Assessing and Quantifying Sediment Loading in the South Branch of the Root River Watershed

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Keywords: SWAT, Calibration, Water Budget, Sediment Loading, Best Management Practices, Runoff Potential, Soil Degradation, Land Use

Abstract

The South Branch of the Root River Watershed (SBRRW) is a part of the Root River Watershed, which drains into the Mississippi River. SBRRW houses the best trout streams in Southern Minnesota with more than 150,000 visitors per year enjoying the aesthetical landscape and natural beauty of the watershed and its tributaries. The total area of the watershed is about 72,980 hectares (180,337 acres). SBRRW land use is dominated by agricultural land, which occupies about 87% of the watershed. The goal of this research was to assess and quantify the sediment yields in SBRRW, and suggest some scenarios to reduce sediment and pollutant loadings. Furthermore, SBRRW has been on the Clean Water Act 303(d) list for impaired waters in the state for several years due to increasing rates of sediments, pollutants, and bacteria. The Soil and Water Assessment Tool (SWAT) was utilized to predict the impact of land management practices on water, soils, land use, and management conditions over a long period of time. SWAT requires an enormous amount of input data such as topographical data, land use/land cover data, soils data, climate data, rainfall data, and land management practices. Additionally, three crop rotations were implemented: corn, soybeans, and alfalfa. SWAT simulated the watershed hydrology process and upper land process for 25 years (1980 – 2005). Predicted sediment yields for each rotation were then compared to the current condition results. The study found that when alfalfa rotation was utilized with either corn or soybean rotations, the sediment yield was less than 0.5 ton/ha, while the corn rotation sediment yield was over two ton/ha, and the soybean sediment yield was 0.8 ton/ha. The SWAT model also showed that the potential sites for sediment loading were in the middle section of the watershed, which contributes more than 80% of the total sediment yield.

Introduction

As water flows across the land during rainfall or storm events, it carries fragments of soil, fertilizers, pollutants, and litter into streams and other open waters. Furthermore, human activities on land and stream networks compromise the quality and quantity of the water budget positively or negatively. However, the SBRRW has a lot to offer in terms of recreational activities, such as fishing and swimming, and more than 150,000 visitors per year enjoy the aesthetical landscape and natural beauty of the watershed and its tributaries. But in recent years, sediment and turbidity in streams have become a concern in SBRRW, especially when pesticides and fertilizers were well pronounced in water samples. Contamination not only threatens aquatic

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Yaya, Sallah. 2007. Assessing and Quantifying Sediment Loading in the South Branch of the Root River Watershed. Volume 9, Papers in Resource Analysis. 13 pp. Saint Mary's University of Minnesota Central Services Press. Winona, MN. Retrieved (date) from http://www.smumn.edu

and wildlife habitats, but also compromises human health. The goal of this research was to assess and quantify sediment yield in SBRRW, and to suggest some scenarios to reduce sediment and pollutant loading. That being said, the South Branch of Root River is on the Clean Water Act Section 303(d) list among the impaired streams in the state due to the high rates of sedimentation, pollutants, and bacteria in the water. According to a Minnesota Pollution Control Agency (MPCA) diagnostic study in 2000, the turbidity rate was 85 Nephometeric Turbidity Units (NTUs). This value was 8 times higher than the water quality standard given by EPA, and the watershed also transported about 16,000 tons of solid sediment. Here the Soil and Water Assessment Tool (SWAT) was used to identify areas of potential sediment loading within the watershed and to offer recommendations for where Best Management Practices (BMP's) might be considered as implementation strategies to improve overall health of the watershed.

Study Area Description

This study was conducted in the SBRRW (Figure 1), which is located within the Root River Watershed (HCU # 0700084) in southern Minnesota, west of Forestville State Park. The total area of the watershed is approximately 72,980 hectares (180,337 acres), 87% within Fillmore County and about 13% in eastern Mower County. The South Branch of Root River traverses about 30 miles to merge with the North Branch of the Root River, and then the Root River drains into the Mississippi River near La Crosse, WI. The region is dominated by agricultural activities, mainly cultivated row crops including corn and soybeans. Most importantly, the SBRRW offers the best trout fishing in the state and activities such as swimming, fishing, and canoeing. Therefore, the SBRRW plays a major role as a financial source for the communities around the watershed.

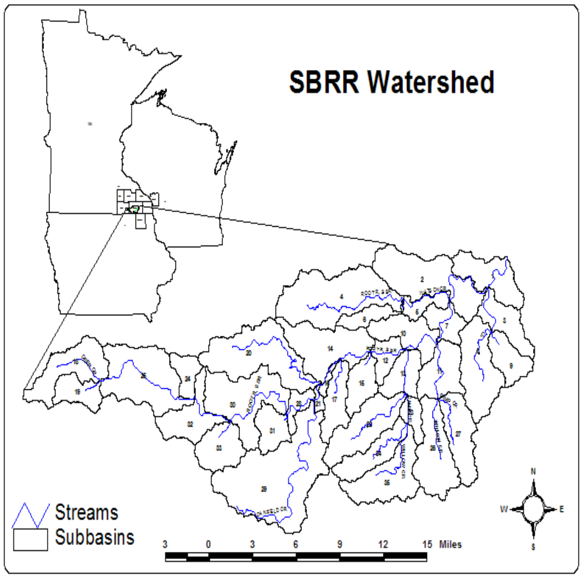

Figure 1. Location of the South Branch Root River Watershed (SBRRW).

The watershed's geological structure consists mostly of limestone (Karst). The SBRRW also has water quality issues that affect recreational activities and aquatic life within and beyond the watershed. According to Minnesota Pollution Control Agency (MPCA) studies, the rates of fecal coliform and sediment have been increasing in the last few years and the Root River and its tributaries are on the Total Maximum Daily Loads (TMDLs) 303(d) list. This research discusses major nonpoint pollutants and suggests reduction runoff scenarios by the SWAT model to improve ecologic stream health. In the last 20 years, the SBRRW has been experiencing sediment and pollutant loadings due to agricultural practices, which promotes significant soil erosion. This study is part of a large project aimed to reduce sediment loading in the Root River by using the SWAT model to calibrate and validate the whole watershed for erosion potential.

Materials and Methods

Watershed Modeling

There are two approaches to model a watershed; either Lump Process, which takes the entire watershed as one unit and does not take into account any spatial variability, or Distributed Process, which considers all spatial variabilities and takes an enormous amount of data and time to analyze (Neitsch et al., 2001). The combination of the two methods is called quasi-distributed. The hydrology process can be deterministic or stochastic, or a combination of the two:

- Deterministic Process characteristics:
  1- No random variables are used.
  2- The model computes fixed, repeatable results.
  3- Governed by equations based on fundamental principles of physics or robust empirical methods as in computing surface runoff and sediment yield.
- Stochastic Process characteristics:
  1- Using distribution for each variable to generate random values for model input.
  2- The result itself is random with its own distribution.
  3- Can be presented as a range of values with confidence limits.

SWAT Model

SWAT is a deterministic, river basin or watershed scale model, and is widely known not only in the United States, but worldwide. SWAT was developed by Dr. Jeff Arnold for the USDA Agricultural Research Services (ARS) at the Grassland, Soil, and Water Research Laboratory in Temple, TX (Neitsch et al., 2001). SWAT also was embedded under Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), which was developed by the EPA. Here, BASINS 3.1 was used to download the needed data from the EPA website and to prepare most of the input data to run SWAT. Because SWAT is a distributed model, it allows incorporation of management practices on the land surface, including fertilizer application, livestock grazing, and harvesting operations (Neitsch et al., 2001). Therefore, SWAT simulates hydrological components and human activities within and beyond the watershed by examining scenarios and testing assumptions of the effects of agricultural activities and geological structure in the watershed. In this study, SWAT was utilized to predict the impact of land management practices on water, soils, land use, and management conditions over long periods of time (Neitch et al., 2001). The SWAT model uses daily average input values. However, the model is not designed to simulate a detailed, single flood event. The major components of the model are hydrology, weather generator, sedimentation, soil temperature, crop growth, nutrients, pesticides, fertilizers, groundwater, surface runoff, and management practices. SWAT also uses the Curve Number and Modified Universal Soil Loss Equation (MUSLE) to compute the rainfall excess, surface runoff, and sedimentation yield. Additionally, SWAT focuses on the soil water balance on the land hydrology cycle (Neitsch et al., 2001).

SWAT Model Equations

SWAT differs from other physical models in its ability to divide the watershed into sub-basins and Hydrological Response Units (HRUs). The watershed is divided into smaller subwatersheds by selecting points on the stream network, which divides the watershed into hundreds of subwatersheds that have homogenous characteristics of land use and soils. The model equations are applied to each HRU and the surface/ground water routed to neighboring HRUs up to the outlet of the main basin (Arnold et al. 1994).

Hydrological Equation

The hydrological equation focuses on a soil water balance, which simulates the water balance, along with plant growth, sediment erosion and transport, nutrient dynamics, and pesticides. Also, the model allows the incorporation of management practices on the land surface, such as fertilizer application, livestock grazing, and harvesting operations. The hydrologic component of the SWAT model is based on the water balance equation:

$$SW_t = SW+\sum (R_i - Q_i - ET_i - P_i - QR_i)$$

Where SW_t is the final soil water content (mm), SW is the water content available for plant uptake which is defined as the initial soil water content minus the permanent wilting point water content (mm), t is time in days, R_i is Rainfall (mm), Q_i is Surface Runoff (mm), ET_i is Evapotranspiration (mm), P_i is Percolation (mm), and QR_i is Return Flow. In most common equations of hydrology, the Digital Elevation Model (DEM) resolution, the detailed land use, and the soil data are crucial for improving the accuracy of the SWAT simulation output. However, the SWAT model process lies mainly in the computation of surface runoff with help of the Soil Conservation Services (SCS) curve (Arnold et al., 1994).

GIS Data

Several sources and resolutions of GIS data may be used in SWAT, such as:

1- Soils: there is currently only one GIS coverage for soils nationwide, which is the State Soil Geographic Database (STATSGO) compiled by the Natural Resource Conservation Service (NRCS). These data are commonly used with SWAT and are available in the BASINS 3.1 database as well. STATSGO was created from generalizations of other soil surveys with 625 ha as the minimum mapping area, and then was divided into map units; each map unit consists of several soils. In addition, an associated Map Unit Interpretations Record (MUIR) database contains the properties and distribution of soils in each map unit. Other, more detailed soil data is SSURGO, which depends on the study area because it does not cover the entire nation. But SSURGO is far more detailed and is a digitized version of the NRCS County soil survey, which is the most accurate data available.

2- Topography: a DEM is used to delineate the watershed's boundaries. The US Geological Survey (USGS) provides DEMs at a variety of scales. Also, DEMs are available in raster format at different resolutions, such as 10, 30, 60, and 90 meters.

3- Land Cover/Land Use data: these data are more complicated to compare than soils or topography. This data also can change over a relatively short time frame. Therefore, land cover is the most important GIS data used in SWAT. There are several options available such as USGS Land Use/Land Cover (LULC) data, which are the least detailed and the easiest data to use with SWAT. LULC data are available nationwide at 1:250,000 and 1:100,000 for limited areas and are included with the BASINS 3.1 database and are readily used by SWAT. Other several Land Cover sources are available; for example, National Land Cover Database (NLCD) using early 1990 imagery at

In this study, AVSWAT 2003 was chosen to simulate the watershed conditions for many reasons, such as SWAT is public domain, user friendly, most input data are public domain, and most importantly, the model can be used in large watersheds for long term planning. AVSWAT 2003 was used under the ArcView3.3 framework (Figure 2), which was utilized to prepare input layers after projecting all layers into Universal Transverse Mercator (UTM) Zone 15, North American Datum 1983 (NAD83) and delineating the watershed boundary.

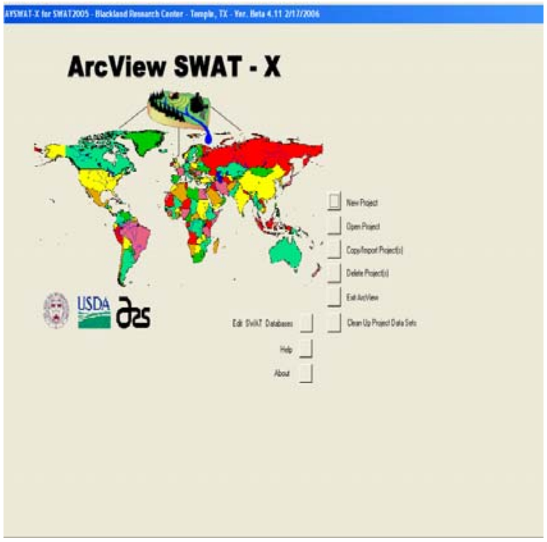

Figure 2. ArcView SWAT Interface (AVSWAT).

Finally, the watershed was divided into sub-basins, which subsequently were divided into HRUs. Each HRU has unique land use, soil, slope, and land management practices. The model evaluates the interaction between sediments, nutrients, fertilizers, soils, and surface runoff to result in output to stream channels. Therefore, SWAT simulation would take place at the HRU level, and then would be routed to sub-basin level and finally to the watershed level. The model automatically assigns initial values to the input files based on the geographical location of the watershed. The locations of the rainfall gages and the stations of meteorological data either within the watershed or near the watershed, define the HRUs and the slope for each sub-basin, and then simulate the hydrological process according to the timeframes that were set by the user. After loading the flow, sediment, nutrients, pesticides, and bacteria from the upland process to the main channel, they are routed through the stream network. There are several main considerations for the model such as:

- Surface runoff by using Curve Number.
- Potential Evaportranspriation that estimates the land cover and simulates the plant growth by utilizing one of the main equations of the Priestly-Taylor equation.
- Percolation when soil water content exceeds the land capacity and determines the amount of water moving from one soil layer to another by using a storage routing method (Neitsch et al., 2001).
- Ground water aquifers are also simulated in each sub-basin. Unconfined and shallow aquifers contribute to stream flow, while deep aquifers do not add to the stream flow.
- Lateral flow is simulated by using a kinematic storage model for subsurface flow.
- Sediment from each HRU is simulated by utilizing MUSLE. This equation estimates event based sediment yield. MUSLE predicts sediment erosion for each day when there is surface runoff and reduces the erosion when there is snow cover.
- Plant growth, nutrients uptake, phosphorous, and the organic

phosphorus cycle in the soils are simulated in each sub-basin and each HRU.

SWAT Model strength and assumptions:

- It is physically based.
- Great documentation.
- Uses daily inputs through BASINS 3.1, which is open and public, developed by the EPA.
- Detailed crop growth model and database.
- Good land management modules and database.
- Suitable to study watersheds from small to very large sizes.
- The model assumes Soil Conservation Services (SCS) Curve Number approach for infiltration, but requires hourly data and assumes that MUSLE is appropriate for the area being modeled.
- Flow in streams and reservoirs are one-dimensional.

SWAT Model limitations:

- Not for simulating sub-daily events such as a single storm or diurnal changes of dissolved oxygen in a watershed.
- Only routes one pesticide each time through the stream network.
- Cannot specify actual areas to apply fertilizers. Assumes one dimensional, well-mixed streams and reservoirs.
- The more HRUs in the watershed, the more input files to manage and to modify.
- The current version does not have a good model post-processor.

Features of the SWAT Model are:

- Watershed hydrology, sediment, and water quality.
- Pesticide rate and transport simulation.
- Channel erosion simulation.
- Rural and agricultural management practices including detailed agricultural land planting, tillage, irrigation, fertilization, grazing, and harvesting procedures.

SWAT Model areas supported:

- Watershed.
- Receiving water.
- Ecological.
- Groundwater.

SWAT Model capabilities:

- Divides the watershed into sub-watersheds that are connected through a stream channel and further divided into HRUs, which are a unique combination of soil and vegetation type in a watershed.
- The model simulates hydrology, vegetation growth, and management practices at the HRU level.
- Water, nutrients, sediment, and other pollutants from each HRU are summarized and routed through the stream network to each watershed outlet.

Watershed Delineation

A DEM was used to provide a valuable resource in analyzing and visualizing the watershed relief (Figure 3), and also to generate contours of the watershed. Watershed slope was also calculated**,** which was essential not only for assessing erodibility and the surface hydrology of the watershed, but also for the planning and management of the watershed. In this study, a DEM was downloaded from the Minnesota Department of Natural Resources (MNDNR) website, with 30-meter resolution. The Spatial Analyst extension within ArcView 3.3 was utilized to derive flow direction, flow accumulation to delineate the watershed boundary, and then to divide the watershed into sub-basins, with an inlet and outlet for each sub-basin. SBRRW was divided into 35 sub-basins. Finally, a topographic report was generated, which provided a summary of the average slope, the number of sub-basins, the area, and the elevation of each sub-basin. All input data were projected into Universal Transverse Mercator (UTM) Zone 15, North American Datum 1983 (NAD83).

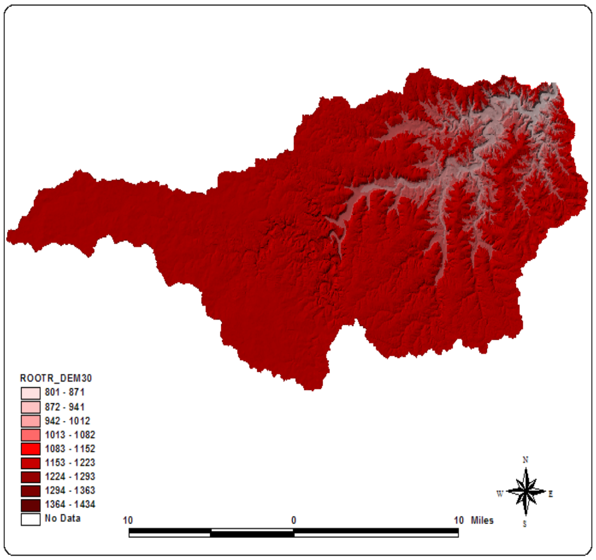

Figure 3. SBRRW Digital Elevation Model.

Stream Data

Stream network data were downloaded from the National Hydrology Dataset website, and then added to the AVSWAT Interface to define the stream network and the outlets (Figure 4). The threshold area was set to 1000 hectares. Subsequently, the watershed and sub-basins were delineated.

Land Use / Land Cover Data

The importance of land use in watershed modeling is well pronounced in the literature of watershed assessment, which not only reflects the diversity of activities on the land, but also their impact on the land, water quality, and the watershed health in general.

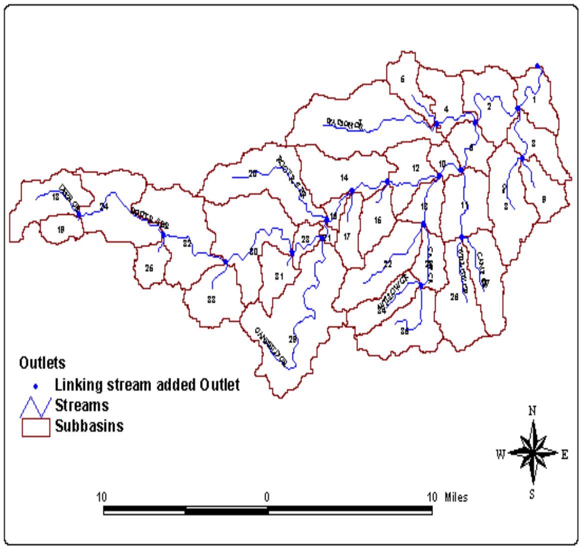

Figure 4. SBRRW streams and outlets.

Moreover, the more detailed and accurate the land use data is, the more realistic and accurate simulation of the watershed. Therefore, watersheds with highly erodible soils and extensive agricultural activities tend to have greater potential for soil loss and sedimentation that affect the streams and water bodies negatively. For the purpose of this study, land use data were downloaded from the USGS website, however that data was developed in the mid 1980's. Furthermore, the current land cover/land use data were not available. ArcView 3.3 was used to convert the land use shapefiles into a grid and then was clipped to the watershed boundary (Figure 5).

SWAT land use codes were then correlated to the grid values by using lookup tables and joining them. Lastly, the land cover layer was reclassified and added to the interface. SBRRW land use was dominated by agricultural land, which occupied about 87% of the total area of the watershed, followed by forested land at about 12%, 2.6 % residential, 1.7 % transportation, and 1.2 % commercial.

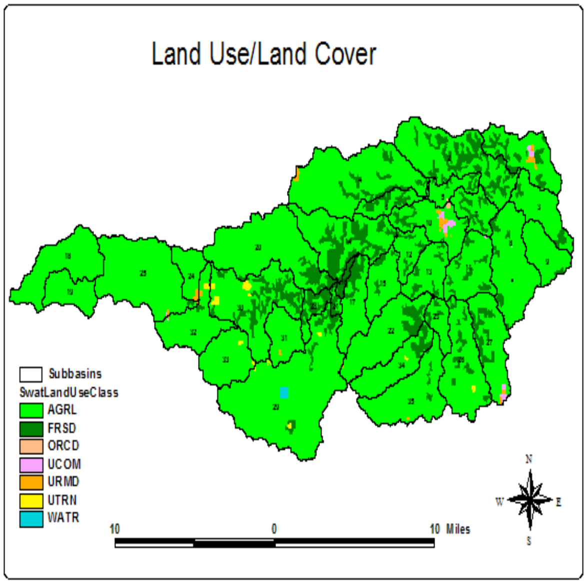

Figure 5. SBRRW land use/land cover.

Soils

This study used the State Soils Geographic Database (STASTSGO) to define soil characteristics. STASTSGO was loaded from the USDA Natural Resources Conservation Services (NRCS) website (Figure 6), and then was added to the AVSWAT 2003 Interface. The soils layer was converted to a grid, clipped to the watershed boundary, and the soil codes were correlated to the USGS codes database by selecting the STATSGO polygon number, and then the AVSWAT 2003 Interface selected the dominant soil phase to link the grid to the soils database. Finally, the soil layer was reclassified. The soil characteristics were assigned to every HRU that was based on the most dominate type of soil. The threshold for the land cover was 3% and the threshold for the soils was 5%, which represents the mapping unit to aggregate the HRU. SWAT assumes the soils were uniformly distributed with the most dominate soils, such as silt loamy and silt clay.

Overlay of Land Use and Soils

Once the land use grid and soil grid were reclassified, they were overlaid using the AVSWAT 2003 Interface. By doing so, land use, soils, and slope were distributed in the watershed. A detailed report was then generated, including the total area of the watershed, the average slope for each HRU, slope length, the percentage of distributed soils, land use, and elevation.

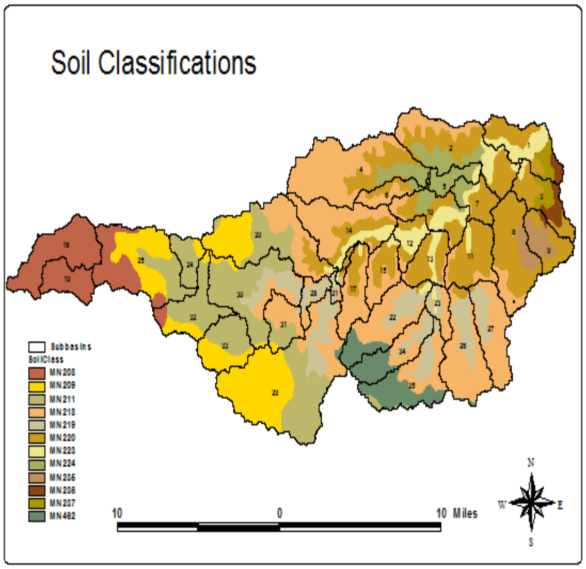

Figure 6. SBRRW soil classifications.

HRU Distribution

Each HRU reflects unique hydrological conditions and different runoff routes. SWAT utilizes this technique to increase the accuracy of load prediction and to provide a better understanding of hydrological behavior within and beyond the watershed. SBRRW was divided into 35 sub-basins and 174 HRUs. Each sub-basin was then assigned multiple HRUs, which controlled the sensitivity of the land use and soils data by setting the mapping units at 3% for land use and 5% for soils.

Meteorological Inputs Data

Climate data are required by SWAT to predict Plant Growth, such as

Evaportranspiration (ET), Potential Evaportranspriation (PET), and Wind Speed. These data are daily rainfall, maximum and minimum air temperature, solar radiation, wind speed, and relative humidity. Also, the Penman-Monteith method was used to determine Potential Evapotranspiration, while channel water routing was performed by using the Muskingum routing method. SWAT permits climate data to be input either from observed records or generated by using stochastic methods to generate random values during simulation. In this study, temperature records, wind speed, and humidity were simulated by using a weather generator. However, daily rainfall records were obtained from the USGS real-time readings at the Lanesboro station gage, two stations in Iowa, and one station in Wisconsin, which were the closest to the watershed (Figure 7). Then, SWAT assigns climate inputs to each sub-basin in the watershed.

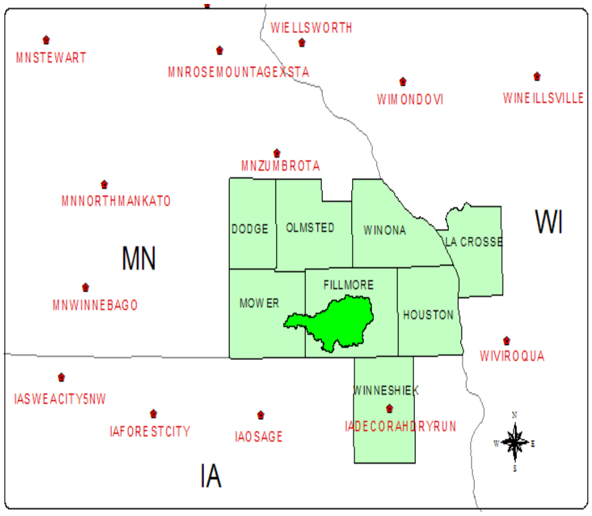

Figure7. Weather gauge locations around SBRRW were utilized to estimate climate inputs.

Management Input Data

One of the main goals of environmental modeling is to assess the impact of human activities on a given system. Therefore, central to this assessment is the itemization of the land and water management practices taking place within the watershed. Management input data were used to summarize these practices at the HRU level and to reflect farming practices in the watershed, such as planting, harvesting, fertilizer application, tillage operations, pesticide application, and crop rotations. For purposes of this study, management data were obtained from the Soil and Water Conservation District of Fillmore County (SWCD) and the MPCA. However, most of the data covers only 40% of the watershed. Therefore, this study used the available data and then generalized that data for the entire watershed. Furthermore, management practices are essential to simulate the current conditions. Despite how the Rasmussen et al. (2003) study detailed land management practices, some information about the watershed was obtained from personal communications due to limited documentation about land management within the watershed. There were three main rotations in the watershed, such as corn for four years, followed by alfalfa for four years, and finally soybeans for four years. Meanwhile, filter strips (7.5 meters) were used to curtail sediment loading from agricultural areas. Automatic application of fertilizers and pesticides and tillage operations depend on the rotation.

The main BMPs in this study were implementing the following scenarios:

1. Corn-corn rotation for four years:
    - Applying fertilizer (130 lb/acre) in pre-planting in early May.
    - Applying tillage operation (mainly chisel plow) in mid May.
    - Planting/growing season in mid May.

  - Harvesting/killing in mid October.
2. Corn-soybean rotation for four years:
   - For corn rotation:
     - Applying fertilizer (130 lb/acre) in pre-planting in early May.
     - Applying tillage operation (mainly chisel plow) in mid May.
     - Planting/growing season in mid May.
     - Harvesting/killing in early October.
   - For soybean rotation:
     - Applying fertilizer (100 lb/acre).
     - No tillage operation.
     - Planting/growing season in mid May.
     - Harvesting/killing in early October.
3. Corn-alfalfa for four years:
   - For corn rotations:
     - Applying fertilizer (100 lb/acre) in pre-planting.
     - Applying tillage operation (mainly chisel plow) in early May.
     - Planting/growing season in May.
     - Harvesting/killing in mid October.
   - For alfalfa rotations:
     - No fertilizers.
     - No tillage operation.
     - Planting/growing season in early May.
     - Harvesting at end of October.

The model was run for a period from 1980 through 2005 to simulate the existing conditions of the watershed, which represents the default simulation and a base line for the model. In the default simulation, the SWAT model used the current conditions as the input parameters without modifying or adding any of the best management practices. Next, the model was used to run for the same period, but some input parameters, such as the cover (C-FACTOR), the runoff curve number (CN), the soil evaporation composition factor (ESCO), the plant evaporation factor (EPCO), and the linear factor for calculating the maximum amount of sediment during channel degradation (SPCON) and the exponential factor for calculating the sediment re-entrained in the channel routing (SPEXP), were adjusted to match observed and simulated sediment loads. Then, the model was utilized to run each scenario under the same conditions, but using filter strips and reducing the amount of fertilizers and pesticides in corn-corn and corn-soybean scenarios. The model output, such as average annually and monthly rainfall, sediment yields, water yield, nutrients, pesticides, and fertilizers were reported per each HRU and sub-basin.

Model calibration

Model calibration was used to refine the model output to represent the actual upland and hydrological processes within the watershed and adjusting the flow and the sediments main input parameters in the model before running the scenarios (DeBarry, 2004). To begin the calibration procedure, the flow must be calibrated and the simulated output compared with observed data. Unfortunately, flow calibration was not done in this study due to unavailability of continuous flow records to cover the calibration period. Also, the flow and discharge records, which were downloaded from USGS website, showed that there was no USGS gauge at the South Branch except the gauge at Lanesboro. Lanesboro station data were incomplete or limited in time with respect to the model simulation period but was the best available and model average annual flow outputs was compared with annual average readings at the nearby gauge at Lanesboro. Flow was adjusted manually to match these flow stream data. Next, the model sediment loadings were calibrated by modifying the following parameters to match the observed data, (1) the cover and management factor (C-FACTOR) that represents the ratio of soil loss from land cropped under specific conditions to the soil loss from any management practice (Wishmeier and Smith, 1978). (2) The linear factor for channel sediment routing (SPCON) to calculate the maximum amount of sediment re-entrained during the simulation. (3) The exponential factor for channel sediment routing (SPEXP) to calculate the sediment re-entrained the channel sediment routing (Arnold et al, 2001).

Then, the calibrated model was used to simulate the three scenarios annually for the period from 1980 through 2005. In the first scenario (corn rotation), corn rotation was used every four years, fertilize was used at (130 lb/acre), tillage operation (chisel plow) was applied in the mid of the season, and filter strips were also implemented at 7.5 meters at the edge to HRU. In the second scenario (corn-soybean rotation), which rotates the two crops every four years; in corn rotation, the existing conditions were modified by adding less fertilizers (130lb/acre), tillage operation(chisel plow) was utilized in mid May, and filter strips were used to curtail the transportation of sediment to the main channel. In soybean rotation, fertilizers and tillage operations were not used, but filter strips were modeled to minimize the sediment traversing through the watershed. In the third scenario (corn-alfalfa rotation), the current conditions were altered by rotating corn crop with alfalfa for every four years; in corn rotation, fertilizer was used at the same rate as the above rotations and the other management practices as well. However, in alfalfa rotation none of the above was applied, because alfalfa was considered as a perennial plant; therefore it was used to balance the nitrogen shortage in the soil and to reduce the sediment yields.

Finally, the model outcome of each scenario was reported in term of annual average of the rainfall on the entire watershed, the amount of sediment entering and leaving each HRU, and the total amount of sediment yield at each sub-watershed outlet.

Results and Discussion

As a result, the total amount of sediment yields from each HRU and each sub-basin in the watershed for each distinct land management practice (i.e. the default simulation and the calibrated model), was reported and compared to each other and to the default simulation. Those scenarios were used to trace the effect of BMP’s and to allow more investigation to take place by utilizing SWAT to improve water quality within and beyond the watershed. The study demonstrated that the estimated sediment yield was dependent mainly on the soil type, the terrain slope, current land use, land management practices, and the weather. The study suggested that the most sediment yields (1.5 ton/ha) was from the middle section of the watershed, followed by the lower section of the watershed (0.3 – 0.8 ton/ha). The upper section of the watershed was modeled to contributed less than (0.3 ton/ha). The study also indicated that the first scenario (corn-corn rotation) and the second scenario (corn-soybean rotation) were major contributors to the increasing rate of the sediment and pollution because they were row crops and were dependent heavily on fertilizers and pesticides to boost the biomass production. The third scenario (corn-alfalfa rotation) was shown to yield the least sediment (0.47 ton/ha) and the lowest pollution rates on the entire watershed.

Corn – Corn Rotation

A corn rotation (Figure 8) was implemented for the whole watershed with additional land management practices, such as filter strips of 7.5 meters on the edges of the HRUs to minimize the amount of sediment and pollution as a result of cropping corn and curbing the surface runoff. The fertilizer application rate was reduced to 130 lb/acre rather than 147 lb/acre as suggested by Rasmussen et al. (2003) report.

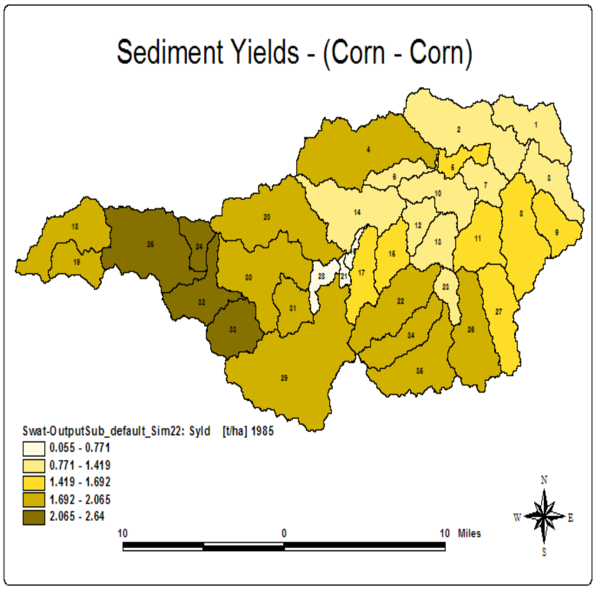

Figure8. Corn Rotation sediment yields hotspots indicating locations of potential sediment yield in the watershed.

Corn – Soybean Rotation

The corn - soybean rotation was utilized to minimize soil erosion, reduce fertilizer by 50%, and minimize tillage operations. Again the fertilizer application rate was reduced to 130 lb/acre as advised by suggested by Rasmussen et al. (2003) report. As a result, the sediment yield was reduced by 10% from the current conditions baseline (Figure 9).

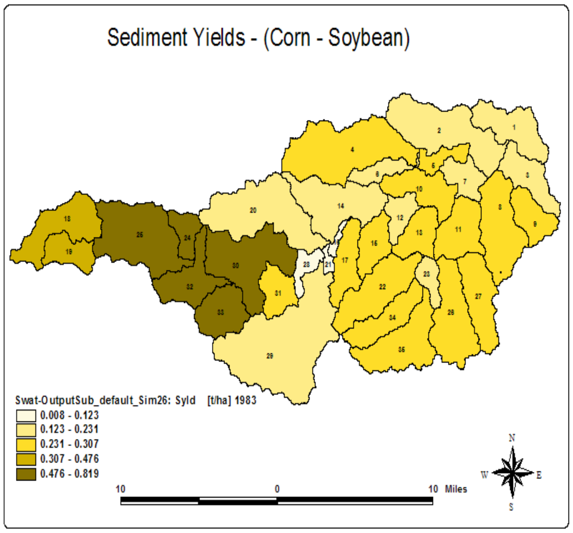

Figure 9. Corn – Soybean Rotation sediment yield hotspots indicating locations of potential sediment yield in the watershed.

Alfalfa – Alfalfa Rotation

The Alfalfa – alfalfa rotation, used as a perennial grass was found effective in reducing the sediment yield in this study.

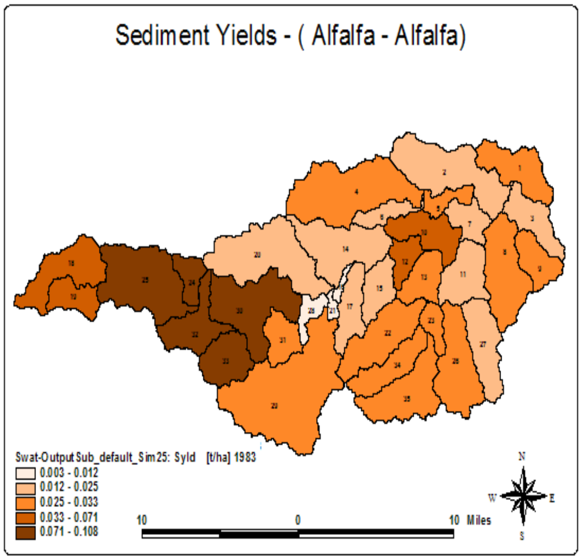

Figure10. Alfalfa – Alfalfa Rotation sediment yield hotspots indicating locations of potential sediment yield in the watershed.

The predicted results showed that the sediment yield was reduced by 85% from the baseline compared to the sediment yield from the corn or soybean rotations. Alfalfa – Alfalfa cropping could reduce overall sediment yield, though gradually as river banks themselves contribute significantly to the total sediment yield (Figure 10).

Conclusion

This study showed that the SWAT model can be used not only to simulate and to quantify the sediment loading within the watershed, but also to highlight potential areas that were contributing the most. This study also provides a general guidance to assist with investigating and examining watershed health, and to encourage local agencies and the public to get involved in collecting and recording flow, nutrients, and sediment data within the watershed. Although, the model was not fully calibrated due to limitation and lack of the continuous discharge flow data for the South Branch of Root River and sediment information for the watershed, this study does shed light on potential sites that contribute the most and how BMP's can help to minimize sedimentation, pollution, and their effects on the watershed and the human being health.

Acknowledgement

I would like to extend my gratitude and appreciation to my family, Nagala, Humodi, and Maabe for their patience and support during the completion of this paper. I also would like to thank the staff of the Department of Resource Analysis. Without their help and support, I would not have come this far, especially Dr. David McConville, Mr. John Ebert, and Mr. Patrick Thorsell. Other thanks go to the GeoSpatial Services family for the opportunity they gave me and I wish the best for you all. Also, I would like to thank Dr. Beckry Abdul-Majed (Winona State University) for his help and guidance. Finally, my thanks goes to the group of the Fillmore County Soil and Water Conservation District office at Preston, MN, especially Donna Rasmussen, Jeremy Maul, Lee Ganske (MPCA, Rochester, MN), Rich Biske (The Nature of Conservancy in Minnesota, Preston, MN), and Tex Hawkins (Fish and Wildlife Services, Winona, MN) for their help and technical support.

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