# FOREST HYDROLOGY
# SEVEN OAKS EXPERIMENT STATION

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# ABSTRACT

The Seven Oakes catchment experiment site is located on the Mondi property Mistley – Canema in the Seven Oakes district east of Pietermaritzburg town, Kwazulu-Natal Province, South Africa. The experimental area for this practical includes upstream catchments of 8.8 $km^2$ with an average altitude of 1050m and a riparian zone of 1.2 $km^2$. The area has a mean annual rainfall of 900mm.

The purpose of this practical is to simulate the effect of commercial forests on streamflow reduction activities using ACRU Agrohydrological model. The simulation considers different scenarios with different types of forests such as Wattle and Eucalyptus; veld and agricultural crops where the veld conditions to be the baseline for the other scenarios. The first run, in the ACRU distributed catchment's model considered an intensively prepared catchment and riparian zone covered with intermediate Wattle. The equation used in the simulation process was Linacre (1991) and the monthly totals of daily A-pan equivalent evaporation (unscreened) equation methods. The change in ground water level from intermediate/ground water store that becomes streamflow on a particular day also considered. The second scenario considered mature Wattle, mature Wattle and veld in good condition, all veld in fair condition, intermediate Eucalyptus and riparian veld in good condition, sugar cane and veld in good condition, maize and riparian veld in good condition. Based on the scenarios considered, the model was run and the result was analysed.

# TABLE OF CONTENTS



# LIST OF TABLES



# LIST OF FIGURES

# 1. INTRODUCTION

Trees have the potential to utilize more water than other dry land crops (Schulze et al., 1995). In estimating the hydrological impact of afforestation, the impact of the current land use on the hydrological responses is often compared to that of the anticipated afforestation. As described by Van Lill et al. (1980; cited by Schulze et al., 1995), the effects of afforestation with Eucalypts grandis in streamflow is noticeable after three years and is greater than the effect of pinus radiata, which is noticeable only a year later. Bosch and Smith (1989; cited by Schulze et al., 1995), suggested tentatively that Eucalypts plantations use more water at an earlier stage of growth than other commercial plantation.

It is the periods of low flow that are critical to the water resource planner (Schulze and Lecler, 1991; cited by Schulze et al., 1995), Although the mean annual rain fall may be reduced by less than 10 percent, the critical low flow periods may be reduced by more than this percentage, resulting in short falls for other water users. Deep-rooted trees can utilize the ground water store (Kienzle and Schulze, 1992; cited by Schulze et al., 1995) and so are often not under soil water stress. The shallower rooted grasses are thus utilising more water, particularly in dry season. This is critical to the planner. As suggested by Bosch (1982), the water use yield decreases more rapidly in warmer climates than in cooler climates.

As noted by Moerdyk and Schulze (1991; cited by Schulze et al., 1995), the higher the intensity of the site preparation, the less the surface run off that can be expected. As noted by Bosch and Von Gadow (1990; cited by Schulze et al., 1995), plantation on the valley floors are likely to have a greater impact on streamflow than plantation at the hill tops. Under certain circumstances it is, however, possible for afforestation to result in an increase in water yield from a catchment. This could happen, for example as a result of clearing vegetation with relatively high water use (e.g. mature indigenous forest) and replacing it with seedlings with lower water use (Smith, 1991; cited by Schulze et al., 1995).

Since biomass production for Eucalypts is relatively greater than for the other genera found in South Africa's commercial forest plantations, the Eucalyptus will tend to use more water in a shorter time period (ACRU FDSS Workshop No 3, 1995; cited by Schulze et al., 1995). Water use by Eucalyptus is therefore hypothesised to be greater than that of pines in the first stages of growth, owing to faster growth and earlier canopy closure. There is consensus amongst forest hydrologists in South Africa that Eucalypts has the highest consumptive use of the three major genera involved, with pinus species the lowest by virtue of their needle like leaf structure (Bosch and Smith, 1989; cited by Schulze et al., 1995). Wattle is estimated to be between that of Eucalyptus and pines, although Wattle is capable of extracting soil water at the same rates as Eucalyptus (ACRU FDSS Workshop No 3, 1995; cited by Schulze et al., 1995).

According to Bosch and Hewlett (1982; cited by Schulze et al., 1995), the decrease in water yield following afforestation is directly proportional to the growth rate. As suggested by Smith (1991; cited by Schulze et al., 1995), catchments planted to Eucalyptus tree shows an effect in the streamflow from the third year onwards while pines respond from the fifth year onwards. Recent results indicate that there may be little difference in daily water use between trees, maize and grassland during the active growing season. However, trees continuing to transpire in the dry season as a result of their deep rooting systems and evergreen perennial canopies (Versfeld et al., 1994; cited by Schulze et al., 1995). During wet summer periods, evaporation rates of Montane Grasslands is as high as those from forest plantation at cathedral peak but evaporation from grass land decreases by mid to late winter (dry period), which is believed to be the principal reason for a reduction in streamflow following afforestation of grasslands (Dye et al., 1995; cited by Schulze et al., 1995).



Ripping of the soil surface is likely to increase the infiltration and facilitate a higher proportion of rainfall to enter the soil. Thus, more water is made available to the tree root system. Total storm flow response is thereby decreased as well as its onset being delayed by a higher initial abstraction of rainfall (Moerdyk and Schulze, 1991; cited by Schulze et al., 1995).

Generally, during the first eight years of rotation, the leaf area index (LAI) of Eucalyptus is greater than that of Wattle and pines respectively, where after LAI for pines exceeds that of Wattle and Eucalyptus respectively. This is as a result of pines growing at relatively slower rates (with consequent longer rotations) than the other genera (Schulze et al., 1995).

# 2. SIMULATION RESULTS

Running the model for intensively prepared intermediate Wattle site in both catchments

Table 2.1 ACRU Model output for different scenarios

| Scenarios | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec.r | **Annual** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COFRU,0.012 | 205.52 | 93.57 | 150.19 | 106.11 | 33.84 | 3.02 | 2.62 | 4.97 | 77.21 | 68.07 | 77.46 | 77.58 | **820.11** |
| COFRU, 0.02 | 205.52 | 93.57 | 150.19 | 106.11 | 33.84 | 3.02 | 2.62 | 4.97 | 77.21 | 68.07 | 77.46 | 77.58 | **820.11** |
| LINACRE 1991Eq. & COFRU, 0.012 | 227 | 113.58 | 170.71 | 108.99 | 35.37 | 4.09 | 3.45 | 5.71 | 79.12 | 67.38 | 74.8 | 79.48 | **885.17** |

Table 2.2 Monthly out put for the simulation period 1981-1999 for all scenarios

| Scenarios | All Catchment with intermedia te Wattle | All Catch. With mature Wattle | Mature Wattle but riparian veld in good con | All veld in fair condition (baseline) | Intermedia te Eucalyptu s and riparian with veld in good condition | Sugar cane & veld in good condition | Maize & riparian with veld in good cond. |
|---|---|---|---|---|---|---|---|
| January | 205.52 | 190.15 | 205.52 | 195.6 | 190.06 | 191.81 | 220.45 |
| February | 93.57 | 86.77 | 93.57 | 91.04 | 86.48 | 87.49 | 100.27 |
| March | 150.19 | 137.83 | 150.19 | 143.45 | 138.18 | 138.99 | 150.18 |
| April | 106.11 | 102.23 | 106.11 | 108.68 | 101.47 | 105.05 | 111.42 |
| May | 33.84 | 32.89 | 33.84 | 35.92 | 32.64 | 33.8 | 38.55 |
| June | 3.02 | 2.98 | 3.02 | 3.6 | 2.98 | 3.03 | 5.53 |
| July | 2.62 | 2.53 | 2.62 | 3.26 | 2.5 | 2.62 | 4.87 |
| August | 4.97 | 4.82 | 4.97 | 5.68 | 4.75 | 4.95 | 6.87 |
| September | 77.21 | 75.12 | 77.21 | 79.6 | 74.75 | 74.82 | 84.88 |
| October | 68.07 | 64.49 | 68.07 | 74.81 | 63.67 | 65.17 | 106.1 |
| November | 77.46 | 71.92 | 77.46 | 73.03 | 72.19 | 71.85 | 111.74 |
| December | 77.58 | 73.12 | 77.58 | 76.62 | 72.76 | 74.85 | 108.01 |
| **Annual** | **820.11** | **769.48** | **820.11** | **813.33** | **767.08** | **777.72** | **948.89** |

** Observed Low flow months are:-June, July, Aug,

Table 2.3 Annual statistics for all scenarios

| Scenarios | All Catchment with intermediate Wattle | All Catch. With mature Wattle | Mature Wattle but riparian veld in good con | All veld in fair condition (baseline) | Intermediate Eucalyptus and riparian with veld in good condition | Sugar cane & veld in good condition | Maize & riparian with veld in good cond. |
|---|---|---|---|---|---|---|---|
| Sum | 820.11 | 769.48 | 820.11 | 813.13 | 767.08 | 777.72 | 948.89 |
| Mean | 45.56 | 42.75 | 45.56 | 45.18 | 42.62 | 43.21 | 52.72 |
| Min | 7.11 | 6.89 | 7.11 | 7.32 | 6.82 | 7.10 | 8.05 |
| Max | 119.91 | 112.14 | 119.91 | 118.96 | 112.94 | 112.04 | 155.36 |
| Obs | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 |
| 5% | NA | NA | NA | NA | NA | NA | NA |
| 10% | 7.56 | 7.34 | 7.56 | 8.04 | 7.26 | 7.55 | 9.59 |
| 20% | 27.63 | 25.69 | 27.63 | 27.17 | 25.49 | 26.14 | 30.83 |
| 33% | 30.46 | 28.37 | 30.46 | 30.06 | 28.10 | 28.96 | 36.27 |
| 50% | 38.62 | 35.63 | 38.62 | 37.57 | 35.30 | 36.50 | 42.01 |
| 67% | 44.97 | 41.55 | 44.97 | 42.68 | 41.55 | 41.52 | 48.67 |
| 80% | 54.08 | 50.85 | 54.08 | 53.80 | 50.59 | 51.87 | 62.78 |
| 90% | 85.98 | 82.62 | 85.98 | 88.12 | 82.14 | 83.62 | 95.43 |
| 95% | NA | NA | NA | Na | NA | NA | NA |
| StDv | 30.23 | 28.86 | 30.23 | 30.91 | 28.94 | 28.73 | 37.48 |
| Variance | 914.07 | 832.93 | 914.07 | 955.20 | 837.24 | 825.21 | 1404.76 |
| Skew ness | 1.48 | 1.51 | 1.48 | 1.59 | 1.53 | 1.47 | 1.83 |
| Kurtosis | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 3.00 |

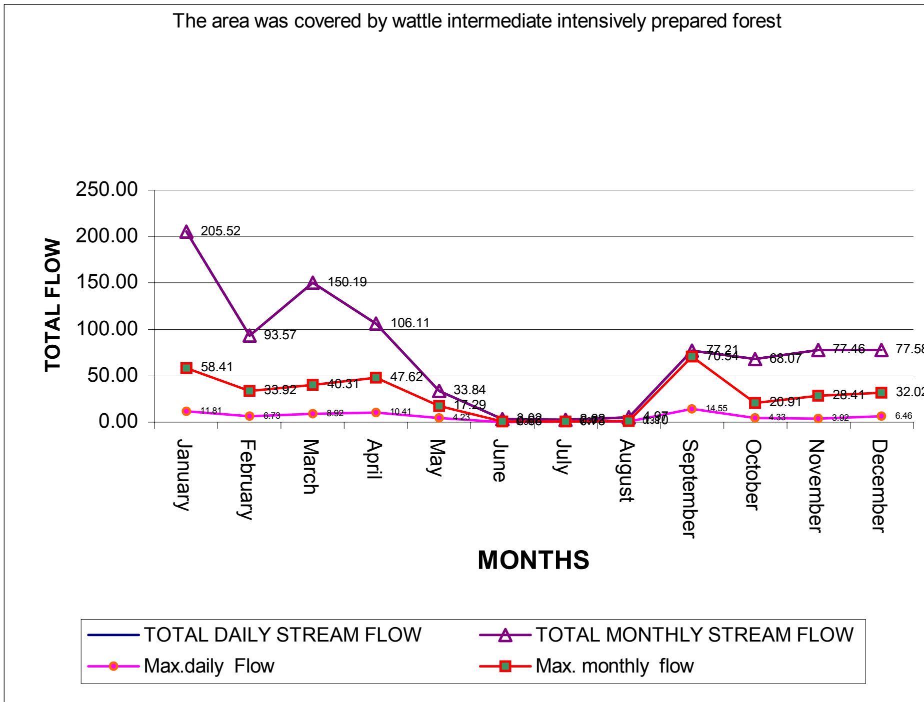


Figure 2.1 Daily and monthly streamflow time series curve (COFRU=0.012)

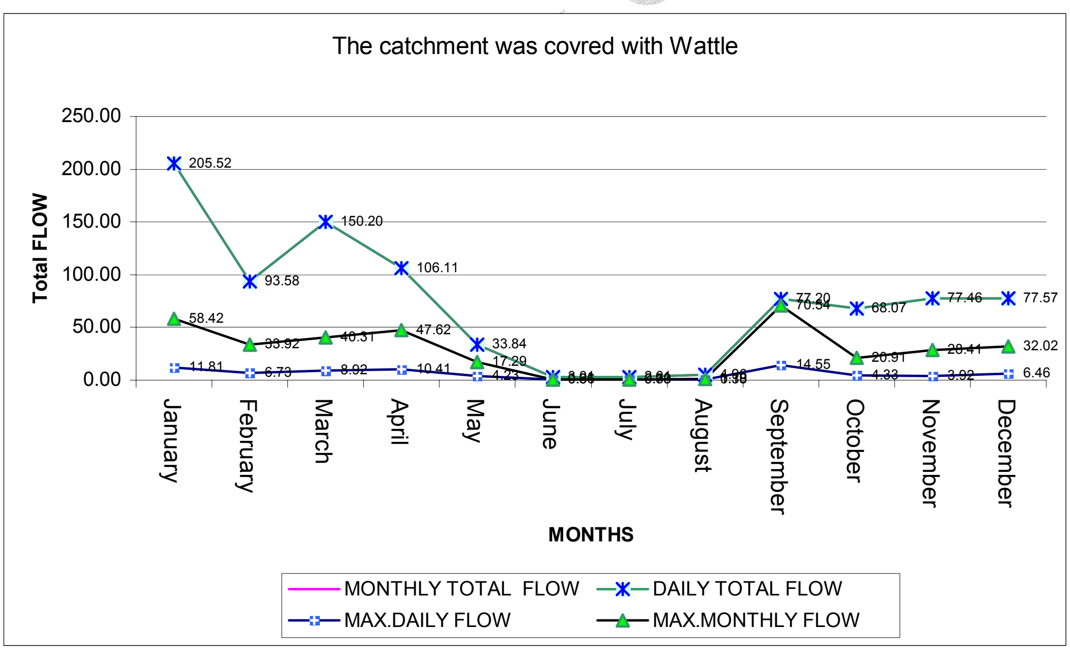


Figure 2.2 Daily and monthly flow time series (COFRU =0.02)

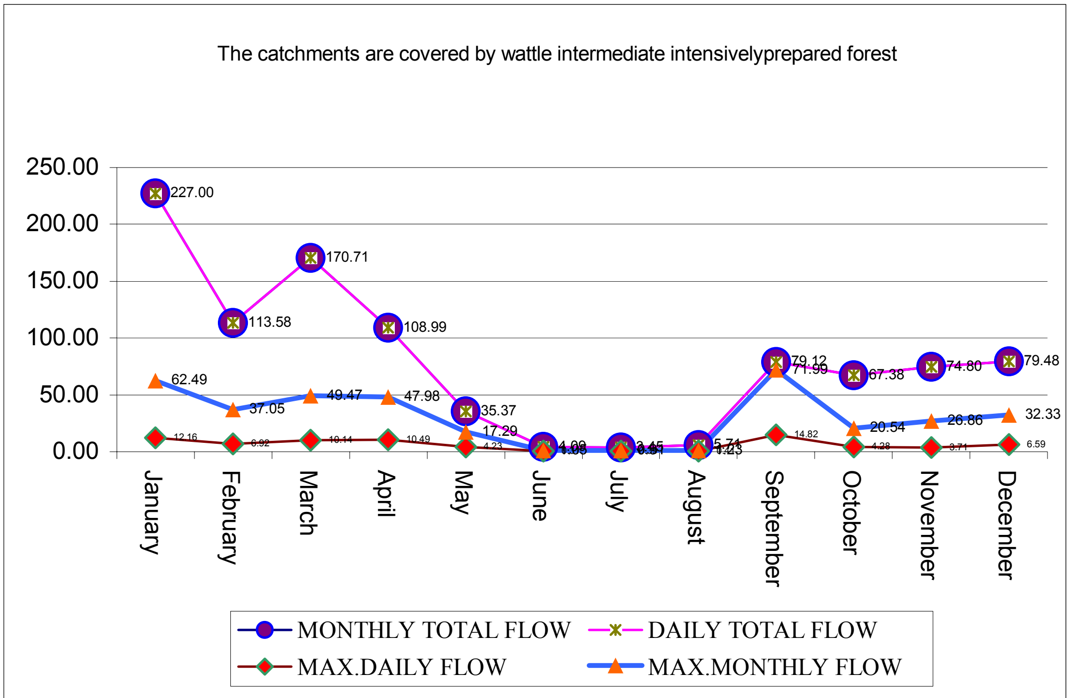


Figure 2.3 Daily and monthly streamflow time series (COFRU=0.012 using Linacre, 1991 Eq)

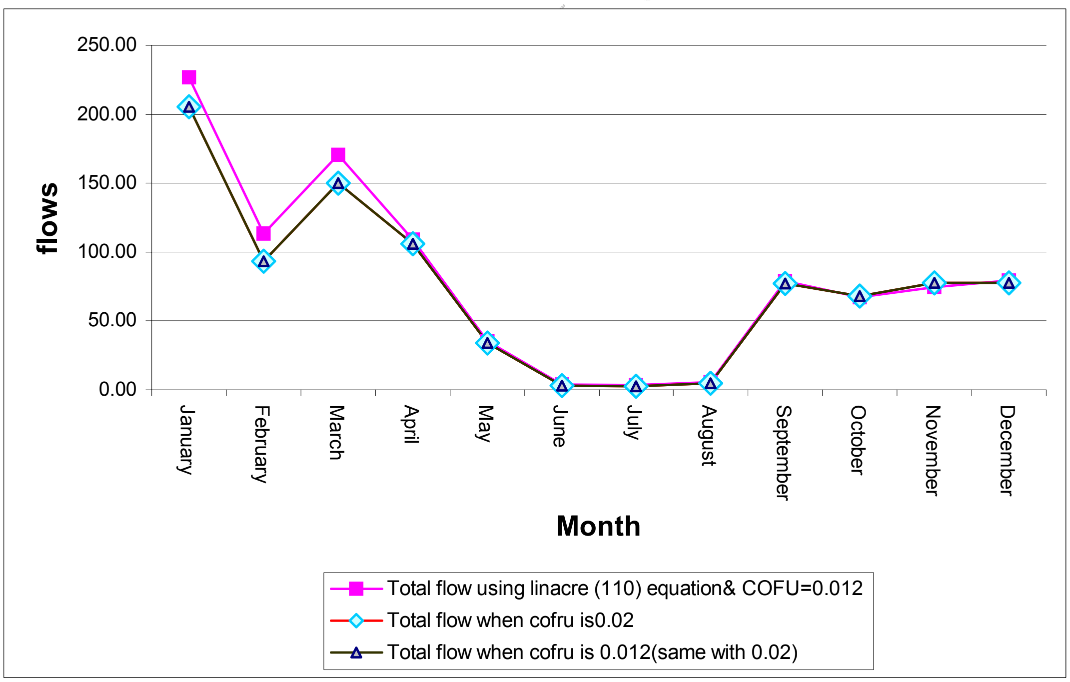


Figure 2.4 Flow VS time curve (Using different methods of evaporation techniques plus changing COFRU (combined graph) in the ACRU model

Table 2.4 Annual statistics for all scenarios

| Scenarios | Veld in good condition (baseline) | Mature Wattle | Mature Wattle & veld in good cond. | Eucalyptus and veld in good cond. | Sugar cane and veld in good cond. | Maize and veld in good cond. |
|---|---|---|---|---|---|---|
| Annual flow | 813.33 | 769.5 | 820.11 | 767.08 | 777.72 | 948.89 |

Percent of reduction in annual flow considering veld in fair condition is taken to be the base line

From the formula of percent of reduction = ((different scenarios – baseline scenario)/baseline scenario)*100

Table 2.5 Percent reductions

| Scenarios | Mature Wattle | Mature Wattle & veld in good cond | Eucalyptus & veld in good cond | Sugar cane & veld in good cond | Maize & veld in good cond |
|---|---|---|---|---|---|
| Percent of reductions | -5.39 | 0.83 | -5.68 | -4.38 | 16.67 |



The negative values in Table 2.5 show's that the reduction of streamflows in comparison with the veld in fair condition.

# 3. DISCUSSION AND CONCLUSION

The model run for the intermediate Wattle with the intensive site preparation in both catchments considering the change in ground water to be from 1.2% to 2 % (that means, when COFRU is 0.012 & 0.02 respectively). The result did not show any change. This might be due to the insensitivity of the model for very little change of COFRU. It is expected that the difference in the output may happen when the change in COFRU is bigger than the values stated above.

As shown in Figure 2.4, changing the method of calculating evapotranspiration in the model, either using the Linacre 1991 equation with a monthly temperature input (110) or using the monthly totals of daily A-pan equivalent evaporation (102) shows small change in the months of high flow periods. Based on the results observed, it is concluded as:

- Planting the whole catchments with mature Wattle decreases the flow by 5.4 percent,
- Planting the catchments with mature Wattle and the riparian with veld in good condition allows the stream to flow more than the baseline condition and increases by 0.83 percent,
- Planting the catchments with intermediate Eucalyptus and the riparian veld in good condition decreases the flow to 5.68 percent,
- Planting the catchments with sugar cane and the riparian veld in good condition decreases the flow by 4.38 percent, and
- Planting the catchments with maize cane and the riparian veld in good condition affects the stream condition and it flows better than the baseline condition. The flow increases by 16.67 percent.

**Comparing clear vs unclear riparian zone**

When the riparian zone is clear, the flow generally increases as compared to the forests that have cover. This is exceptional for the intermediate Wattle.

**Comparing afforestation with mature Wattle and intermediate Eucalyptus against a base line condition**

Planting the site with Eucalyptus instead of Wattle decreases the streamflow with a 6.51 percent difference. As described by ACRU FDSS Workshop No 3 (1995; cited by Schulze et al., 1995), the reason might be due to the higher biomass production of Eucalypts than the Wattle. It is proved from the tentative suggestion done by Bosch and Smith (1989) that eucalyptus plantation uses more water at an earlier stage of growth than the other commercial plantation.

The comparison of different scenarios in the catchments revealed that the intermediate Wattle does not affect the flow as such for the reason that the water using rate depends up on the stage of growth and also the canopy closure. Hence, the experiment has to be done in different growth stages. The streamflow condition affected differently due to change in root depth, Leaf area index. There is also seasonal effect in the flow reduction activities. Trees transpire more in the summer time for they have deep root system and evergreen canopies but in the case of the short rooted plant, the plant becomes dormant for the reason that they are short rooted and could not get the deep soil water. So the streamflow increases much better than the forests in the agricultural plants.

Finally, from the results obtained, it could be recommended to cover the upstream catchments with the maize and leaving the riparian zone veld. This may be a better choice to maximize the streamflow to the down stream side in the seven Oakes experimental station.

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