

**USING LANDSAT 5 TM TO DETERMINE LANDUSE CLASSIFICATION FOR
REPRESENTING SEASONAL EVAPOTRANSPIRATION FROM 2 UNIQUE
DRAINAGE BASINS IN A HYDROLOGIC BUDGET**

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1 ABSTRACT

The accurate determination of landuse/landcover is an important component in the study of the environment. Use of satellite imagery allows for high resolution spatio-temporal data for watershed studies. The objective of this research was to utilize satellite image interpretation to determine landuse classes to be incorporated into a simple hydrologic water budget model. These studies took place in the Joshua Creek basin, located in DeSoto County, FL and the Payne Creek basin located in Polk, Hardee and Hillsborough Counties, FL. Joshua Creek encompasses ~120 square miles and has agricultural and rural land usage, while Payne Creek includes ~122 square miles and has phosphate mining as well as rural and agricultural sections. Landsat 5 TM images were obtained for summer and winter of 1995-2000 (path 16, row 41) and classification performed. The result was input into the model to determine evapotranspiration losses from the differing land cover types.

2 INTRODUCTION

Central Florida has long had arguments over the potentially negative impacts that phosphate mining has on the environment, therefore this study was proposed to compare a mined and

unmined drainage basin to examine how the changes in land use over time might have impacted the resulting measured streamflow. This research focused on two sub-basins of the Peace River watershed. These were the Payne Creek and Joshua Creek drainage basins (Figure 1). The Payne Creek drainage basin is located in central Florida, mostly contained within Polk and Hardee counties with a small portion in Hillsborough County. The Joshua Creek drainage basin was chosen for its lack of mining, similar underlying potentiometric makeup and similarity in size to Payne Creek. Joshua Creek is located to the southeast of Payne Creek, almost entirely within DeSoto County. Nearly 70 percent of the total surface area in the Payne Creek basin has been affected by phosphate mining, some has been reclaimed already. No phosphate mining has taken place or is scheduled to occur in the Joshua Creek basin, in which 30 percent of the land is used for irrigated agriculture (mostly citrus).

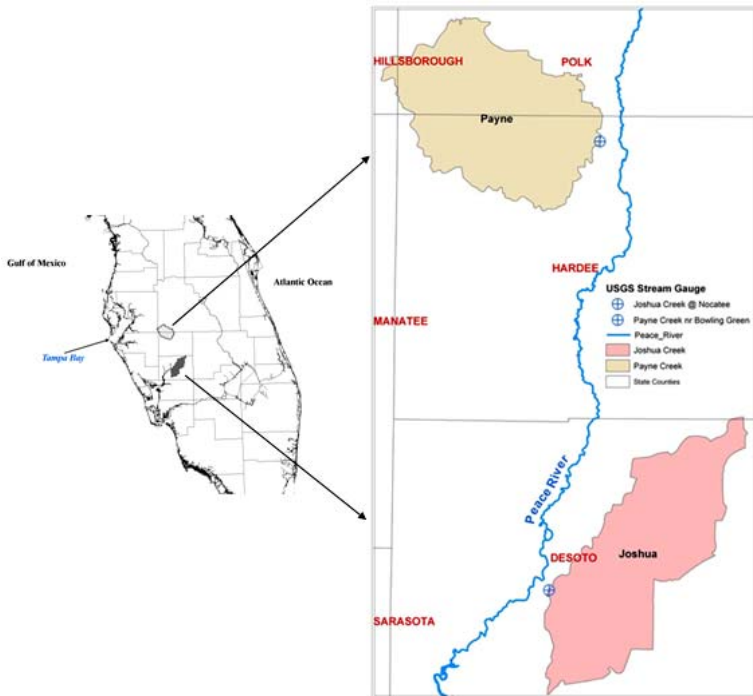


FIGURE 1
LOCATION OF DRAINAGE BASINS IN STUDY

The research design include i) mapping of the progression of land use changes over a 16-year period, ii) assign ET rates to land use categories, iii) calculate overall change in ET for selected drainage basins, iv) enter the values in a basin-wide water budget to calculate streamflow from the selected basins, and v) compare these calculated values to the measured streamflow leaving the basins.

Satellite images formed the basis of the change in land use/land cover (LU/LC) analyses. Satellite images are invaluable assets for doing environmental work, as has been published in an article by Carlson & Arthur (2000). The selection of ET/EV rates for the different land use surfaces was a key part of developing the spreadsheet model. In the USGS Water Supply Paper

2430 “Evapotranspiration from Areas of Native Vegetation in West Central Florida” (W.R. Bidlake, *et. al.*, 1996), the annual ET losses from dry prairie is 39.8 inches; from marsh vegetation 39.0 inches; from pine flatwoods 41.7 inches; and from a cypress swamp 38.2 inches. When mining begins and a pine flatwood is stripped from the area to be mined, ET losses will be reduced, assuming that ET from bare soil is less than that from a vegetated area. Observations were made regarding the conditions of the land prior to mining, progression of mining and the subsequent reclamation were mapped and basin-wide capacity for ET losses estimated. These findings were then correlated to the daily records at gaging stations operated by the USGS and others (when available). The aim of this study was to provide a quantitative assessment of the contributory relationship between phosphate mining and streamflow. Work by Bill Lewelling (pers. commun.) of the USGS on the comparisons between unmined and reclaimed basins appears to support the hypothesis that the contribution to surface water flow could be higher from reclaimed basins than from unmined basins. Studies on EV and ET have varied in methodology; unfortunately, the results have been somewhat inconsistent as well.

3 METHODS

3.1 Data source: Satellite Imagery

The Payne Creek and Joshua Creek drainage basins are located within the Peace River basin and are similar in size, 122 mi² and 120 mi², respectively, but represent vastly different land use. Bi-annual satellite images were purchased for the years of 1985-2000 to represent the wet (June–September) and dry (October–May) seasons for each year. These images were not always usable due to cloudiness in some of the wet seasons. Landsat 5 Thematic Mapper (TM) was launched in 1984 and therefore was operational for the length of study. Landsat 5 TM scene has an instantaneous field of view (IFOV) of 30 meters by 30 meters in Bands 1 through 5 and Band 7, and an IFOV of 120 meters by 120 meters for Band 6 (thermal band). For this study, Bands 1, 2 and 4 were used to perform the unsupervised classification and other bands were used in various combinations for reference when performing the final tidying. ERDAS IMAGINE 8.6 remote sensing software incorporates functions of both image processing and GIS. For the purposes of this study, the program was used for 1) Satellite Band Layerstacking, 2) Image Georectification, 3) Image Subsetting, 4) Image Classification, 5) Image Tidying, 6) Accuracy Assessment and 7) Generation of Numbers in LU/LC Categories for Spreadsheet.

LU designation was a critical component in this study. Non-irrigated vegetation represented in this study any vegetation that was not considered either wetland or a source of imported water into the watershed, for example, pasture, mixed rangeland, herbaceous lands, etc. Citrus was comprised of all tree crops, as most in these basins falls in the citrus tree category (FLUCCS Code # 2200). Wetland was a combination of all wetland classes of vegetation (everything in the 6000 range in the FLUCCS Codes). Timber was considered pine flatwoods (FLUCCS Code # 4110). Crop was representative of row crops, nurseries, sod farms and vineyards (FLUCCS Codes # 2140, 2400 and 2440). Water was represented in the Joshua basin by the reservoir and a few small ponds; whereas in the Payne basin there was some mixture between the water and clay settling area (CSA) classes (FLUCCS Codes # 5100, 5200, 5300 and 5400). The CSA category was water falling within the walls of a CSA (FLUCCS Codes listed previously). Reclaimed CSA's would be classed as their land use type in the image for the particular year of interest (for example, disturbed land, wetlands or NI Vegetation). The SWFWMD's classification of mined/extractive land is a guideline of where the mine land boundaries are, not whether or not the land is actively being mined.

3.2 Satellite Image Processing

The procedure of satellite image processing is a repeatable procedure. Images came on a CD as seven separate Bands. They were layer-stacked for manipulation. In this case, Band 6 (thermal) was omitted due to its resolution being different from the other Bands.

The next step completed was georeferencing the images. Topologically Integrated Geographic Encoding and Referencing system (TIGER) files were used to rectify the images as they were obtained from USGS to ensure that all GIS files would overlay properly and the images would be usable. A standard map area with boundaries set in UTM is established for each scene so that all images will occupy the same map area once rectified..

The subsequent method of investigation was to perform principal components analysis on subsetted basins (to an area roughly twice the final study size). The PCA gives maximum variation (diversity) of data by Band, then creates a composite Band that the ERDAS user further classifies (ERDAS, 1999). In this case, Bands 1, 2, & 4 were examined by the software and condensed into a composite band for detailed classification. These bands were chosen from those available after investigating their ability to differentiate between the land use types decided to be important in this study, namely vegetation types and mining practices.

Next, the classification step was performed on the resulting image from the previous step. After testing , it was decided the most accurate means to determine land use/land cover was to have ERDAS perform an unsupervised classification using the Iterative Self-Organizing Data Analysis Technique (ISODATA). The user sets a convergence threshold at which the iterations stop (in this case, 95) so better than 95 percent of the pixels are staying in the same classes. The user sets the number of output classes. The number of classes selected through trial and error was 30. Using aerial photography, multi-year LU/LC maps and DOQQs for reference, these results were then renamed by the user into their respective classes (i.e. citrus, NI Veg, CSA, etc). This file was then subsetted to the exact area of interest (the particular drainage basin).

The next step was to “tidy” the images. This required more intensive analysis using the aforementioned supplementary reference materials. In this final classification process, it was determined helpful to compare as many different sources of ancillary data as possible. It is recognized that these supplementary sources have varying degrees of accuracy and image resolution; and it was actually beneficial to use them as a check for the accuracy of the classification and interpreting the images. Another valuable approach was utilizing unclassified images in differing band combinations, while classifying a processed image. By looking at the image in raw form and numerous band combinations, certain land use types were more readily distinguishable than from the processed but untidied image.

The last step was a final “recode” of the image, where the number of classes goes from thirty to the final seven or nine. Once accomplished, the result was used to arrive at the square mileage of land use types for the ET measures in the water budget spreadsheet.

3.5 Accuracy Assessment

The process of checking accuracy is vital in every area of scientific research, particularly when there is user-interpretation that creates potential for biasing or altering results. In the area of remote sensing, the best way to accomplish an accuracy assessment is by ground-truthing the data. Ground-truthing data consists of going in the field with randomly generated points and, determining what type of land cover exists, then comparing that to the land cover type that has been determined by the program. In this particular case, the study was somewhat handicapped by the fact that the most recent satellite images being studied were from 02-04-2000, while the year the ground truthing took place was 2003. Therefore, some minor interpretation must be done and reliance placed in the hands of the operator's ability to accurately interpret changes. For some of the mines there were more recent aerial photographs that could be used. The accuracy assessment computed for this test was using randomly generated reference points that were then ground-truthed in the field. Overall accuracy for Joshua Creek drainage basin classification was 76 percent and for the Payne Creek drainage basin was 78 percent.

3.6 Water Budget Spreadsheet Model

The square mileage from the satellite images was then put into a water budget spreadsheet model. Recognizing that the general water budget is defined as in Equation 1, where R equals rain, P equals pumpage, SFI equals streamflow in, ET equals ET/EV, RC equals recharge, SFO equals streamflow out and ΔS equals change in storage. The equation was then revised to Equation 2 and the water budget spreadsheet developed to operate by trying to predict the known measured data of SFO and assuming that ΔS and RC are constant or unchanged over the time periods within their respective basins. Agricultural irrigation pumpage estimates from deep wells tapping the Upper Floridan Aquifer for the Joshua Creek basin were estimated from the LU/LC area estimates. These estimates were multiplied by the irrigation requirements for a particular crop as used in the SWFWMD AGMOD model. This leaves the only undetermined variable to be ET. It is recognized that this is a considerable portion of almost every water budget, especially in Florida where ET can be as much as 85 percent of the water budget.

$$R + P + SFI = ET + RC + SFO + \Delta S \quad [1]$$

By rearranging terms, Equation 1 was revised to Equation 2 to calculate resultant streamflow SFO after the LU/LC have been mapped and multiplied by the appropriate ET factor.

$$SFO = R + P + SFI - ET - RC \quad [2]$$

Figure 2 below outlines the design of the water budget spreadsheet model used in this research.

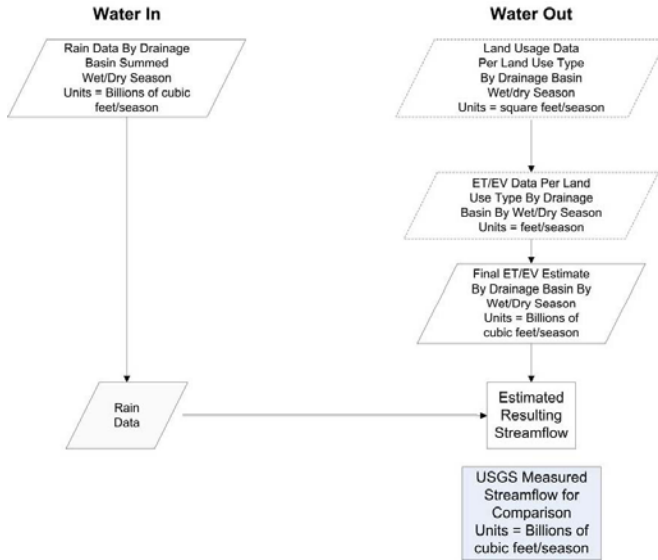


FIGURE 2
FLOW DIAGRAM OF WATER BUDGET SPREADSHEET MODEL

4 RESULTS

The results of the land use mapping are presented in Tables 1 & 2 below (note: images without eligible imagery for both basins were not included in these tables).

TABLE 1
LU RESULTS (MI²) BY SEASON FOR JOSHUA CREEK BASIN.

LU	Pasture	Citrus	Wetland	Urban	Timber	Water	Crop
J'85w	67	26	18	3	5	0	0
J'85s	66	26	18	5	5	1	0
J'86w	69	26	15	5	5	0	0
J'86s	69	25	17	5	4	1	0
J'88w	70	23	17	5	4	1	0
J'88s	66	26	17	4	5	1	0
J'91w	58	34	18	6	3	1	1
J'91s	60	35	13	6	4	1	1
J'92w	58	34	15	6	5	1	1
J'92s	59	33	16	6	4	1	1
J'93w	57	35	16	5	4	1	2
J'93s	58	34	16	6	4	1	2
J'95w	53	34	20	6	4	1	2
J'95s	56	34	16	6	4	2	2
J'96w	54	34	19	6	4	1	3
J'96s	53	34	20	6	4	1	2
J'98w	54	35	18	6	3	2	2
J'98s	55	35	17	6	3	1	2

TABLE 2
LU RESULTS (MI²) BY SEASON FOR PAYNE CREEK BASIN.

LU	Pasture	Citrus	Wetland	Urban	Timber	Water	CSA	Sand Tailings	Dist. Land	Crop
P'85w	42	14	22	2	5	8	4	5	20	0
P'85s	40	14	17	2	5	9	3	6	26	0
P'86w	43	14	22	2	5	12	5	5	14	0
P'86s	45	14	22	2	5	11	4	5	15	0
P'88w	39	14	26	2	6	9	4	3	17	2
P'88s	39	15	24	3	6	13	5	8	7	2
P'91w	34	15	21	3	7	11	6	4	21	2
P'91s	29	16	23	3	6	18	7	5	12	2
P'92w	33	17	15	3	5	16	8	3	21	2
P'92s	30	15	20	2	4	18	6	10	14	3
P'93w	23	16	26	2	7	15	6	9	17	1
P'93s	27	14	25	3	4	15	7	7	20	1
P'95w	24	13	20	2	6	13	12	8	23	1
P'95s	30	14	21	3	7	10	13	8	15	1
P'96w	31	11	22	2	4	13	12	9	18	0
P'96s	27	11	17	3	3	13	15	13	19	1
P'98w	30	12	25	2	2	13	8	7	24	0
P'98s	22	10	26	20	2	12	8	9	30	0

A chart of the streamflow and rain inputs used for the water budget spreadsheet model are shown below in Figure 3. For the rain inputs, all available historic rain gauges within the drainage basin were used (and outside the drainage basin when necessary), the data was summed seasonally and the average taken. In the Joshua Creek drainage basin, only one rain gauge was located within the basin, so ones were used from the surrounding area as well.

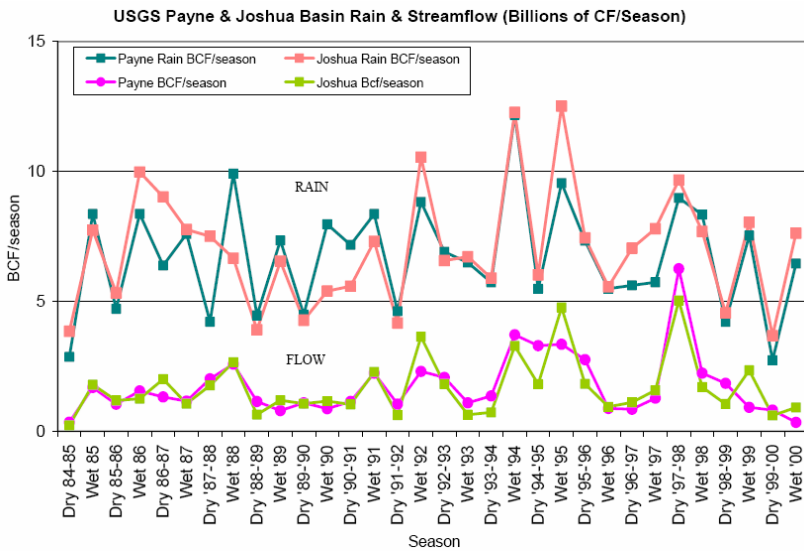


FIGURE 3
STREAMFLOW & RAIN FOR JOSHUA & PAYNE CREEK DRAINAGE BASINS

4.1 MODEL RESULTS AND VERIFICATION

In the water budget model the outputs were the predicted surface water outflows from the Joshua and Payne Creek basins. We attempted to quantify all the model input parameters, but was not able to obtain these inputs for all the years that were to be modeled. The ET/EV parameters are derived from the size and the land-use, multiplied by the ET/EV rate for that land-use category. There were nine years in which satellite coverage was sufficiently clear simultaneously in both basins and both seasons to determine the individual land-use sizes. Very little or no information was reliably available for pumpage or recharge for the time period. It was therefore decided to calculate streamflow as a function of rainfall and ET/EV. To accommodate the differences between the dry season and wet season, the observed and modeled streamflow as well as modeled results were listed as dry season, wet season and water year. The water year results are the addition of the dry season and wet season results which do not coincide with calendar years. The results are in billion cubic-feet per season and water year.

The modeling results of predicted seasonal and annual streamflow correlated reasonable well with the actually measured streamflow (Figures 4 & 5 below). The scatter diagram sum of least squares (R^2) of model-predicted and measured streamflow values ranged from 70 percent to 80 percent. This spreadsheet model approach confirmed the general trends but did not offer a clearly defined quantitative definition of the increased contribution of mined/reclaimed phosphate lands to streamflow.

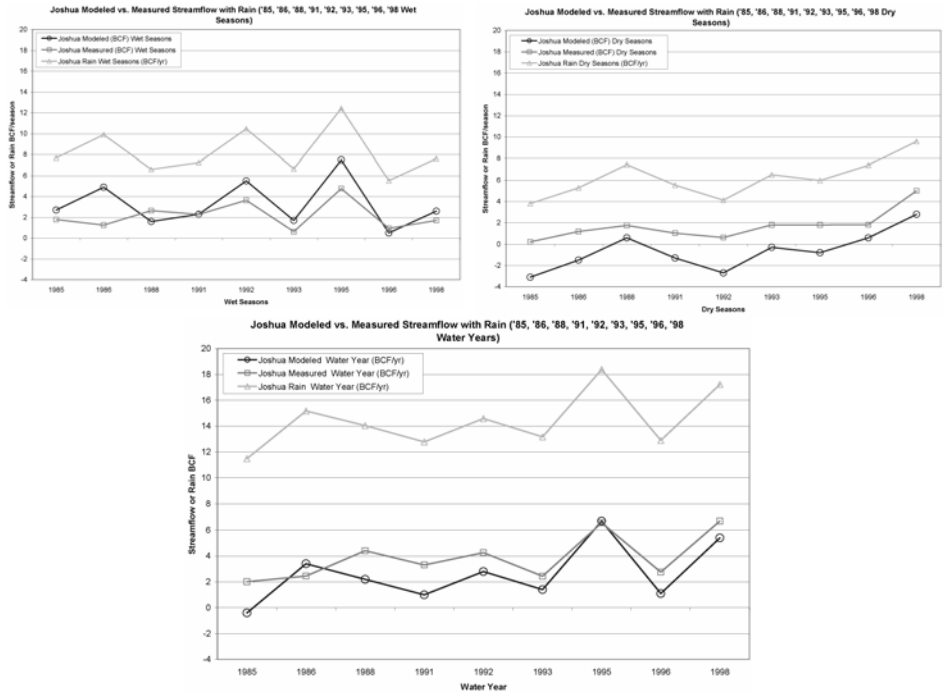


FIGURE 4

MODELED & MEASURED STREAMFLOW WITH RAIN FOR JOSHUA CREEK DRAINAGE BASIN

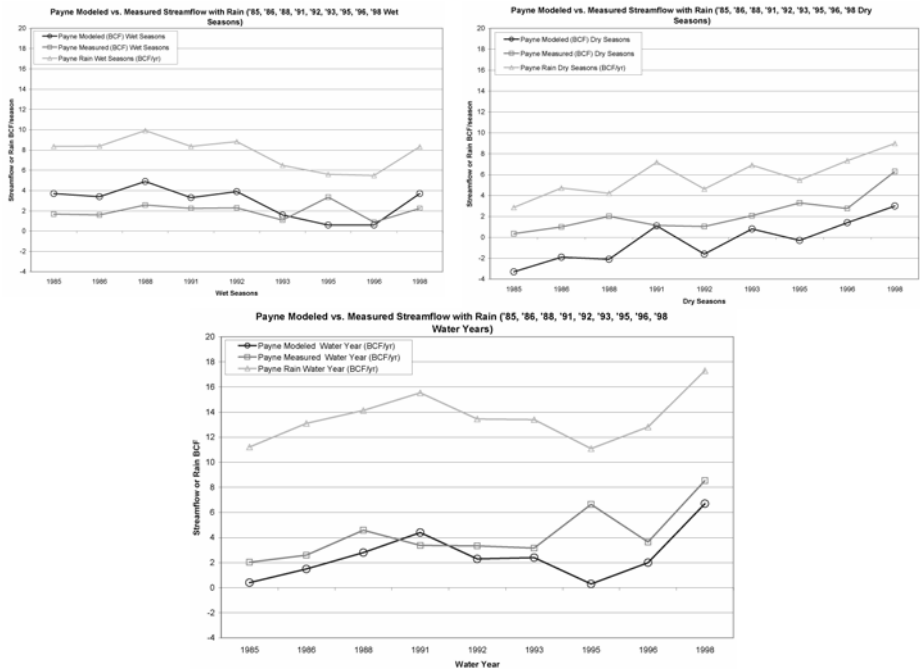


FIGURE 5
MODELED & MEASURED STREAMFLOW WITH RAIN FOR PAYNE CREEK DRAINAGE BASIN

5 CONCLUSIONS

The main conclusion that can be drawn from the water budget and satellite imagery analysis portion of the study is that while it may be impossible to account for every single input and export of water into and from the Joshua and Payne Creek drainage basins successfully (particularly over an extended period of time), the overall water budget spreadsheet model provide a reasonable match between the modeled and measured streamflow. Analyzing satellite imagery from 1985 through 2000 resulted in model-predicted streamflow that were generally lower than the measured streamflow. Results of this study show relatively good success when comparing to the SWFWMD GIS database and a definite correlation to the changes of land use within the two study basins. As part of the model verification process, the rainfall falling onto the Joshua Creek and Payne Creek basins as well as the streamflow during the 1985 through 2000 period were compared. This analysis revealed that while slightly more rain fell onto the Joshua Creek basins than on the Payne Creek basin, streamflow from the Payne Creek basin was slightly larger, this observation led to the preliminary conclusion that the change in land-use associated with phosphate mining clearly did not reduce streamflow.

6 ACKNOWLEDGEMENT

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