A Study on Crop Residue Coverage in State of Iowa and its Importance in Urban Water Supply

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Project Outline

• Project Background
• Project Objectives
• Literature Review
• Methodology
• Spatial Analysis
• Results
• Policy Based Analysis
• Conclusion
Project Background

Recent lawsuit of the Des Moines Water Works against Sac, Buena Vista and Calhoun counties in north-western Iowa.

Disposal of agricultural runoff in the Raccoon River.

According to the CEO of Des Moines Water Works, “It costs about $4,000 a day to operate the facility (The Des Moines Register, 2015)”. 
Project Background

This study has been conducted on the South Fork portion of the Iowa River and main consideration of the study was to analyze the presence of tillage practice in the agricultural fields.

Disposal of nutrients and pollutants from non-point sources depend on the strength of the soil, residue coverage, annual rainfall etc. issues.

Presence of higher residue coverage in agricultural fields reduces the force with which rain drops fall on the top soil and decreases presence of polluted soil in agricultural runoff during flood.
Study Area (South Fork Watershed)
Study Area (South Fork Watershed)

South Fork portion of the Iowa River has been selected for the study, which covers 775 sq. km.

Around 85% of this watershed is under the corn and soybean production and the remaining non-agricultural land are dominated by pasture and deciduous forest, which were typically located in riparian valleys (Tomer, 2008).

Presence of gully erosion is another significant characteristics of the area. The terrain is young, and therefore natural stream incision and development of alluvial valleys has only occurred in the lower parts of the watershed (Green, 2014).

Drainage is the most important procedure to control the erosion in the area, but the presence of the gully erosion and the fragile soil makes the task difficult.
Objectives of the Study

The study will try to achieve below objectives related to the urban water supply:

I. Developing standard remote sensing protocols for the inventory of residue coverage in agricultural fields.

II. Analyzing proper procedure of identifying erosion prone areas to control municipal water quality.

III. Proposing some design based initiatives to control quality of water in cities located at close proximity to agricultural areas.
Literature Review

Tillage and No-Tillage Farming

Agricultural fields with tillage practice have higher rate of agricultural runoff generation, because of the presence of lower organic content in the soil.

Tillage practice coverts soil into concrete like structure with lower micro pores and, which plays a key role behind the agricultural runoff generation.

It decreases the rate of soil erosion in area, because of the presence of higher residue coverage or the dead plants on the top layer of the soil.

Most significant benefit of the no-tillage farming is that it keeps the biological fertility and makes the soil more resilient.
Residue Coverage Calculation:

Normalized Difference Tillage Index (NDTI):

Tillage measurement index depends on the Landsat image of band 5 and 7. Calculation procedure for the NDTI index,

$$\text{NDTI} = \frac{\text{TM5} - \text{TM7}}{\text{TM5} + \text{TM7}}$$

Tillage is calculated at the beginning of the planting season around April-May to identify amount of small tree coverage.
Delineation of the Watershed

"that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community (EPA, 2014)."
Methodology of the Study

- Analysis of the land use pattern in study area
  - Spatial Analysis of the Area
    - Geographical Threat Analysis
      - Solution Analysis
        - Integrated Agricultural Runoff Management
  - Residue Coverage Calculation
  - Tillage Coverage Calculation
  - Slope Analysis
    - Possible
    - Likely
    - Less Likely
      - Spatial Analysis of the Area
# Data Collection

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Source</th>
<th>Use</th>
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<tbody>
<tr>
<td>Landsat Imagery</td>
<td>USGS</td>
<td>NDTI Calculation</td>
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<tr>
<td>Common Land Unit (CLU) data</td>
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<td>Elevation Data</td>
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</tr>
<tr>
<td>Residue Coverage</td>
<td>AGREN</td>
<td>Comparison</td>
</tr>
</tbody>
</table>
NDTI Calculation:

Downloaded data from http://glovis.usgs.gov/

Date: May 12, 2013
Cloud Coverage: <5%
NDTI Calculation:

Python Script (NDTI Calculation):

```python
import arcpy, sys, os, glob, math, traceback
from arcpy.sa import *
from subprocess import call
arcpy.CheckOutExtension('Spatial')
arcpy.env.workspace = os.getcwd()
arcpy.env.overwriteOutput = True
tifDir = 'F:\Thanksgiving\Dr. Brian Research\Final Data Processing\NDVI_NDTI\'
# get a list of all 'las' files in cmd
L_B1 = glob.glob(os.getcwd() + '\\B1.TIF')
for each_file in L_B1:
    lsID = os.path.basename(each_file)[-7]
    B1T = Raster(tifDir + lsID + '_B1.TIF')
    B2T = Raster(tifDir + lsID + '_B2.TIF')
    B3T = Raster(tifDir + lsID + '_B3.TIF')
    B4T = Raster(tifDir + lsID + '_B4.TIF')
    B7T = Raster(tifDir + lsID + '_B7.TIF')

# NDVI & NDTI Calculation
NDVI = Float(B4T - B7T)/Float(B4T + B7T)
NDVI.save(tifDir + lsID + '_NDVI.TIF')
NDTI = Float(B3T - B7T)/Float(B3T + B7T)
NDTI.save(tifDir + lsID + '_NDTI.TIF')
```

Residue Coverage Calculation of Fields:

```python
import arcpy, sys, os, glob, math, traceback
from arcpy.sa import *
from subprocess import call
from arcpy import env
from arcpy.sa import *

arcpy.CheckOutExtension('Spatial')
arcpy.env.workspace = os.getcwd()
arcpy.env.overwriteOutput = True

# Zonal Statistics
# Set environment settings
env.workspace = "F:\Thanksgiving\Dr. Brian Research\Final Data Processing\Buffer\NDVI_NDTI"

# Create List of NDTI Files
NT = glob.glob(os.getcwd() + 'NDTI_C.TIF')

for each_value in NT:
    # Set local variables
    inZoneData = "Residue_Coverage_Query_Buffer.shp"
inZoneField = "FID"
inValueRaster = os.path.basename(each_value)

    TID = os.path.basename(each_value)[-4]
    outTable = TID + ".shp"

    # Execute ZonalStatistics
    outZSaT = ZonalStatisticsAsTable(inZoneData, inZoneField, inValueRaster,
                                    outTable, "DATA", "ALL")
```

Saved NDTI values in excel file
Residue Coverage Calculation of Fields:

Zoning .dbf file to the residue coverage shape file

```python
import arcpy, sys, os, glob, math, traceback
from arcpy.sa import *
from subprocess import call
from arcpy import env
from arcpy.sa import *

arcpy.CheckOutExtension('Spatial')
arcpy.env.workspace = os.getcwd()
arcpy.env.overwriteOutput = True
env.workspace = "F:\Thanksgiving\Dr. Brian Research\Final Data Processing\Buffer\Zonal"

# Create List of NDTI Files
JF = glob.glob(os.getcwd() + '\*\TI.dbf')

for each_file in JF:
    LJF = os.path.basename(each_file)
    FN = os.path.basename(each_file)[7:9]
    MFN = os.path.basename(each_file)[11:16]
    BFN = os.path.basename(each_file)[24:25]
    NN = "N" + str(FN) + str(MFN) + str(BFN)

    IP = os.path.basename(each_file)[7:9]
    RP = os.path.basename(each_file)[11:16]
    MNF = "M" + str(IP) + str(RP) + "T"

    arcpy.JoinField_management("Residue_Coverage_Query_Buffer.shp", "FID", LJF, "FID_", ["FID_", "MEAN"])

    arcpy.AddField_management("Residue_Coverage_Query_Buffer.shp", NN, "FLOAT")
    arcpy.CalculateField_management("Residue_Coverage_Query_Buffer.shp", NN, "!" + "FID_" + ":1", "PYTHON")
    arcpy.DeleteField_management("Residue_Coverage_Query_Buffer.shp", ["FID_"])

    arcpy.AddField_management("Residue_Coverage_Query_Buffer.shp", MNF, "FLOAT")
    arcpy.CalculateField_management("Residue_Coverage_Query_Buffer.shp", MNF, "!" + "MEAN" + ":1", "PYTHON")
    arcpy.DeleteField_management("Residue_Coverage_Query_Buffer.shp", ["MEAN"])
```
Residue Coverage Calculation of Fields:

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</table>
Residue Coverage Output

Average Residue Coverage: 27%

NDTI: 0.0695

y = 0.0004x + 0.0569
Residue Coverage Output

Corn Fields Average Residue Coverage: 28%
NDTI: 0.067

Soybean Fields Average Residue Coverage: 17%
NDTI: 0.071

Corn is more highly responsive crop compared to the soybean, so the curve between NDTI and residue coverage are going to be more positively slope in corn compared to the soybean.
Economic Benefits of Higher Residue Coverage

There is no directly standard for defining that residue coverage in the agricultural fields.

Provision of different government benefits:

- FSA loans and disaster assistance payments
- NRCS and FSA conservation program benefits
- Federal crop insurance premium subsidies
Delineating Watershed

Flow Direction:

Flow direction map shows the direction of the water movement in case of major storm events.

Although storm water flow in an area depends on the elevation, infiltration, soil type etc. issues in an area, flow direction map normally prepared based on the elevation change in an area.

Maximum drop = (Change in Z-value/distance) * 100
Delineating Watershed

Spatial Analyst > Hydrology > Flow Direction >
Delineating Watershed

Flow Accumulation:

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster.

Stream Order Method
Delineating Watershed

Legend
- Impact_Cities
- Stream Order
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
- Agricultural Fields

Presence of gully erosion

Flow of water through the Cities
Precipitation and Soil Loss Rate in South Fork Watershed (May, 2013)

Precipitation: 18.96 mm

Soil Loss: 0.005952 KGM²

Source: Iowa Daily Erosion Project, 2015
Watershed of Iowa River

Total area: 8854 sq. m.

No. of Cities: 150
Precipitation Rate

It can be easily identified from the picture that rain is most common at the south-east portion of State of Iowa.

Erosion from an area depends on both precipitation and soil characteristics.

Mean Precipitation Rate in State of Iowa: 16.9 mm

In Iowa River Watershed Area: 19.5 mm

Source: Iowa Daily Erosion Project, 2015
Soil Loss Rate

Soil Loss is basically the combined effect of the precipitation and soil structure in an area.

Mean Soil Loss Rate in State of Iowa: 0.043 KGM2

In Iowa River Watershed Area: 0.05 KGM2

Source: Iowa Daily Erosion Project, 2015
Findings and Solutions

From the residue coverage and NDTI graph one thing can be easily identified that residue coverage in most of the agricultural fields are less than 30% and the positive correlation between the NDTI and Residue Coverage curve represent the effectiveness of the data collection process.

The 2010 USGS assessment found that concentrations of nitrate were highest in shallow groundwater beneath agricultural lands, with a median concentration three times greater than the national background level of 1.0 mg/L.43 (Environmental Working Group, 2013).

State of Iowa is dependent on the voluntary initiatives to counter the problem of nutrient disposal in the major rivers. So, they require some policy and design based initiatives to solve the problem of nutrient disposal.
Policy Related Solutions

Clean Water Act (1972):

Formerly known as the Federal Water Pollution Control Act, this statute was enacted to control the quality of the river water and preserve the present condition by reducing the discharge of pollutants into lakes, rivers, streams and wetlands (US Department of Agriculture, 2014).

The Clean Water Act has reduced much of the pollution in the Mississippi River from “point sources” such as industries and water treatment plants, but problems stemming from urban runoff, agriculture, and other “non-point sources” have proven more difficult to address.

The act also called for zero discharges of pollutants into navigable waters by 1985 and “fishable and swimmable” waters by mid-1983 (The National Academy of Engineers, 2014).
Policy Related Solutions (NEPA)

The National Environmental Policy Act (NEPA) is a law in United States, which was established to promote policies related to the environmental protection. The main catalyst behind this act was the 1969 Santa Barbara Oil Spill.

NEPA contains three sections:
1. The declaration of national environmental policies and goals
2. The establishment of provisions for federal agencies to enforce policies and goals
3. The establishment of the CEQ in the Executive Office of the President (Wikipedia, 2014)
Urban Planning Initiatives

Use of Buffer Zone:

Eightmile River watershed of Connecticut:

Three factors have been considered,
1. Proximity of row crops to streams
2. Sub-watershed slope
3. Proximity of feedlots to rivers

Properly installed riparian buffer is capable of removing 50 of the nutrients and pesticides. In order to prevent most erosion, vegetated buffers of 30 feet to 98 feet have been shown to be effective.

“The Use of Spatial Data in Creating a Riparian Buffer Suitability Model: Whitewater River Watershed, Minnesota” by Budlong, R.
Urban Planning Initiatives

Use of Ground Cover:

Chesapeake Bay area:

From the storm order map of the study area one thing can be identified, that is the presence of the increased number of smaller order stream. So, if these connecting streams can be brought under appropriate ground coverage then pollution in the ground water and surface water will significantly decrease.

Seed mix might be applied above the agricultural fields prior to place the blanket cover on the agricultural fields. Different types of ingredients might be used as the blanket cover, like straw rolls, also known as the fiber rolls, coir rolls.
Limitations

- Normalized Difference Tillage Index (NDTI) curve has been prepared for only a small portion of the Iowa River Basin area. Policy and design based solutions have proposed whole Iowa River Watershed. Significant portion of these areas might be already under the no-tillage farming practice with higher residue coverage. So, collection of residue coverage information of the whole Iowa River Basin was mandatory before proposing any policy based solution.

- Soil type has not been considered in this study based on the Normalized Difference Tillage Index (NDTI). But storm runoff generation depends significantly on the soil type in an area, especially percentage of clay, sand and silt in the soil.
Conclusion

Problems are at much broader scale so taking one or two initiatives are not going to solve the problem. It will require policy based solution over longer period covering broader area.

Ground water might be also polluted in the long run, which will significantly increase their financial burden.

From the watershed map of the Iowa River, we can identify that agricultural runoff problem might not create any problem in the adjacent cities in the South Fork Area, because of their dependence on the ground water, but it will definitely create problem in further away in Iowa City, because of their dependence on the surface water.
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Everyone else from Department of Community and Regional Planning, ISU
Thank You All

Questions?
Reference


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Reference


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Reference


