INCIDENTAL RECHARGE IN THE LOWER FLINT RIVER BASIN: AGRICULTURAL IRRIGATION AND CONSUMPTIVE USE

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Abstract. The purpose of this study is to develop a method for estimating the irrigation consumptive use of water in the Lower Flint River Basin. Based on a derivative of the soil-water balance equation, the model utilizes evapotranspiration rates, crop coefficients and effective precipitation to estimate what volume of water applied for irrigation purposes is utilized by crops and how much percolates below the effective root zone and essentially returns to the system as incidental recharge. The study will estimate the consumptive agricultural use and incidental recharge over a growing season for three of the most widely cultivated crops in the Lower Flint River Basin: cotton, corn and peanuts.

INTRODUCTION

In the last decade or so, managing water uses in the Lower Flint River Basin has taken on greater significance. The impetus, in part, stemmed from the urgent need for city, state and local authorities to pay more attention to assessing and evaluating how water needs and usage impact critical hydrological processes in the Apalachicola-Chattahoochee-Flint (ACF) River Basin and more specifically, sub-basins like the Flint River Basin. The Flint River Basin is of particular interest to planners not only because of its location, but also because it houses more than half of the over 1.2 million acres of land devoted to agriculture in Georgia-- the majority of which lies within the confines of the Lower Flint River Basin (Georgia Wildlife Federation 2002).

Though Georgia is relatively humid and more than half of its annual precipitation (~30 inches) falls during its growing season, irrigation is still necessary in places like the Lower Flint Basin to maintain crop health and sustain yield. This is primarily because the spatial, temporal and uneven distribution of the rainfall makes most of the precipitation across the state ineffective (for reviews see Smajstrla and others 2006). Low effective precipitation amounts coupled with the poor "moisture holding" capacity of the predominantly sandy soils in the Coastal plain (NRCS 1997) and extensive periods of relatively high temperatures (in the 90° F to 100° F range) makes irrigation management in southwest Georgia is a uniquely complex and challenging enterprise.

Consequently, a reliable estimate of the consumptive water use in the Lower Flint River Basin can go a long way towards the proper allocation of water resources within the state. As such, this study will examine three of the predominantly cultivated crops in the Lower Flint River Basin (peanuts, corn and cotton), estimate their consumptive use and their incidental recharge over a growing season.

Irrigation and Consumptive Water Use

By definition, consumptive water use refers to the quantity of water that is removed from an immediate water environment or system; however, it is also frequently used to refer primarily to the quantity of water utilized by crops in a water cycle (USGS 2006). In areas dominated by agricultural activities such as the Lower Flint River Basin, evapotranspiration constitutes a major portion of the overall consumptive use. For the purpose of this study, irrigation refers to any water artificially applied to crops.

Modeling Approach and Derivation of the Equations:

When water is applied to the surface of a soil, some may either pond and/or runoff the surface and some will infiltrate into the soil. A portion of the infiltrating water will subsequently return to surface through evapotranspiration or as stream flow and the remainder will infiltrate below the effective root zone of the available crops (deep percolation) and return to the system as incidental recharge. This study will model the any water "lost" to deep percolation as the quantity of incidental recharge available in a system.

The study uses a simple equation derived from the general soil-water equation which estimates the quantity of gross irrigation required in an area as a function of its evapotranspiration, precipitation, ground water contributions and antecedent soil moisture (USDA 1993). The general soil-water equation is expressed as follows:

$$\mathbf{F_g = Et_c + D_p + RO - P - GW + SDL - \Delta SW}$$

Where:

- Fg = gross irrigation required during the period,
- Etc= amount of crop evapotranspiration during the period,
- Dp = deep percolation from the crop root zone during the period,
- RO = surface runoff that leaves the field during the period,
- P = total precipitation,
- GW = ground water contribution to the crop root zone during the period,
- SDL = spray and drift losses from irrigation water in air and evaporation off of plant canopies
- ΔSW = change in soil water in the crop root zone during the period

Based on the preceding equation, the variables can be rearranged to determine deep percolation as follows:

Dp = Fg – Etc– RO + P + GW – SDL + ΔSW

For the purpose of this study any water that percolates below the root zone (deep percolation) in the irrigated area will be considered as incidental recharge. Unfortunately, recharge tends to be a very slippery concept which makes any attempt to quantify it challenging at the least. This is primarily because recharge to ground water sources involves a complex interplay of several site-specific factors including but not limited to the physiography, hydrogeology and meteorology of an area.

To compensate for this, a water-balance approach was utilized to account for all the inputs entering the system and which uses accessible and available data (rainfall, soil type, temperature etc.). Consequently, the volume of incidental recharge within the system can be estimated as the difference between the inputs (precipitation and irrigation) and outputs (evapotranspiration) and based on soil water in the crop zone during the period.

Variables

Gross irrigation (F_g) will be estimated from available data and records based on agricultural water use permits issued by the EPD.

Crop evapotranspiration (Et_c) is determined by the amount of energy available to evaporate water and will be estimated as the product of the crop coefficient and the potential evapotranspiration for the area. $Et_c = K_c \; ET_0$

Potential Evapotranspiration (ET_0) values for the study area will obtain from available data sources (e.g. UGA Georgia Automated Environmental Monitoring Network)

Crop coefficient values (K_c) will be calculated using the method originally developed by Doorenbos and Pruitt in 1977 and subsequently modified by Howell and others in 1986, which divides the growing season in 4 stages: initial, canopy development, mid-season and maturation.
Since the objective of the study is to estimate the incidental recharge over an entire growing season, an average Kc value (over 4 stages) will be used for each crop.

Runoff (RO). RO will be determined SCS curve number method (USDA-SCS 1985), which is based on the assumption that for a single storm event the ratio of the actual soil retention (F) after the onset of runoff to its potential maximum retention (S) is equal to the ration of direct runoff (Q) to the available rainfall [Total rainfall (P) – Initial abstraction (I_a)] that is $\frac{F}{S} = \frac{Q}{(P - I_a)}$, since can be empirically shown to be 0.2S, this relationship can be simplified to produce the following equation :

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \text{for } P > 0.2S, \text{ otherwise } Q = 0$$

and $$S = \frac{25,400}{CN} - 254 \text{ (mm)}$$

Curve numbers (which represent the texture of the soil and the type of land cover in an area) will be obtained from the USDA – SCS National Engineering Handbook (1993). For the purpose of this study, irrigation events will be treated the same as precipitation events.

Precipitation (P) values will be obtained from available data sources (UGA Georgia Automated Environmental Monitoring Network) and if necessary used to create monthly precipitation surfaces for available point data.

Ground water contributions (GW). Can be calculated using Anat's solution (USDA 1993). However, table contributions tend to be significant only to a depth of about 10 ft of crop root zone. The depth of the water table in the study area –by and large—tends to be between 50 and 60 ft, as such their contributions, if any, will be relatively insignificant and will be ignored in this study.

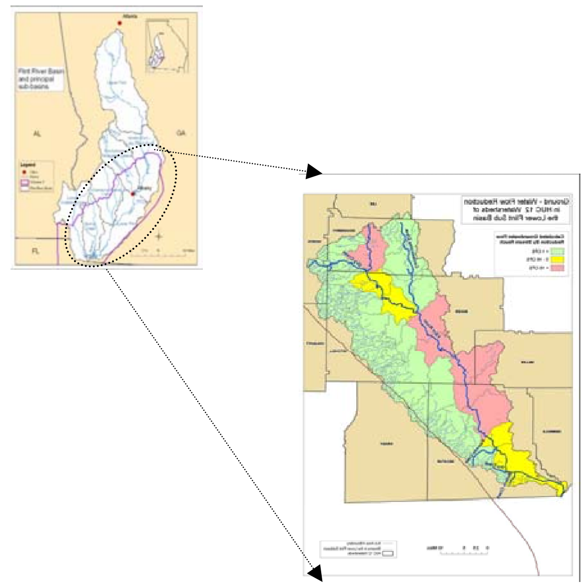
Spray and Drift Losses (SDL). The main method of irrigation application in the Lower Flint River Basin is by sprinkle irrigation, thus the major losses are due to excessive or unnecessary water application, evaporation and wind drift (USDA 1993). Consequently, these values will be estimated as a function of the application efficiency of the irrigation system using published efficiency values.

Soil Water Changes (ΔSW) this is one of the more complex functions and requires several steps. First, the initial water content of the soil (θ_i) will be ascertained and the water content at natural saturation (θ_s) (based on its porosity). Next, the quantity of water infiltrating into the soil calculated as a function of the ponding time, infiltration capacity of the soil, the initial abstraction and the rainfall rate(for reviews see USDA 2001). The moisture in the root zone would then be estimated using time step calculations and the water available for recharge as the sum of the individual recharge quantities for each of the three crops cultivated in the study area.

Assumptions and Limitations. This is a simple and rather general model designed to produce rough estimates of the quantity of water available for recharge due to deep percolation in the irrigated areas of the Lower Flint River Basin. As such, it will not provide daily recharge quantities, but an estimate of available recharge over a growing season in the study area, typically early April to the end of September. To simplify the calculations, the model makes the following assumptions: (a) that the soil has maintained its structural integrity (original soil profile), (b) that there are no structural impediments to the plant root system (hardpans, impervious areas etc.) that can impact the effective root depth of the plants and the ability of the water to infiltrate the soil and percolate below the root zone.

Study Area. The study area for this project encompasses 14 counties in the Lower Flint River Basin. These include: Baker, Calhoun, Crisp, Decatur, Dougherty, Early, Lee, Miller, Mitchell, Seminole, Sumter, Randolph, Terrell and Worth. The area is predominantly agricultural lands with over 1.2 million acres of crop lands. Though barley, rye, sorghum, oats and soybeans are cultivated in the area, the most prevalent crops are cotton, corn, peanuts and tobacco and to a lesser extent wheat, straw and hay (for reviews see Center for Agribusiness and Economic Development 2006)

In spite of its relatively high levels of rainfall, extensive periods of high temperatures and the proliferation of sandy soils necessitates frequent irrigation within the growing season to prevent crop stress and low yields.



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