Biofuel and Its Impacts on Water Resources

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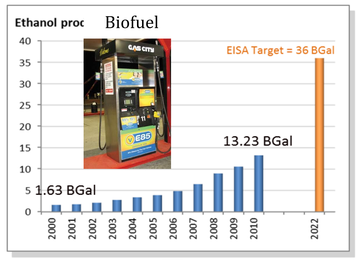
Motivation

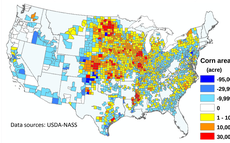


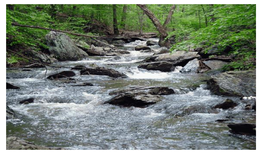
Data sources: RFS

Changes in land-use and rotation, harvesting crop and forest residues

Changes in agricultural practices: fertilizer application, tillage, irrigations

- Corn area difference from 2000 to 2010 (increased by 6.96 M. acres)





Research Question

- Sustainability of Biofuel in terms of water resources ?

- The projected large-scale Biofuel production could lead to changes in land-use, crop rotation, and agricultural practices that potentially affect regional water resources and quality.

Objectives

- Develop a watershed model for the Ohio River basin (ORB) using the Soil and Water Assessment Tool (SWAT)(Arnold et al. 1998) that simulate hydrology, water quality, crop growth, and biomass productions in the basin.
- Simulate the current and future hydrology and stream water quality under *baseline* and *business-as-usual (BAU)* scenarios, respectively, during which there is no biofuel related land-use and management changes in the basin.
- Conduct scenario analysis to quantify the potential effects of increased conventional and cellulosic feedstocks productions on the basin's hydrology and water quality relative to the baseline conditions.

Acknowledgement

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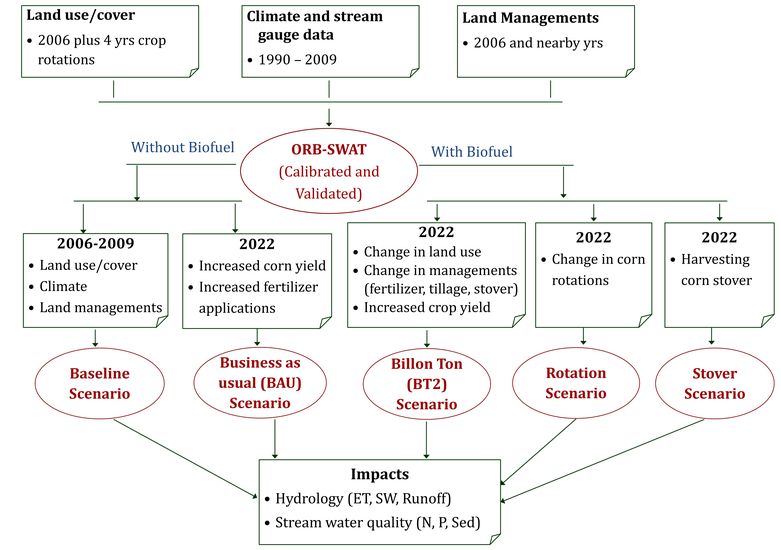
References:

- Arnold, J.G., R. Srinivasan, R.S. Muttiah, and J.R. Williams, 1998. Large area hydrologic modeling and assessment part I: Model development. Journal of the American Water Resources Association, 34(1), 73-89.
- Aulenbach, B.T., H.T. Buxton, W.A. Battaglin, and R.H. Coupe, 2007. Streamflow and nutrient fluxes of the Mississippi-Atchafalaya River basin and subbasins for the period of record through 2005. U.S. Geological Survey Open-File Report 2007-1080.

Methodologies

Schematic of the watershed model and impact assessment

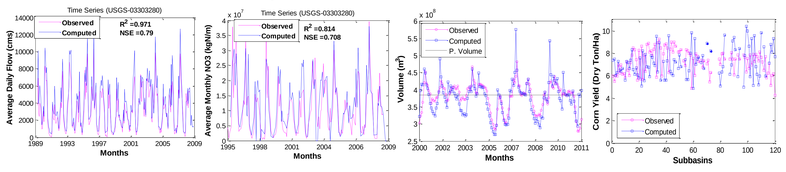


Study Site (ORB):

- One of the six USGS's 4-digit HUC subbasins contributing to the Mississippi River (MR).
- Covers 42 million ha areas, constituting 51% forest, 20% hay and pasture, 17% cultivated crops.
- Only 20% of the MRB area, but it is the primary sources of flow (49%), phosphorus (29%), and nitrogen (32%) to the MR (Aulenbach et al., 2007).

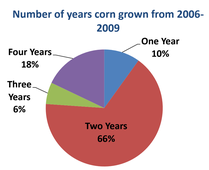
Scenarios

(a) Model calibration



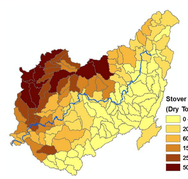
(S1) Rotation Scenario

- Change corn grown in rotations to continuous growing (gain 1.90 M. ha for growing corn continuously).



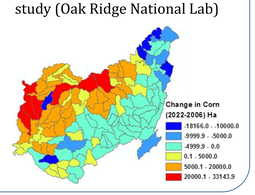
(S2) Stover Scenario

- 50% of the stover are harvested together with the grain (produced 14.9 million dry ton)



(S3) Billion-Ton (BT2) Scenario

- Uses projected land-use, tillage, stover removal, and fertilizer application from the Billion-Ton study (Oak Ridge National Lab)

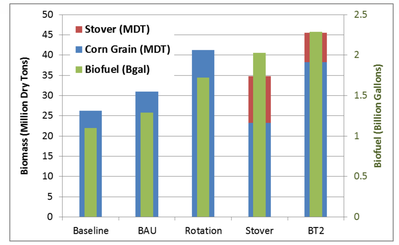


Results

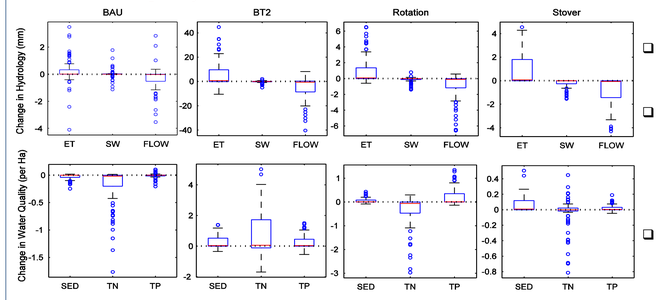
Baseline's annual hydrology and water quality

- ET = 648.4 mm
- Runoff = 487.2 mm
- Sediment loading = 0.78 ton/ha
- Nitrogen loading = 9.6 kg/ha
- Phosphorus loading = 1.22 kg/ha

Biofuel Productions



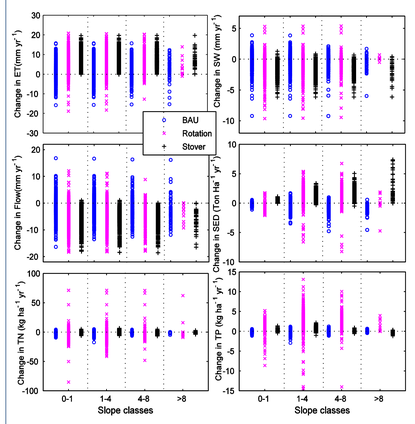
Impacts on annual hydrology and water quality: Basin-Wide



Observations

- The box-plots represent the variation of the impacts over the 120 subbasins of the ORB.
- Compared to the baseline, both the future scenarios have relatively higher ET rates from the majority of the subbasins, with the impact being more noticeable for the BT2 scenario.
- Increased sediment and phosphorous for biofuel scenarios, but decreased nitrogen loading except BT2.

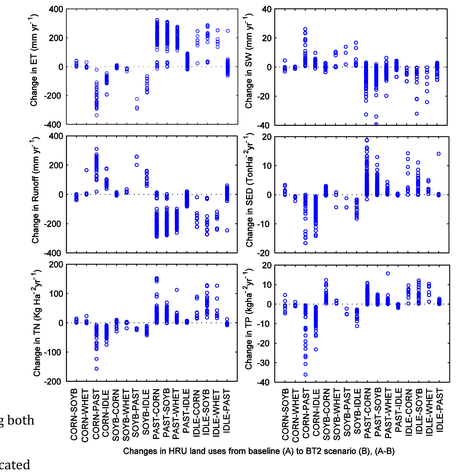
Impacts at HRU (farm) level for BAU, Rotation, Stover scenarios relative to the Baseline scenario



Observations

- Each data points represents a single HRU that grew corn during both baseline and scenarios years.
- ET – no apparent trend for BAU, higher for most of the HRUs located on all the slope groups for rotation and stover scenarios, with the impact becoming more apparent for the rotation scenario when slopes increased.
- Sediment – increased erosion from the HRUs, which increased with slope for the rotation and stover scenarios, but decreased for BAU.
- Nitrogen – decreased slightly for majority of the HRUs in the BAU and rotation scenarios, but showed no clear trend for the stover scenario.
- The loadings from the rotation scenario have showed relatively higher variability, which might be caused by the original land-use of being soybean, hay or wheat.

Impacts at HRU (farm) level for Billion-Ton (BT2) scenario relative to Baseline scenario



Observations

- Each circle represents a single HRU, whose baseline land-uses were converted from crop A to crop B during the BT2 scenario (denoted as A-B on the x-axis).
- Conversions of pasture and idle lands to row crops such as corn, soybean, and wheat led to increased annual ET, sediment, nitrogen, and phosphorus loadings, but decreased in soil moisture and runoff from majority of the HRUs, and vise-versa.