and 30 meters DEM are used for ArcSWAT simulations. The model was run for 12 years from 1995 to 2006. High percentage of cropland and heavy soils indicate sediment may be a major pollutant concern in the watershed.

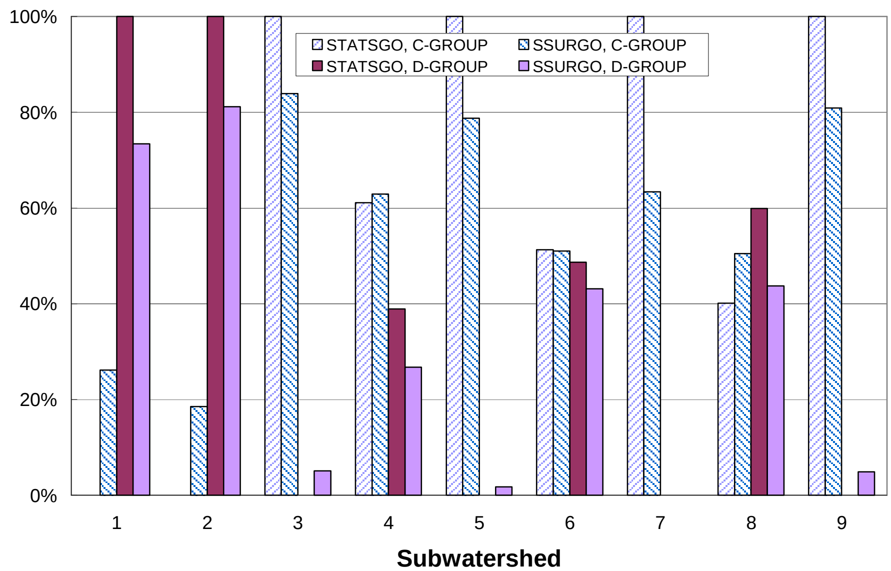


Figure 4. Percentage of C and D group soils in a watershed for STATSGO and SSURGO soil datasets. Bars for C-group soils are filled with a shaded pattern, while D-group soils are shown as solid bars.

All subwatersheds consistently produced more runoff and higher sediment yields with the STATSGO soil input as illustrated in Fig. 5. The reason for that seems to be in the larger areas of D group soils for agricultural land in STATSGO dataset. In 10% of the watershed, the SSURGO dataset contains high infiltration soils of A and B groups that affect infiltration and therefore reduce runoff and sediment yield. It can be seen during a wet year 2005 when a runoff is twice lower for SSURGO input data comparing to the one for STATSGO.

# Conclusions

The ArcMap extension tool for pre-processing SSURGO soil database was developed to assist in using SSURGO soils in ArcSWAT projects. A framework developed by Peschel et al. (2006) for AvSWAT was extended for ArcSWAT and incorporated in a form of extension to ArcMap GIS. The extension tool was successfully applied to a watershed in the South Central Kansas. Simulated by ArcSWAT with SSURGO soils demonstrate a lower runoff and sediment yield comparing with the STATSGO soils. The developed ArcMap GIS extension is available for download at http://www.bae.ksu.edu/watershed.

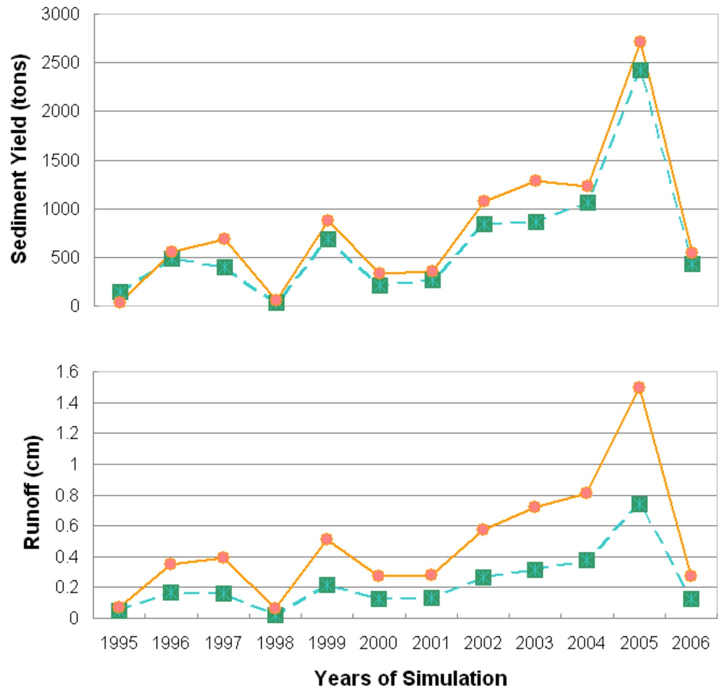


Figure 5. Annual sediment yield and runoff for Black Kettle Creek watershed. Solid lines represent STATSGO soil input, while the results with the SSURGO soil dataset are shown by dash lines.

## References

Di Lizio M., J.G. Arnold, and R. Srinivasan, 2004. Integration of SSURGO Maps And Soil Parameters Within A Geographic Information System And Nonpoint Source Pollution Model. *J. Soil Water Conserv.* 59(4): 123-133.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, R. Srinivasan, and J.R. Williams, 2004. Soil and Water Assessment Tool Input/Output File Documentation Version 2005. Grassland, Soil and Water Research Laboratory, USDA-ARS.

NRCS. 2009a. Soil Survey Geographic (SSURGO) Database. USDA Natural Resources Conservation Service. Available at: http://soildatamart.nrcs.usda.gov. Accessed 30 June 2009.

NRCS. 2009b. U.S. General Soil Map (STATSGO2). USDA Natural Resources Conservation Service. Available at: http://soils.usda.gov/survey/geography/statsgo. Accessed 30 June 2009.

Peschel, J.M., P.K. Haan, and R.E. Lacey. 2006. Influences of soil dataset resolution on hydrologic modeling. *J. Amer. Water Resour. Assoc.* 42(5): 1371-1389.