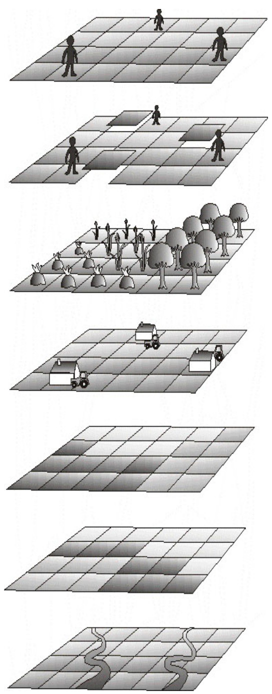
VIRTUAL WATERSHED: A SPATIAL DECISION SUPPORT SYSTEM FOR AN AGRICULTURAL WATERSHED



Seth Soman, Girmay Misgna, and Steven Kraft

ACES 2018
Washington D.C. , December 4- 6

Based upon work supported by the National Science Foundation under Grant No. 0410187

Introduction

Watershed management takes place on a landscape controlled by private landowners. Their decisions will, in large part, reflect economic criteria like profit maximization.

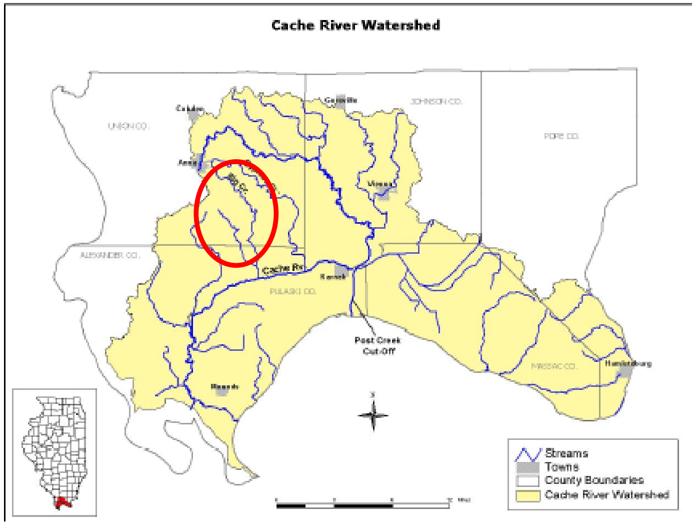
To maintain or enhance ecological integrity, as well as avoid conflict with the land users, watershed management plans should reflect the economic uses to which the privately held land can be put.

Virtual Watershed

- *Virtual Watershed* is a prototype web-based agricultural watershed planning tool based on the Big Creek watershed in Southern Illinois
- Aimed at helping to explore and gain insight in to tradeoffs among
  - agricultural and environmental policies,
  - landowner decision-making processes,
  - and environmental and economic outcomes.

Big Creek watershed issues

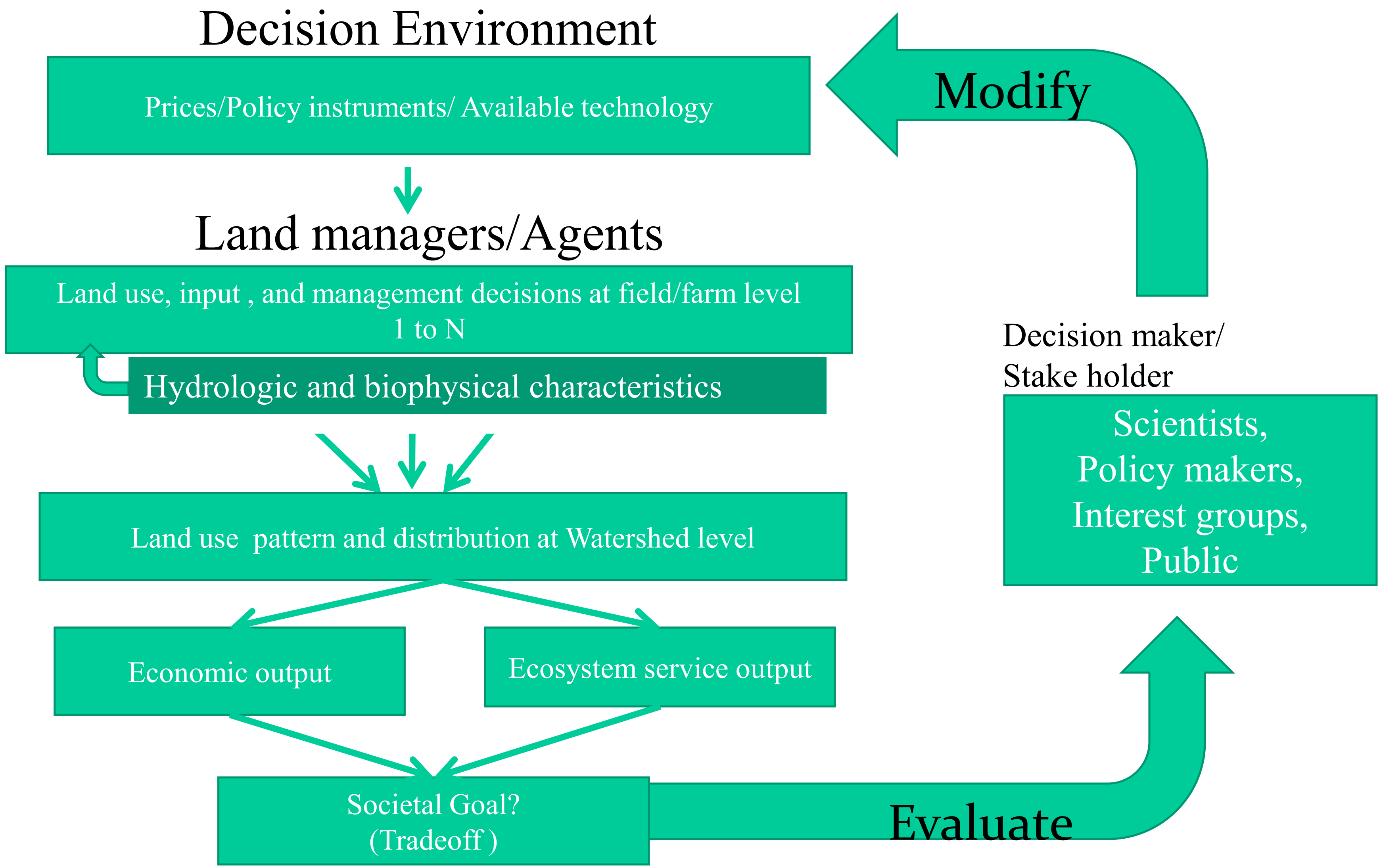
- Identified by ISWS as primary source of sediment in the Lower Cache River (Demissie et al., 1992).
- More than 70% of sediment inflows in to the Lower cache based on 1985-1988 data (Demissie et al., 2001)
- Significant amount of nutrient pollution(NPS)



Integrated System

- The tool combines several important systems-related models
  – multi-objective optimization model (evolutionary algorithms)
  – agent-based model, and
  – environmental/hydrologic simulation model

Conceptual Framework

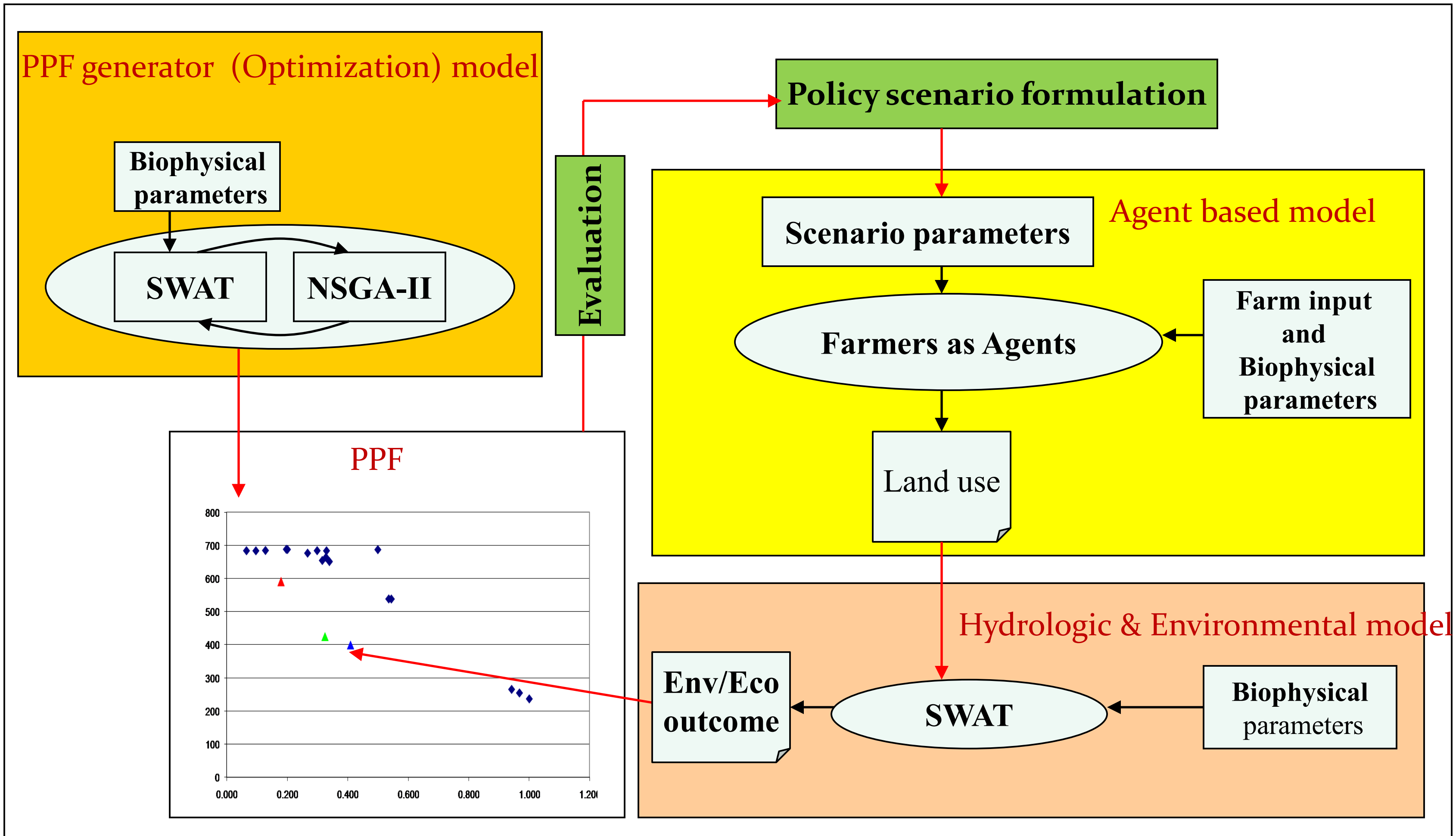


Translation from Concept to Model

Four essential modeling requirements:

- **Representing the socio-economic driving forces or the decision environment?** Using scenario analysis and formulating scenarios expressed by relevant parameters
- **Representing farmers/farm operators response to specific decision environment?** Using Agent based model
- **Simulating the economic and environmental outcomes?** Using Environmental/Hydrologic simulation model.
- **Evaluating performance of each outcome?** Using a tradeoff curve or Production Possibility Frontier (PPF)

Integrated modeling Framework

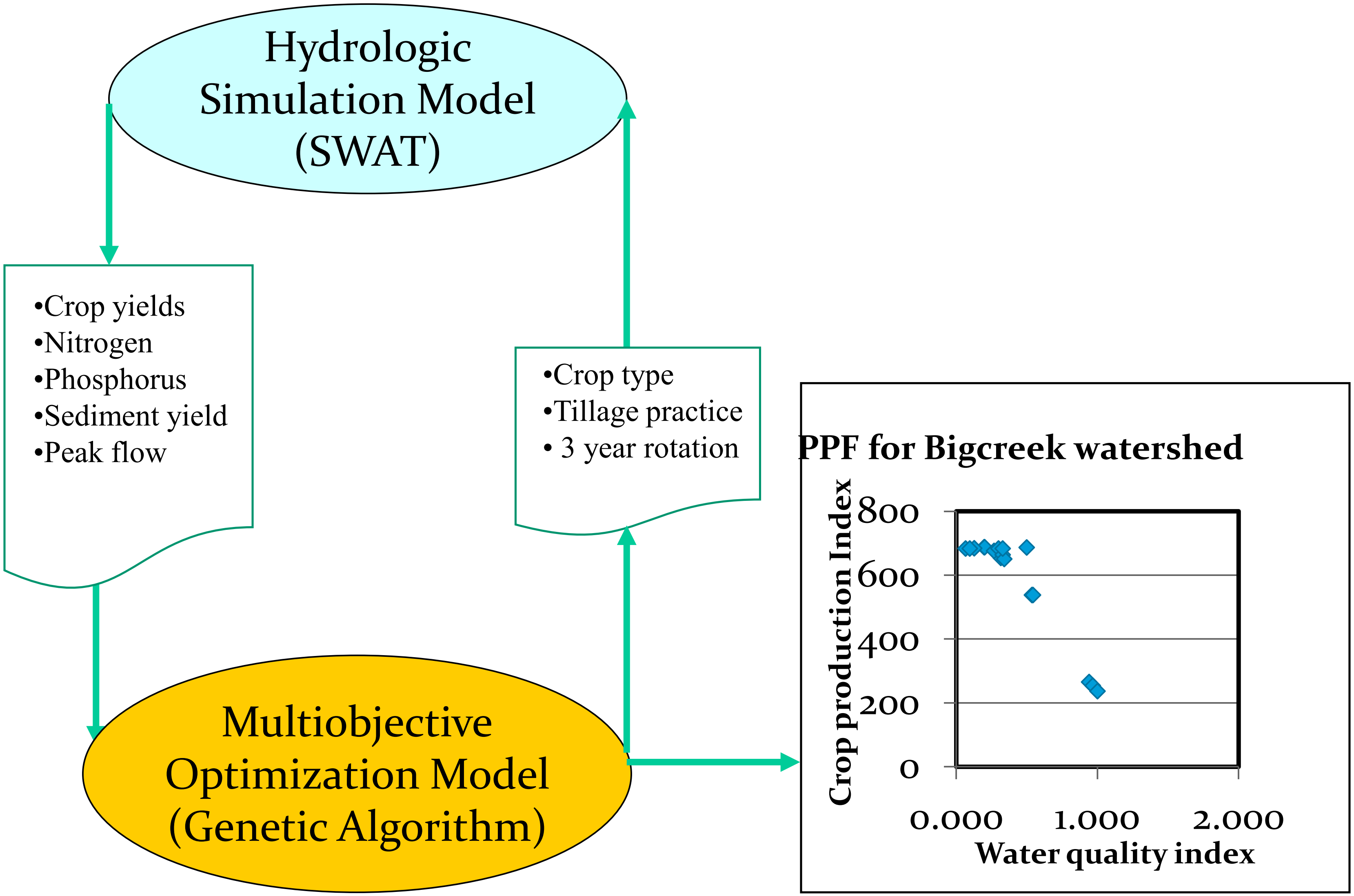


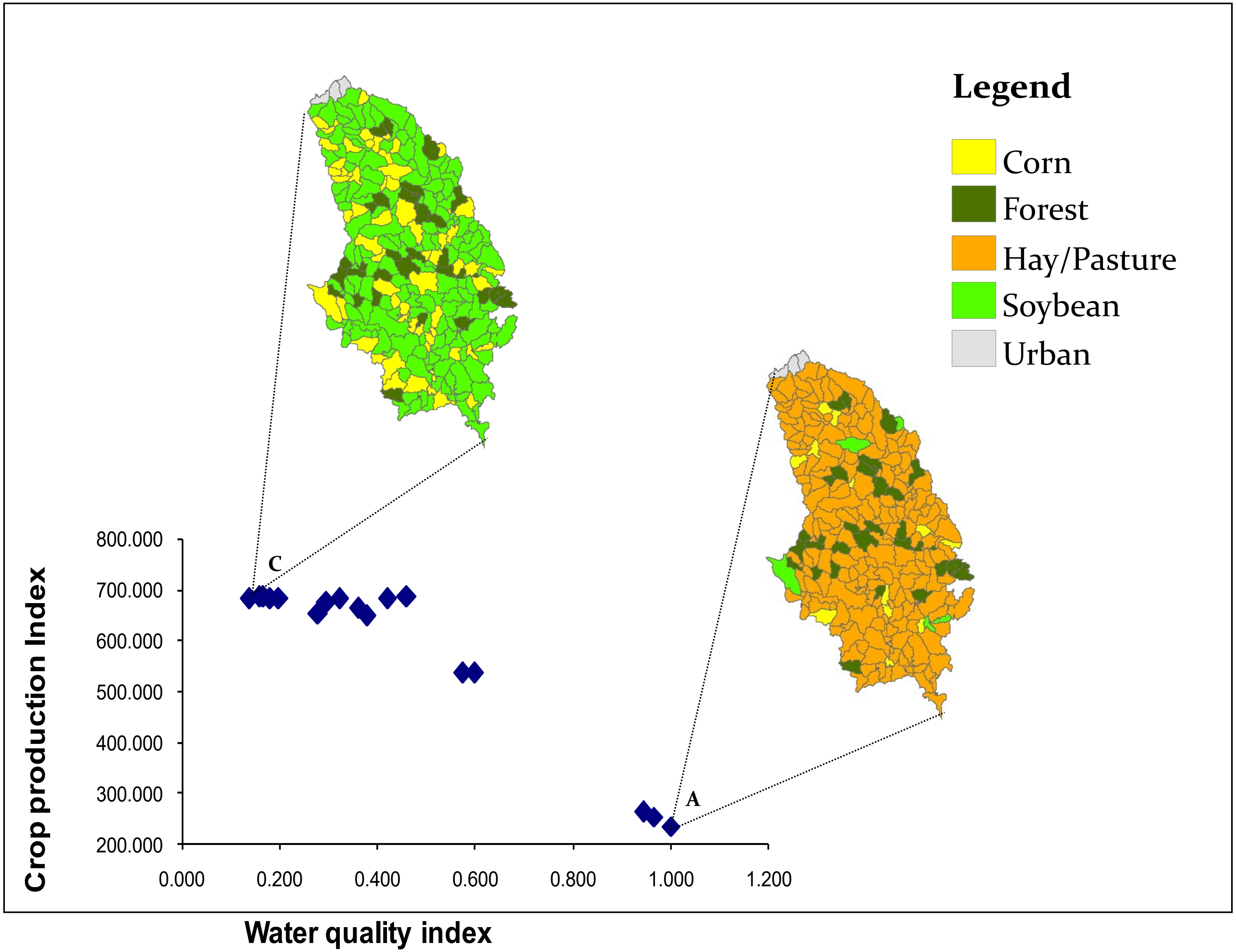
NSGA-II : Non-dominated Sorting Genetic Algorithm II (Deb, 2002)

Production Possibility Frontier (PPF)

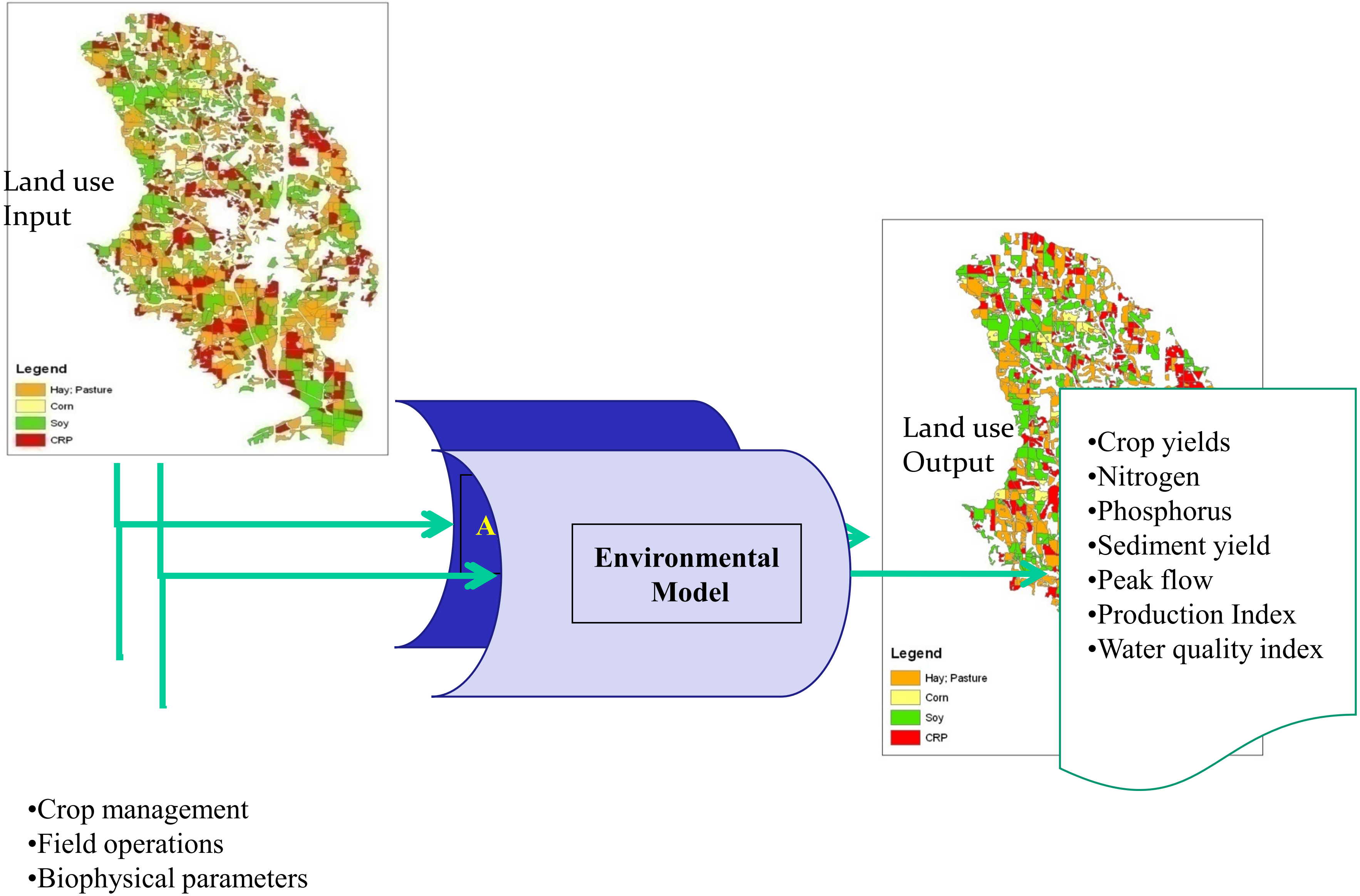
- The Production Possibility Frontier is a graph that shows all the combinations of goods (or services) that can be produced at maximum efficiency given a set of inputs (resources, labor, etc.)
- **PPF for Virtual Watershed constructed based on:**
  - **Two competing alternatives**
    - Production of Agricultural commodities (indicated by **Crop production index**) and
    - Production of Ecosystem services (indicated by **Hydrologic water quality index**)

PPF Generator Model for optimal land uses



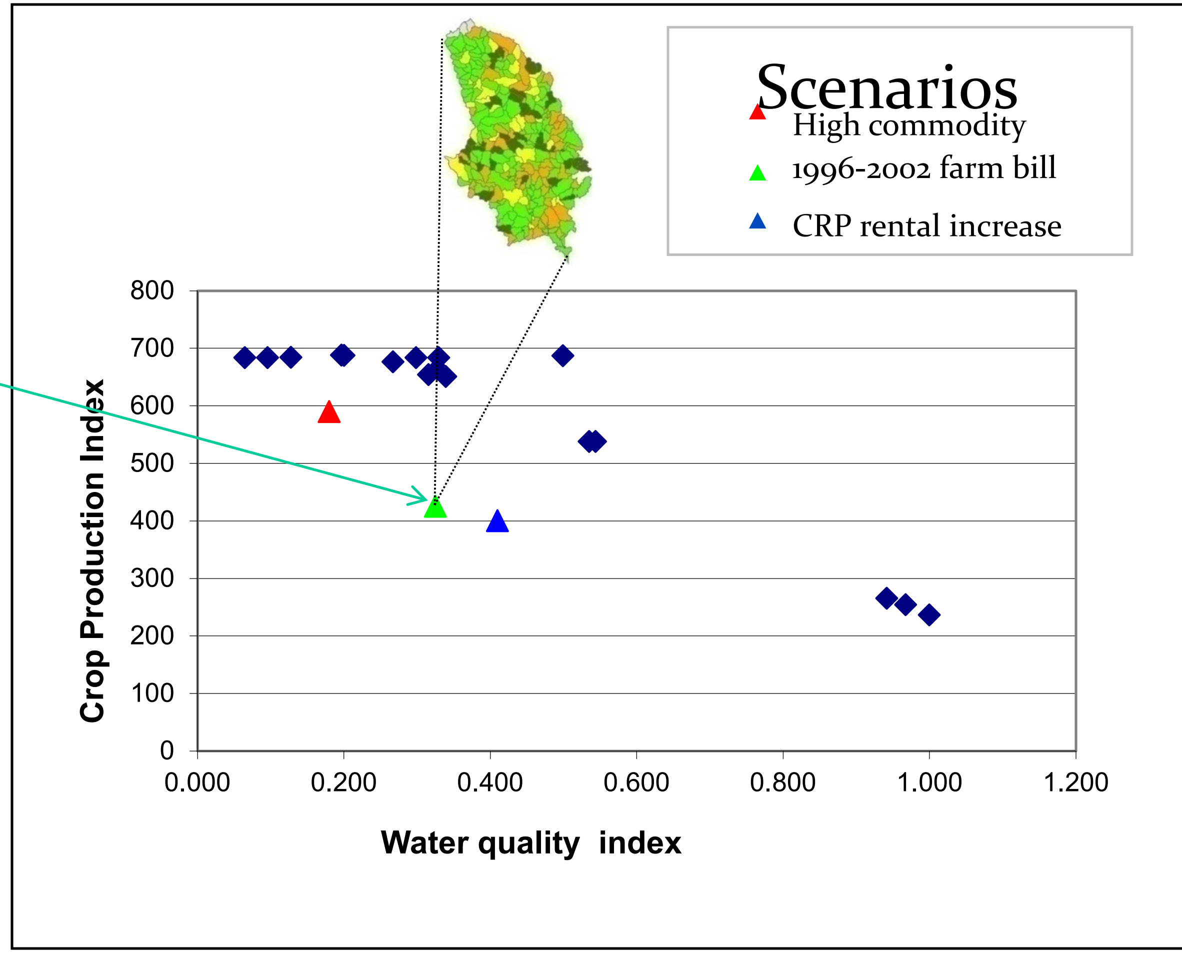


Two dimensional PPF where each point represents a discrete land use pattern with considerably different levels of economic and ecological performance.


Land use Input
Legend
Hay; Pasture
Corn
Soy
CRP
A
Environmental Model
Land use Output
Legend
Hay; Pasture
Corn
Soy
CRP
•Crop yields
•Nitrogen
•Phosphorus
•Sediment yield
•Peak flow
•Production Index
•Water quality index
•Crop management
•Field operations
•Biophysical parameters

- Crop yields
- Nitrogen
- Phosphorus
- Sediment yield
- Peak flow

- Crop Production Index
- Water quality index



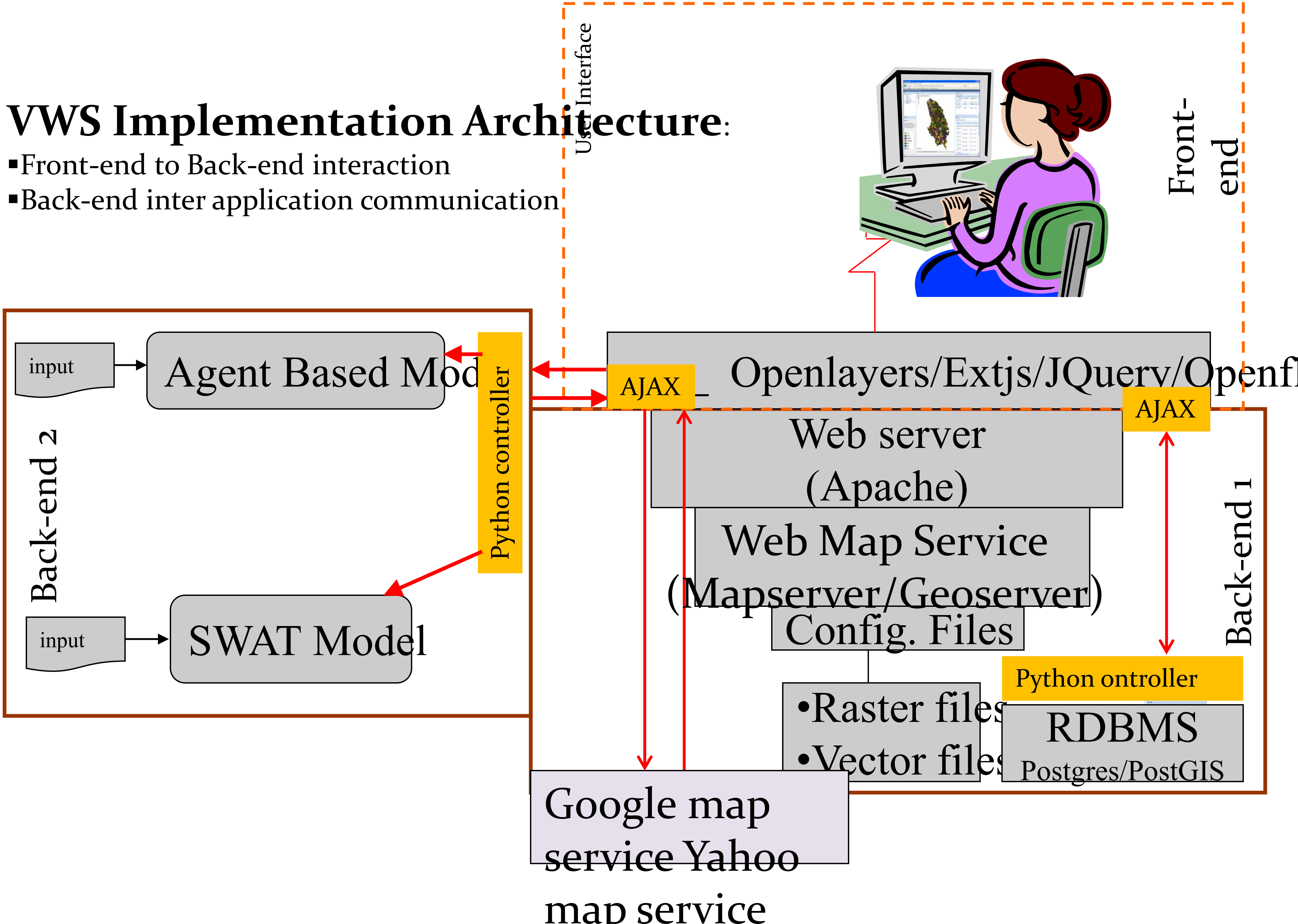
The management problem involves user determination of how policy (e.g., public subsidization and regulation) and price structures can be altered to provide incentives so that to move the landscape closer to the PPF through the improvement space.

Virtual Watershed Web Application Demo

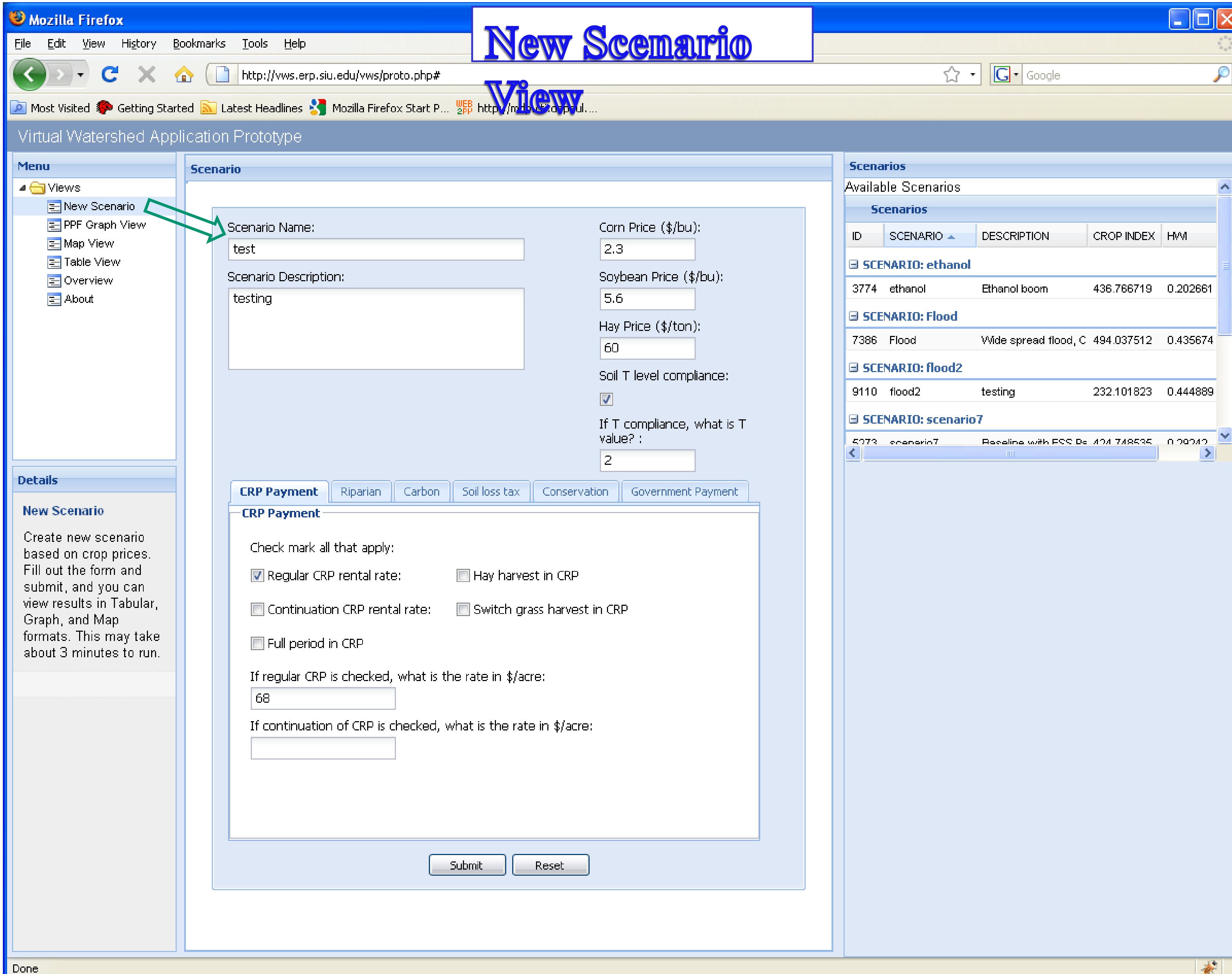
- Virtual Watershed can be accessed at http://vws.erp.siu.edu:90/vws/
- Users define scenarios and submit through the scenario entry form
- Policy scenarios are represented by parameters like crop prices, CRP rental rates and level of soil loss
- Simulation results are then displayed in various views as maps, graphs, and tables .

VWS Implementation Architecture:

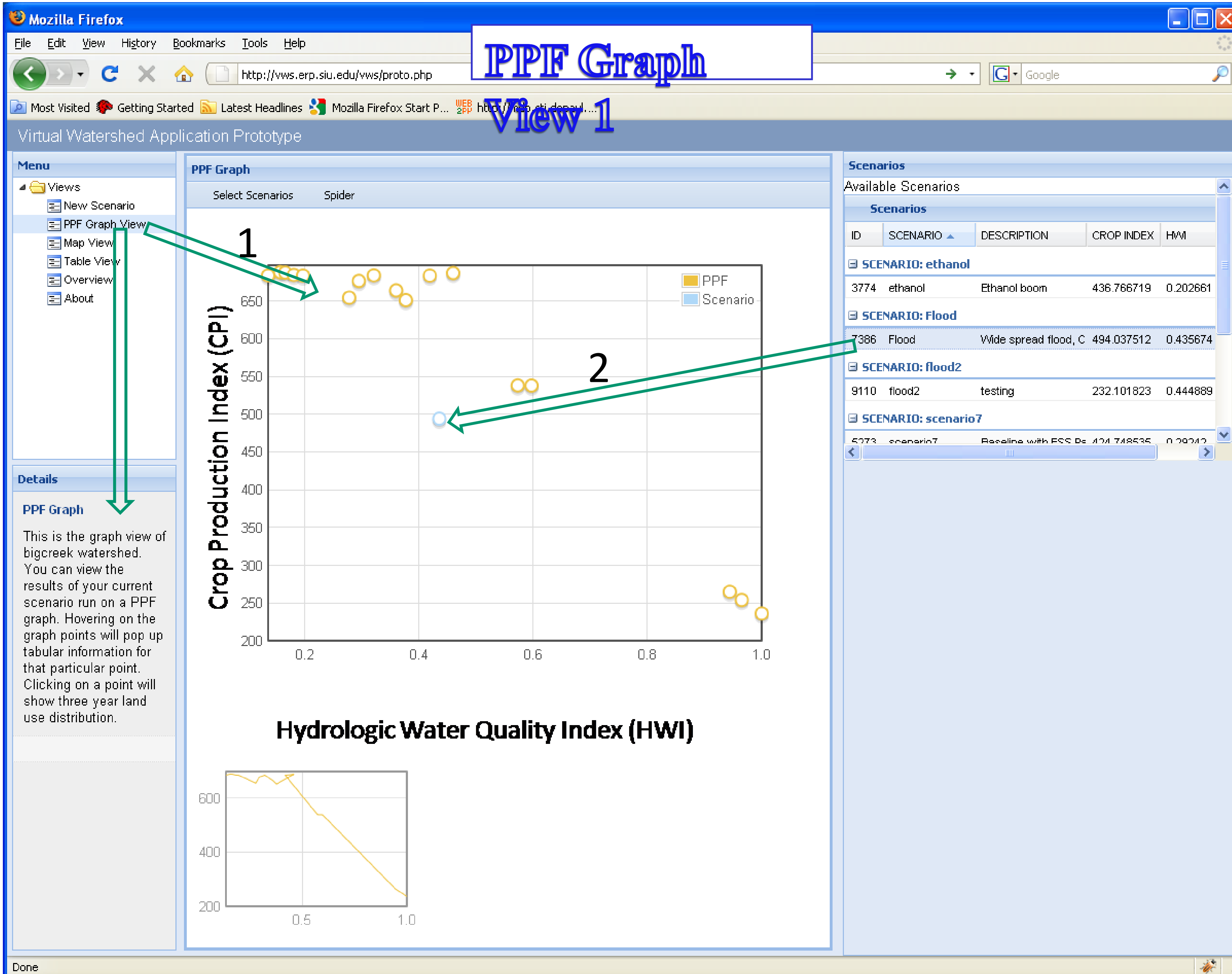
- Front-end to Back-end interaction
- Back-end inter application communication

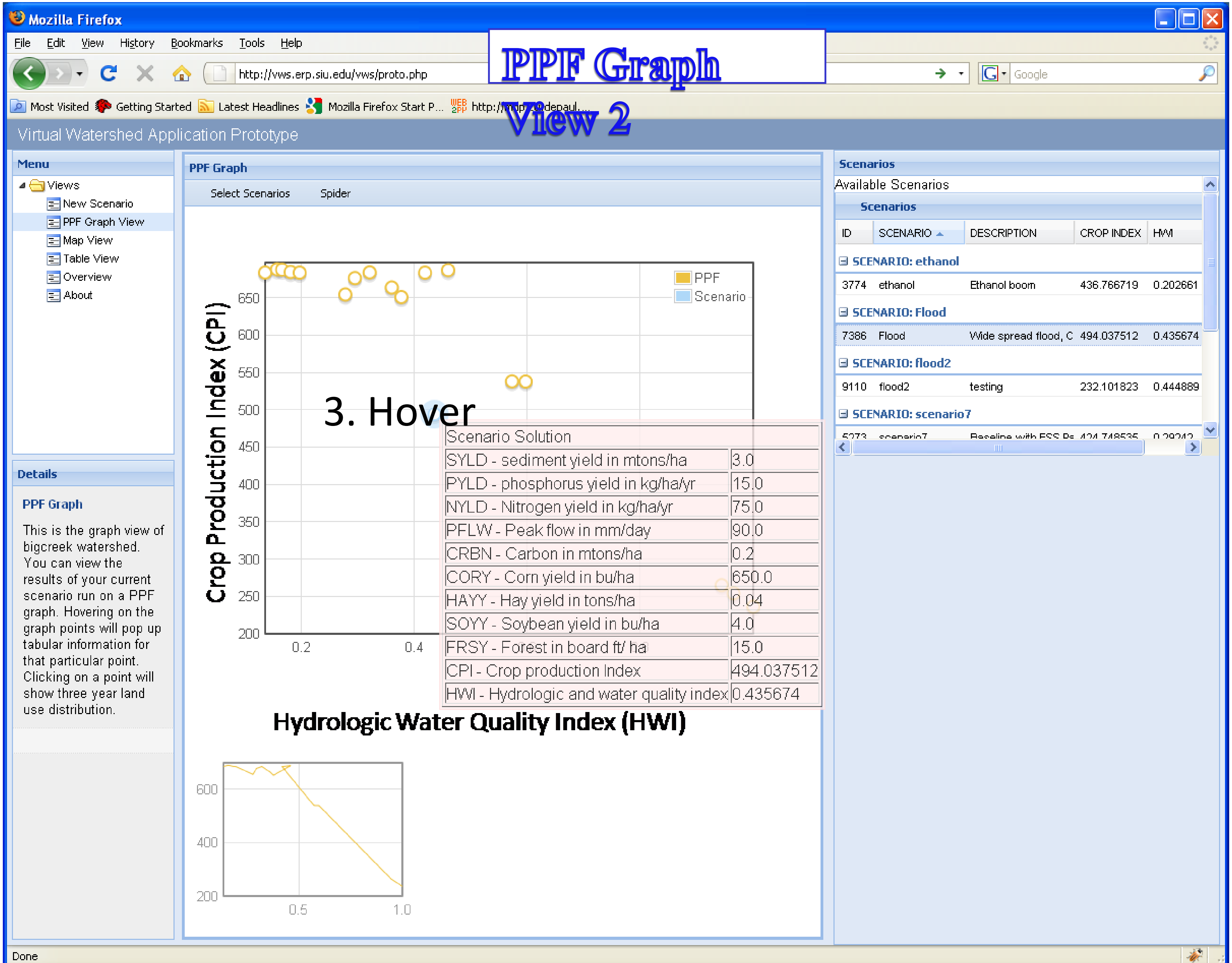


New Scenario View

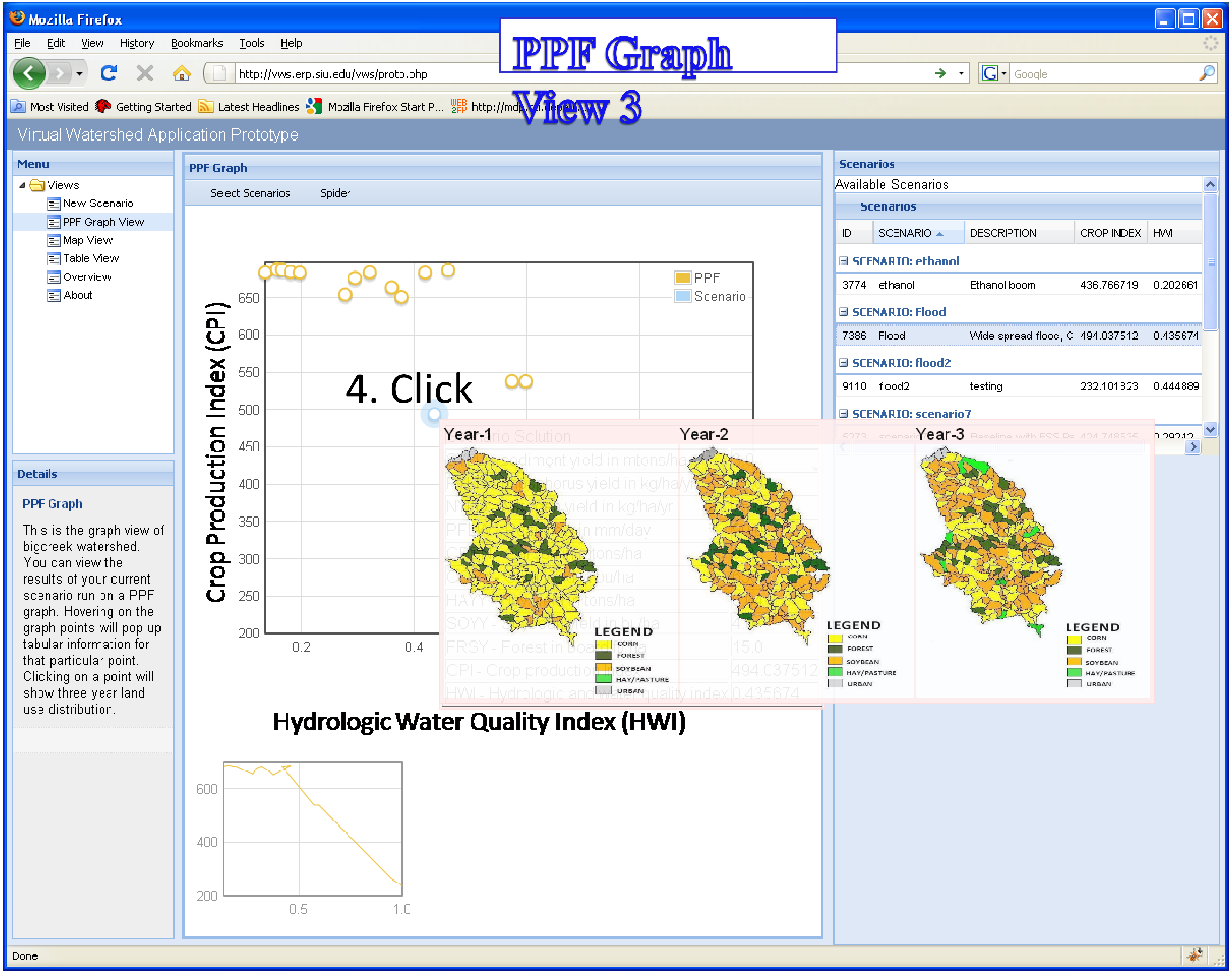


PPF Graph View 1

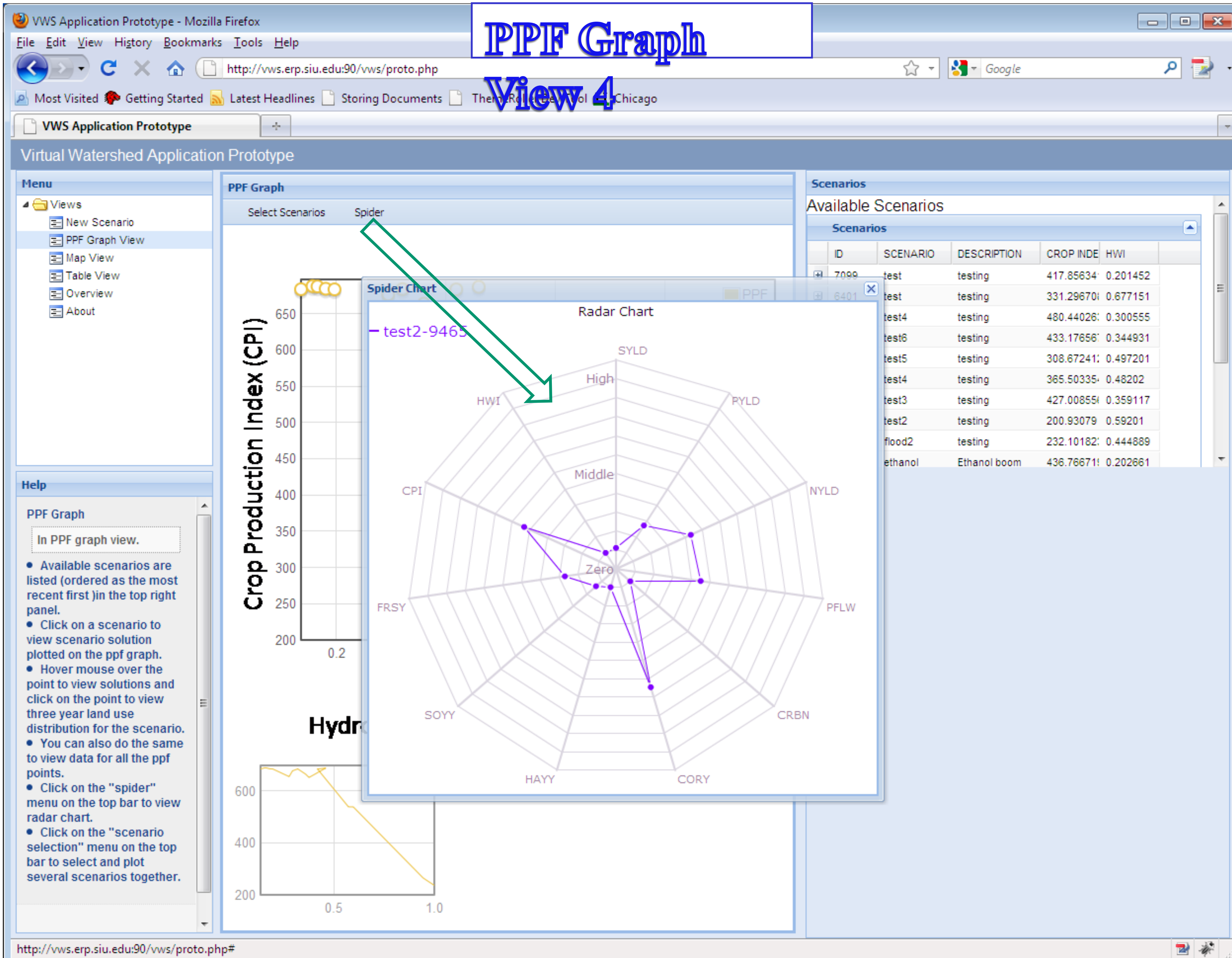


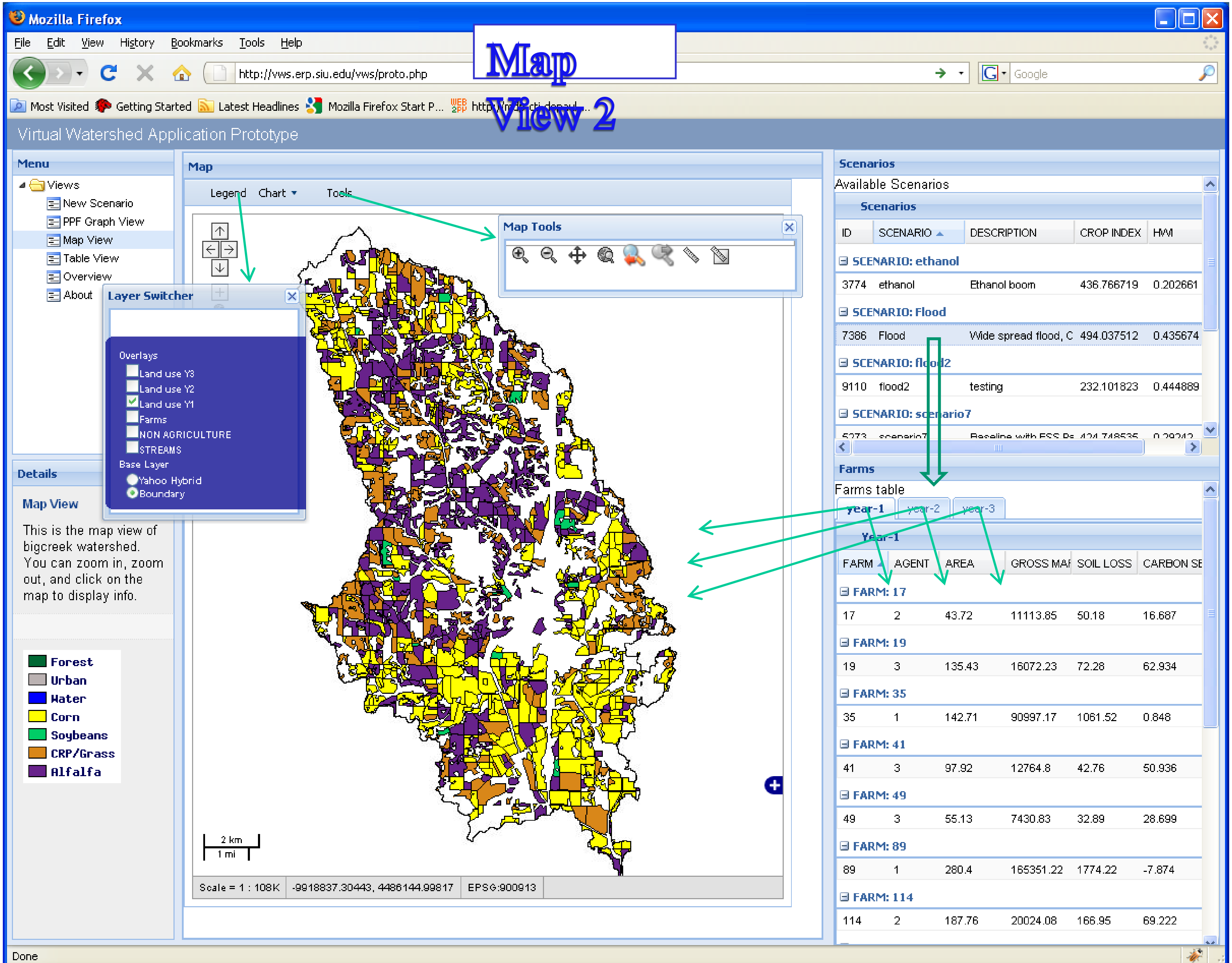

PPF Graph
View 2
Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php
Most Visited Getting Started Latest Headlines Mozilla Firefox Start P...
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Details
PPF Graph
This is the graph view of bigcreek watershed. You can view the results of your current scenario run on a PPF graph. Hovering on the graph points will pop up tabular information for that particular point. Clicking on a point will show three year land use distribution.
PPF Graph
Select Scenarios
Spider
PPF
Scenario
Crop Production Index (CPI)
3. Hover
Scenario Solution
SYLD - sediment yield in mtons/ha 3.0
PYLD - phosphorus yield in kg/ha/yr 15.0
NYLD - Nitrogen yield in kg/ha/yr 75.0
PFLW - Peak flow in mm/day 90.0
CRBN - Carbon in mtons/ha 0.2
CORY - Corn yield in bu/ha 650.0
HAYY - Hay yield in tons/ha 0.04
SOYY - Soybean yield in bu/ha 4.0
FRSY - Forest in board ft/ ha 15.0
CPI - Crop production Index 494.037512
HWI - Hydrologic and water quality index 0.435674
Hydrologic Water Quality Index (HWI)
Scenarios
Available Scenarios
Scenarios
ID SCENARIO DESCRIPTION CROP INDEX HWI
SCENARIO: ethanol
3774 ethanol Ethanol boom 436.766719 0.202661
SCENARIO: Flood
7386 Flood Wide spread flood, C 494.037512 0.435674
SCENARIO: flood2
9110 flood2 testing 232.101823 0.444889
SCENARIO: scenario7
Done

PPF Graph View 3

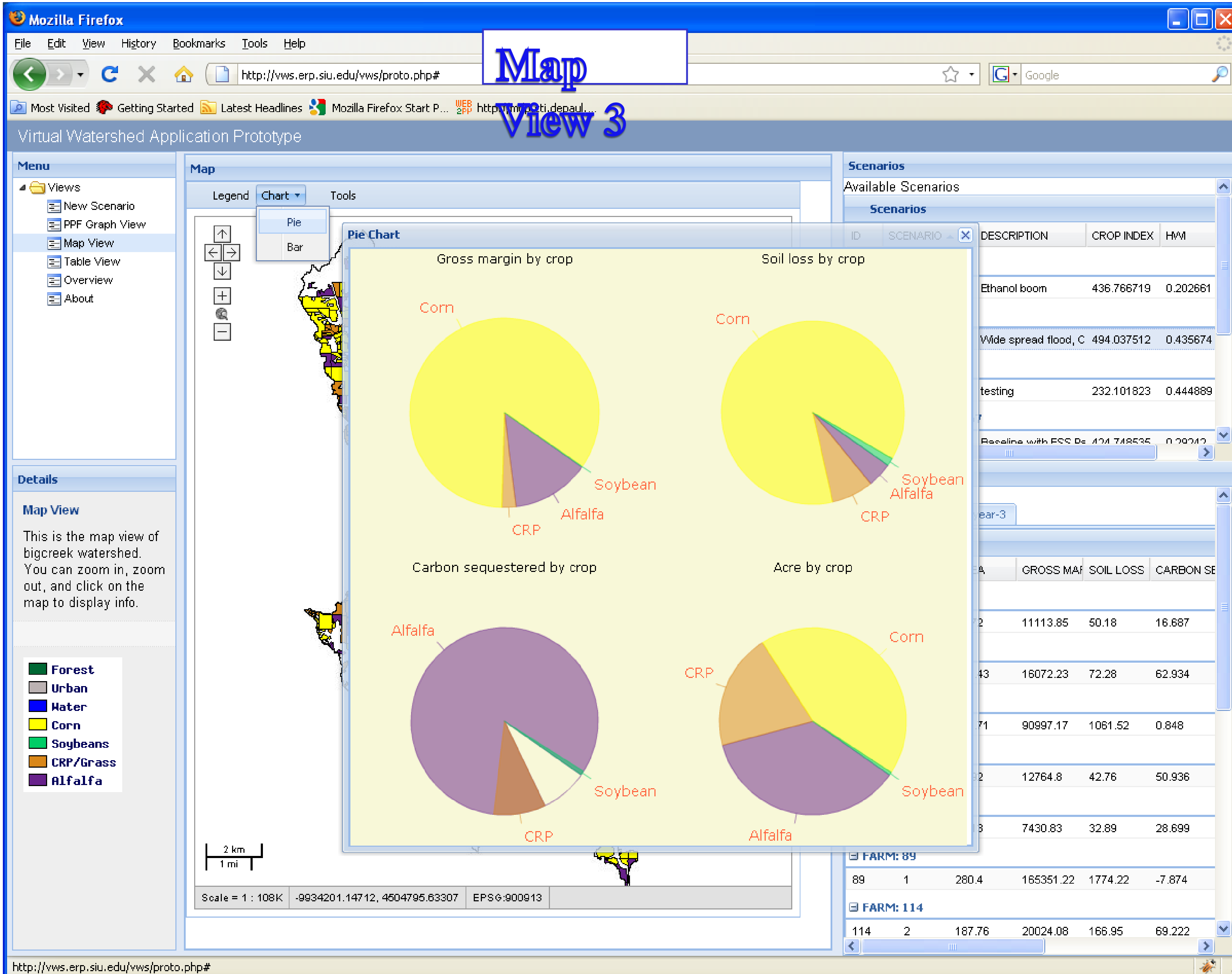


PPF Graph View 4



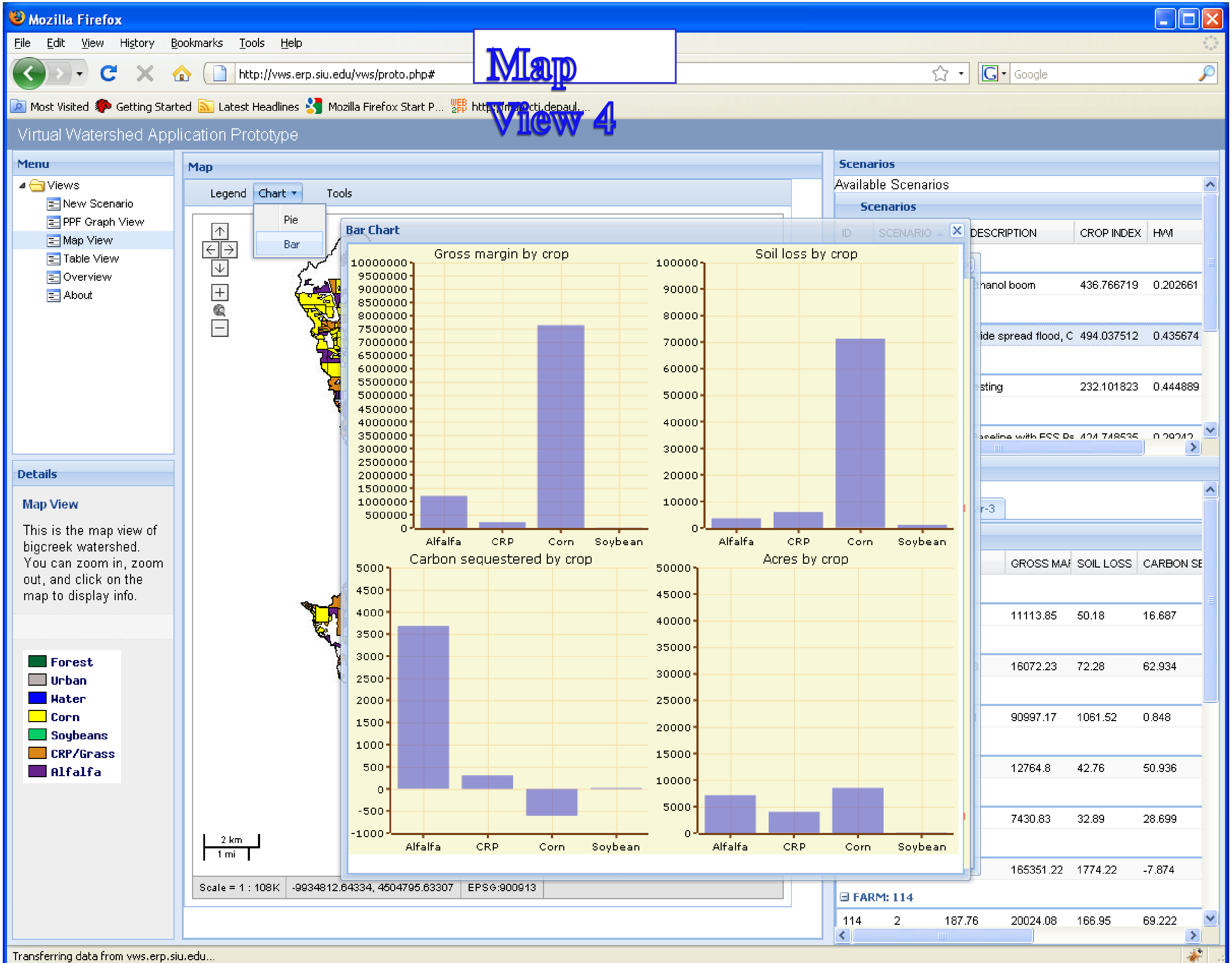

Map View 2
Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php
Most Visited Getting Started Latest Headlines Mozilla Firefox Start P...
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Details
Map View
This is the map view of bigcreek watershed. You can zoom in, zoom out, and click on the map to display info.
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend Chart Tools
Map Tools
Layer Switcher
Overlays
Land use Y3
Land use Y2
Land use Y1
Farms
NON AGRICULTURE
STREAMS
Base Layer
Yahoo Hybrid
Boundary
2 km
1 mi
Scale = 1 : 108K -9918837.30443, 4486144.99817 EPSG:900913
Scenarios
Available Scenarios
Scenarios
ID SCENARIO DESCRIPTION CROP INDEX HWI
SCENARIO: ethanol
3774 ethanol Ethanol boom 436.766719 0.202661
SCENARIO: Flood
7386 Flood Wide spread flood, C 494.037512 0.435674
SCENARIO: flood2
9110 flood2 testing 232.101823 0.444889
SCENARIO: scenario7
Farms
Farms table
year-1 year-2 year-3
Year-1
FARM AGENT AREA GROSS MAI SOIL LOSS CARBON SE
FARM: 17
17 2 43.72 11113.85 50.18 16.687
FARM: 19
19 3 135.43 16072.23 72.28 62.934
FARM: 35
35 1 142.71 90997.17 1061.52 0.848
FARM: 41
41 3 97.92 12764.8 42.76 50.936
FARM: 49
49 3 55.13 7430.83 32.89 28.699
FARM: 89
89 1 280.4 165351.22 1774.22 -7.874
FARM: 114
114 2 187.76 20024.08 166.95 69.222
Done

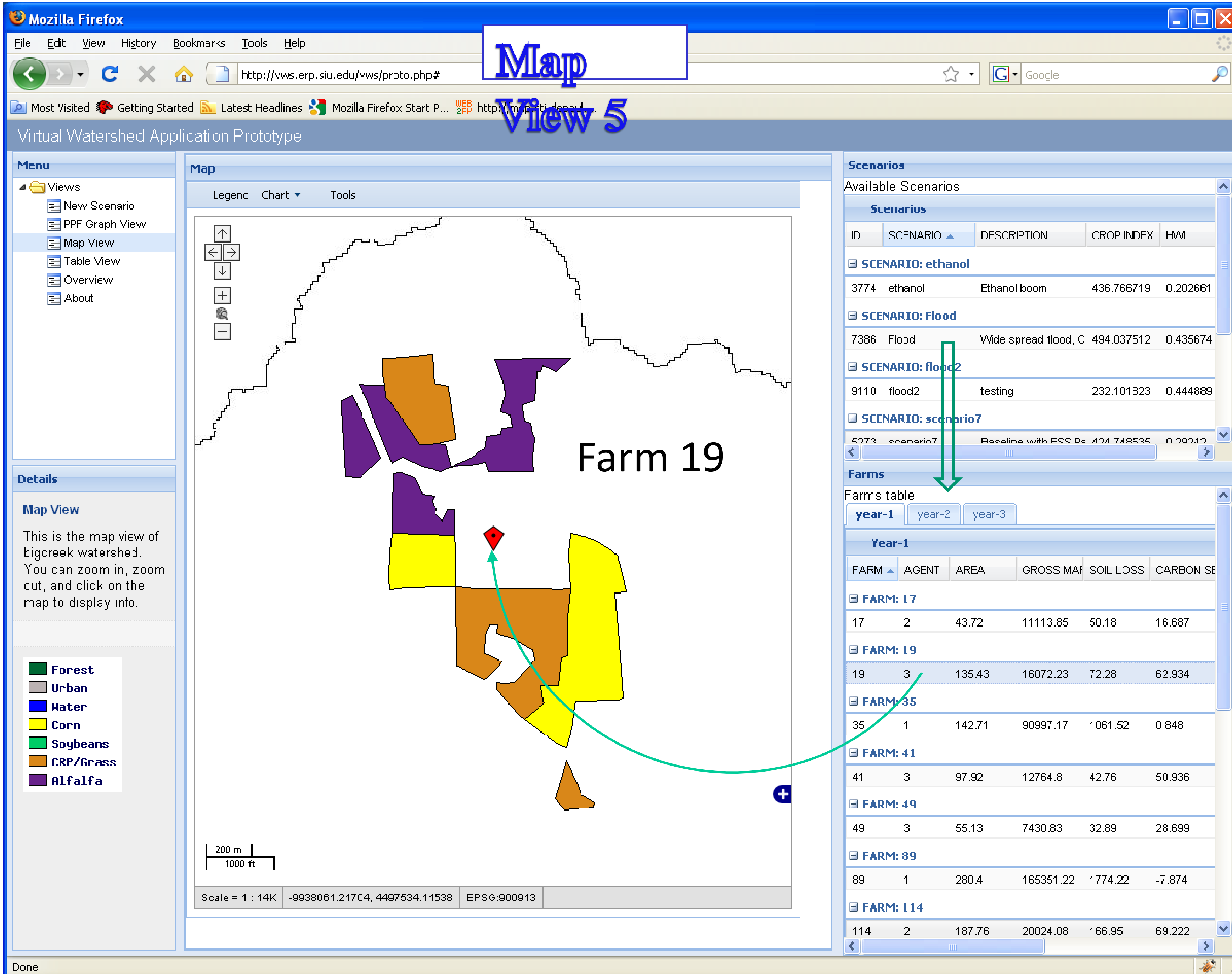
Map View 3



Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php#
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Details
Map View
This is the map view of bigcreek watershed. You can zoom in, zoom out, and click on the map to display info.
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend
Chart
Tools
Pie
Bar
Pie Chart
Gross margin by crop
Soil loss by crop
Carbon sequestered by crop
Acre by crop
Corn
Soybean
Alfalfa
CRP
Scale = 1 : 108K
-9934201.14712, 4504795.63307
EPSG:900913
Scenarios
Available Scenarios
DESCRIPTION
CROP INDEX
Ethanol boom
436.766719
0.202661
Wide spread flood, C
494.037512
0.435674
testing
232.101823
0.444889
GROSS MAR
SOIL LOSS
CARBON SE
11113.85
50.18
16.687
16072.23
72.28
62.934
90997.17
1061.52
0.848
12764.8
42.76
50.936
7430.83
32.89
28.699
FARM: 89
165351.22
1774.22
-7.874
FARM: 114
20024.08
166.95
69.222

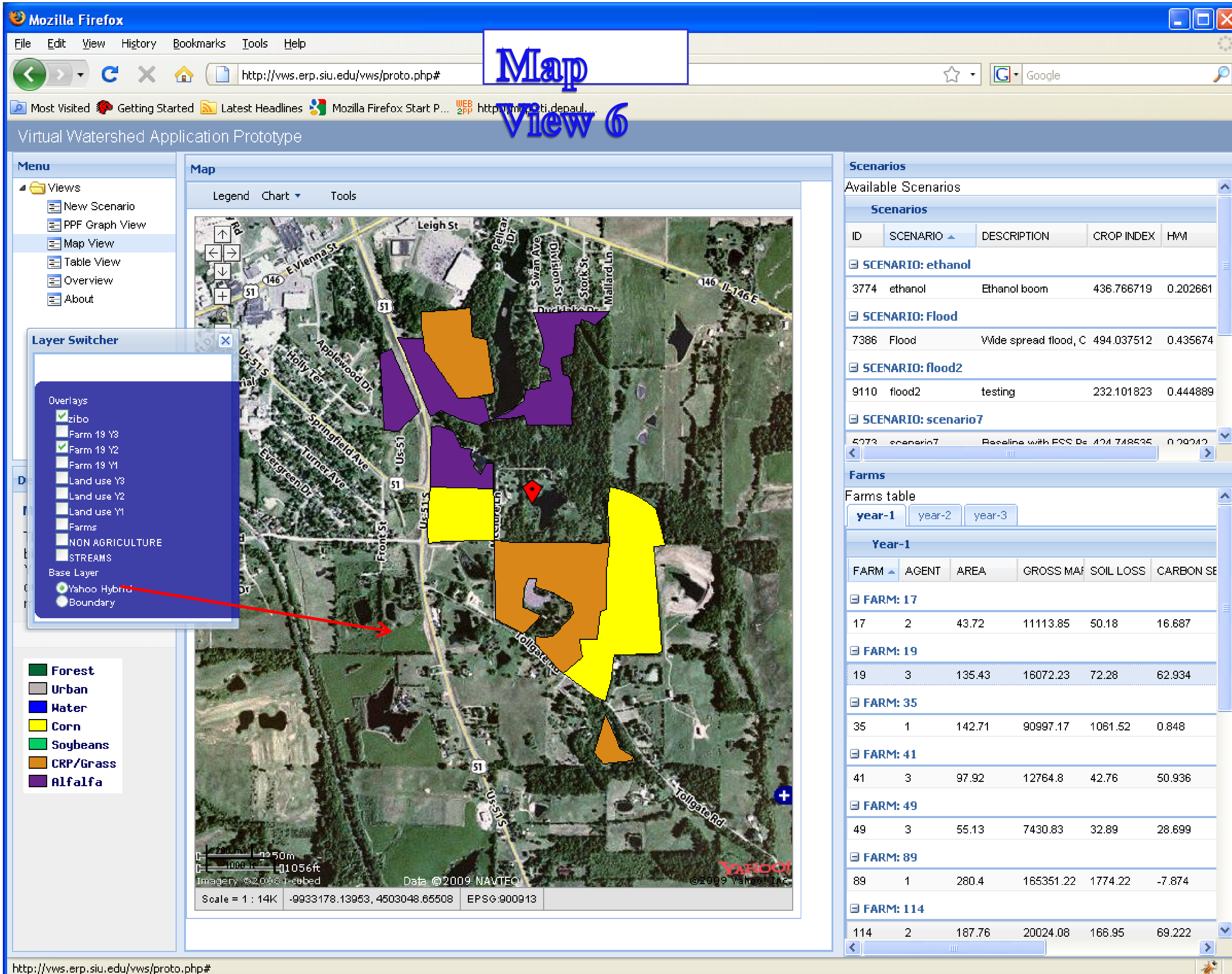
Map View 4

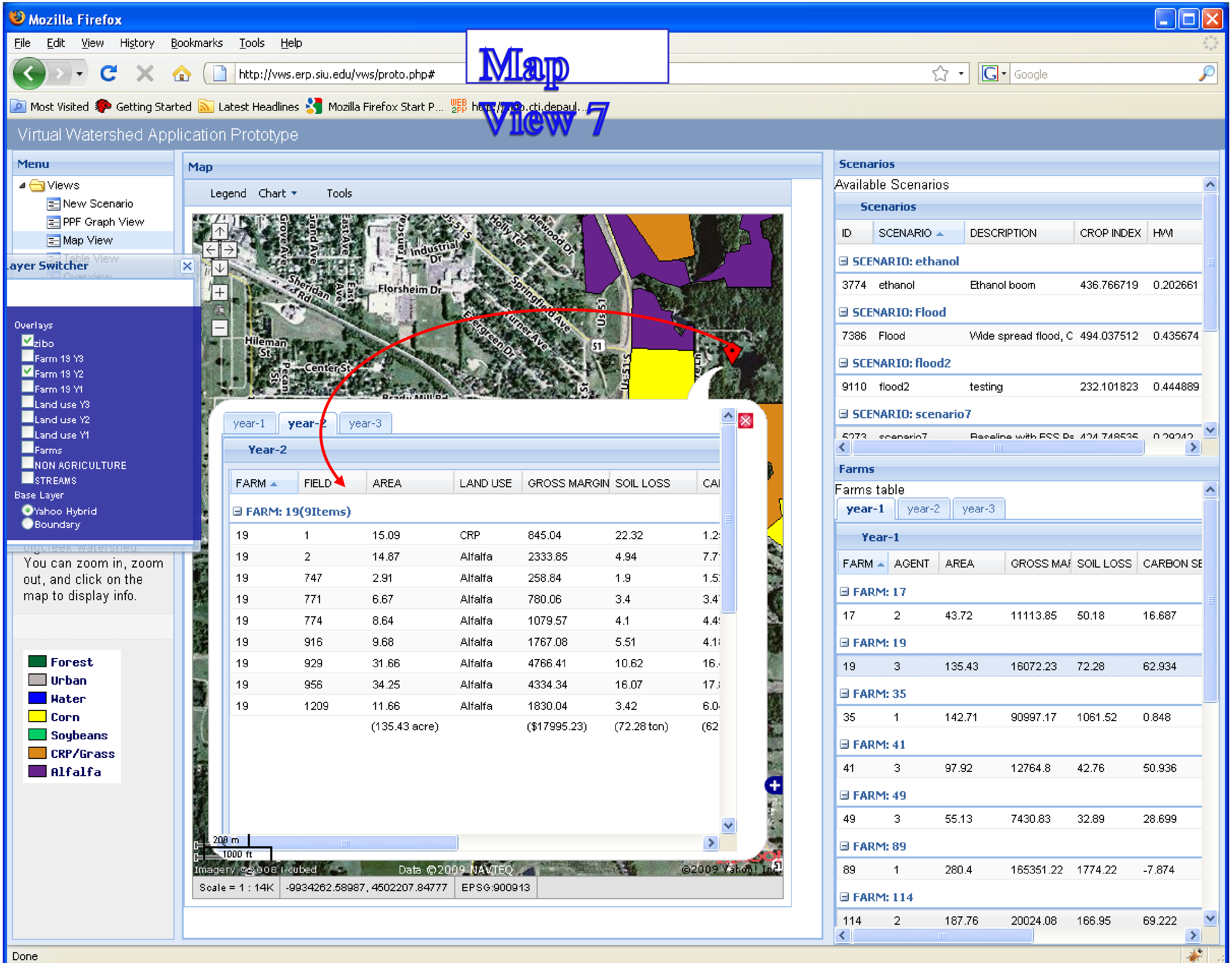

Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php#
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Details
Map View
This is the map view of bigcreek watershed. You can zoom in, zoom out, and click on the map to display info.
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend
Chart
Tools
Pie
Bar
Bar Chart
Gross margin by crop
Soil loss by crop
Carbon sequestered by crop
Acres by crop
Alfalfa
CRP
Corn
Soybean
Scale = 1 : 108K
-9934812.64334, 4504795.63307
EPSG:900913
Scenarios
Available Scenarios
DESCRIPTION
CROP INDEX
HWI
GROSS MAR
SOIL LOSS
CARBON SE
FARM: 114
Transferring data from vws.erp.siu.edu...



Map
View 5
Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php#
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Details
Map View
This is the map view of bigcreek watershed. You can zoom in, zoom out, and click on the map to display info.
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend Chart Tools
Farm 19
200 m
1000 ft
Scale = 1 : 14K
-9938061.21704, 4497534.11538
EPSG:900913
Scenarios
Available Scenarios
ID SCENARIO DESCRIPTION CROP INDEX HWI
SCENARIO: ethanol
3774 ethanol Ethanol boom 436.766719 0.202661
SCENARIO: Flood
7386 Flood Wide spread flood, C 494.037512 0.435674
SCENARIO: flood2
9110 flood2 testing 232.101823 0.444889
SCENARIO: scenario7
Farms
Farms table
year-1 year-2 year-3
Year-1
FARM AGENT AREA GROSS MAI SOIL LOSS CARBON SE
FARM: 17
17 2 43.72 11113.85 50.18 16.687
FARM: 19
19 3 135.43 16072.23 72.28 62.934
FARM: 35
35 1 142.71 90997.17 1061.52 0.848
FARM: 41
41 3 97.92 12764.8 42.76 50.936
FARM: 49
49 3 55.13 7430.83 32.89 28.699
FARM: 89
89 1 280.4 165351.22 1774.22 -7.874
FARM: 114
114 2 187.76 20024.08 166.95 69.222
Done

Map View 6


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php#
Most Visited Getting Started Latest Headlines Mozilla Firefox Start P...
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Table View
Overview
About
Layer Switcher
Overlays
zibo
Farm 19 Y3
Farm 19 Y2
Farm 19 Y1
Land use Y3
Land use Y2
Land use Y1
Farms
NON AGRICULTURE
STREAMS
Base Layer
Yahoo Hybrid
Boundary
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend Chart Tools
Leigh St
E Vienna St
Springfield Ave
Evergreen Dr
Turner Ave
Tollgate Rd
Imagery ©2008 i-cubed
Data ©2009 NAVTEQ
©2009 Yahoo! Inc
Scale = 1 : 14K
-9933178.13953, 4503048.65508
EPSG:900913
Scenarios
Available Scenarios
ID SCENARIO DESCRIPTION CROP INDEX HWI
SCENARIO: ethanol
3774 ethanol Ethanol boom 436.766719 0.202661
SCENARIO: Flood
7386 Flood Wide spread flood, C 494.037512 0.435674
SCENARIO: flood2
9110 flood2 testing 232.101823 0.444889
SCENARIO: scenario7
Farms
Farms table
year-1 year-2 year-3
Year-1
FARM AGENT AREA GROSS MAF SOIL LOSS CARBON SE
FARM: 17
17 2 43.72 11113.85 50.18 16.687
FARM: 19
19 3 135.43 16072.23 72.28 62.934
FARM: 35
35 1 142.71 90997.17 1061.52 0.848
FARM: 41
41 3 97.92 12764.8 42.76 50.936
FARM: 49
49 3 55.13 7430.83 32.89 28.699
FARM: 89
89 1 280.4 165351.22 1774.22 -7.874
FARM: 114
114 2 187.76 20024.08 166.95 69.222
http://vws.erp.siu.edu/vws/proto.php#


Map
View 7
Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://vws.erp.siu.edu/vws/proto.php#
Most Visited Getting Started Latest Headlines Mozilla Firefox Start P...
Virtual Watershed Application Prototype
Menu
Views
New Scenario
PPF Graph View
Map View
Layer Switcher
Overlays
zibo
Farm 19 Y3
Farm 19 Y2
Farm 19 Y1
Land use Y3
Land use Y2
Land use Y1
Farms
NON AGRICULTURE
STREAMS
Base Layer
Yahoo Hybrid
Boundary
You can zoom in, zoom out, and click on the map to display info.
Forest
Urban
Water
Corn
Soybeans
CRP/Grass
Alfalfa
Map
Legend Chart Tools
year-1 year-2 year-3
Year-2
FARM FIELD AREA LAND USE GROSS MARGIN SOIL LOSS
FARM: 19(9Items)
19 1 15.09 CRP 845.04 22.32
19 2 14.87 Alfalfa 2333.85 4.94
19 747 2.91 Alfalfa 258.84 1.9
19 771 6.67 Alfalfa 780.06 3.4
19 774 8.64 Alfalfa 1079.57 4.1
19 916 9.68 Alfalfa 1767.08 5.51
19 929 31.66 Alfalfa 4766.41 10.62
19 956 34.25 Alfalfa 4334.34 16.07
19 1209 11.66 Alfalfa 1830.04 3.42
(135.43 acre) ($17995.23) (72.28 ton)
Scale = 1 : 14K -9934262.58987, 4502207.84777 EPSG:900913
Scenarios
Available Scenarios
ID SCENARIO DESCRIPTION CROP INDEX HWI
SCENARIO: ethanol
3774 ethanol Ethanol boom 436.766719 0.202661
SCENARIO: Flood
7386 Flood Wide spread flood, C 494.037512 0.435674
SCENARIO: flood2
9110 flood2 testing 232.101823 0.444889
SCENARIO: scenario7
Farms
Farms table
year-1 year-2 year-3
Year-1
FARM AGENT AREA SOIL LOSS
FARM: 17
17 2 43.72 11113.85 50.18 16.687
FARM: 19
19 3 135.43 16072.23 72.28 62.934
FARM: 35
35 1 142.71 90997.17 1061.52 0.848
FARM: 41
41 3 97.92 12764.8 42.76 50.936
FARM: 49
49 3 55.13 7430.83 32.89 28.699
FARM: 89
89 1 280.4 165351.22 1774.22 -7.874
FARM: 114
114 2 187.76 20024.08 166.95 69.222
Done

Advantages of Web Applications

No special configuration or hardware requirements for the user.

Lower costs.

Centralized data is secure and easy to backup.

Updates can be made quickly and easily.

Information is accessible to a wide audience anywhere in the world.

Everybody has a browser. Familiar interface encourages use.

Web-applications make collaboration easy, as basically everyone is using one “instance” of an application.

Because all activity takes place on your servers you can see how people are using your application.

Source: http://www.pssuk.com/AdvantagesWebApplications.htm