Climate change impacts on water yields from irrigated catchments of southwest of Western Australia

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Introduction

The Harvey Water Irrigation Areas (HWIA) is an important irrigated dairying and horticulture area situated in Southwest of Western Australia. The history of irrigated agriculture in HWIA started with the establishment of a weir in 1916. Since that time, pastures and horticultural crops have been irrigated through surface (flood) irrigation (Ali, 2007). The clearing of native vegetation with the replacement of shallow rooted crops and pastures, construction of dams, irrigation by flooding and the construction of a drainage network, has modified the water balance of HWIA. More water now enters the soil and evapotranspiration has been reduced. Water that is not used by cereal crops and pastures contributes to loss of crop yield (McFarlane and Cox, 1992; McFarlane *et al*., 1992). Also, this water may recharge saline groundwater causing them to rise and seep out at the land surface (dryland salinity; Nulsen and Henschke, 1981). In addition to this recent change in climate has resulted in the overall decrease in annual rainfall as well as increase in thunderstorm intensity during summer seasons. This change in rainfall amount and intensity during recent years has posed a great challenge to the farming community of HWIA's farmers in managing their land and water resources. This study has been conducted to assess the impact of changing climate in term of rainfall quantity and its impact on catchment water yield. The water yields of catchments were estimated for wet, average and dry climates and the possibilities of flooding, storage and waterlogging and salinity were explored. Most of the farmers have installed drains to manage their surface water during winter and summer rainfall events. The role of these drains has also been investigated in the water yields of the irrigated catchments.

Methodology

For this study, MIKE SHE fully integrated and spatially distributed hydrological model was selected (DHI, 2007). MIKE SHE is capable to simulate all the hydrological processes in the landscape including irrigation and drainage. The data required to calibrate MIKE SHE to capture spatial variation was not completely available in the catchment, therefore, some of the data was used from the previous studies and entered into the model as lumped parameter instead of distributed. Most of the data like soil physical, meteorological, rainfall, irrigation, cropping pattern, groundwater depths and flow data was collected from the study area. To define the type of climates in term of wet, average and dry a simplistic approach was adopted. The daily rainfall and meteorological data from 1976 to 2004 was collected from 11 meteorological stations nearby the study area. The daily effective rainfall was estimated by ignoring the daily rainfall less than two millimeters. The average of the effective annual rainfall for all meteorological station was calculated. This average effective annual rainfall from 1976 to 2004 was arranged in descending order. Then it was grouped into three equal parts. The upper, middle and lower part's averages were calculated and found to be equal to 839, 738 and 596 mm respectively. The rainfall year with rainfall ≈ 839 mm was considered as wet rainfall year for the study area. Year 1982 (had rainfall close to 839 mm) was considered as wet year and its climate data was used to represent wet climate for the study area. Therefore, actual meteorological data for 1982 was used as an input into MIKE SHE to represent wet climate in the study area. Similarly, 1995 and 2001's climate data was used as an input into MIKE SHE for average and dry climates. Many simulations were run to calibrate MIKE SHE using the actual and simulated groundwater table depths from a set of four bores. The calibrated model was validated on another set of two bores. The correlations between actual and simulated water table depths are shown in Table 1 and 2.

Table 1 Correlation between Observed and Simulated Water Table Depths

Correlation	Bore 1	Bore 2	Bore 3	Bore 4
R	0.83	0.85	0.93	0.87
R^2	0.69	0.73	0.87	0.76

Table 2 Correlation between Water Table Depths Predicted by Calibrated model and Observed Data

Correlation	Bore 5	Bore 6
R	0.87	0.91
R^2	0.75	0.82

Results and discussion

The calibrated MIKE SHE was used to simulate six scenarios with two irrigation rate (10 and 16 ML/ha-annum) and three climates (wet, average and dry) to estimate the irrigated catchment water yield Table 3 describes the six scenarios. The MIKE SHE was also used for estimating the impact of 1 and 2 meter deep drains on water yield.

Table 3 Description of Scenarios with two irrigations and three climates

Irrigation (ML/Y/H)	Type of climate		
	Wet (W)	Average (A)	Dry (D)
10	S1 = SW-I10	S2 = SA-I10	S3 = SD-I10
16	S4 = SW-I16	S5 = SA-I16	S6 = SD-I16

(Note Subscripts SW=Wet, SA=Average, SD= Dry, I0, I10 and I16 = 0, 10 and 16 mega litres/year irrigation)

The simulation results of all six scenarios were analysed to estimate the water yield of the irrigated catchments. Table 4 shows the simulated monthly water yields from the irrigated catchments with 10 and 16 ML/ha-annum irrigation rates in mm.

Table 4 Monthly water yield in six simulated scenarios (mm)

Month	Water Yield (mm)					
	S1	S2	S3	S4	S5	S6
Jan	8	7	11	13	4	6
Feb	9	7	7	14	1	3
Mar	11	5	5	17	8	6
Apr	4	1	4	12	3	6
May	17	8	2	55	71	64
Jun	118	42	14	183	62	31
Jul	175	133	18	250	166	19
Aug	120	90	40	168	91	39
Sep	138	86	37	198	93	53
Oct	55	27	16	51	45	28
Nov	8	11	12	17	25	31
Dec	5	8	4	13	13	19

Table 4 shows that with the 10 ML/ha-annum irrigation application rate (S1 to S3), there was 118, 42 and 14 mm of water yield during the first moth of winter rainfall during wet, average and dry climate years respectively. Whereas, with 16 ML/ha-annum irrigation application rate (S4 to S6), there was 183, 62 and 31 mm of water yield during wet, average and dry climates respectively. The maximum water yield was observed during the wet climate during the winter rainfall (scenario S1 and S4). These results indicate that a significant amount of water is available during wet climate to be harvested and stored or diverted into the groundwater resource system for future use. In average climate (scenario S2 and S5), the water yield was 133 and 166 mm during the month of July. For the month of August and September it was 90 and 86 mm for scenario S2. For scenario S5 it was 91 and 93 mm for the same periods. These quantities indicate that during average climate, there is sufficient water available from the irrigated catchments of HWIA.

Installation of the drainage system in the HWIA has dramatically increased the water yield of the irrigated catchments. Increased drain flow from the drained area can also provide a viable water resource if its water quality is suitable for domestic, agricultural or industrial use. The amount of the drained water from a given area can easily be estimated by using the Water Balance Module of the MIKE SHE family. A comprehensive procedure for using the Water Balance Module is given in MIKE SHE Reference Guide and Technical Manual (DHI, 2007). Water Balance Module of MIKE SHE was used to simulate eight scenarios (2x2x2) for two drain depth, irrigation rate and climates. Drain depths were assigned a value of 1 and 2 m. Irrigation rates were used as 0 and 16 ML/haannum. Two types of climate (wet and dry) were used. The simulated results of drain out flow of these eight scenarios are shown in Table 5.

Table 5 Drain outflow (Discharge) from the area (mm)

Irrigation rate ML/Y/H	Drain Depth			
	1 metre		2 metres	
	Wet	Dry	Wet	Dry
0	298	59	623	337
16	566	312	886	596

Table 5 revealed very interesting results about the impact of the 1 and 2 m deep drains in wet and dry climate with and without 16 ML/ha-annum irrigation application rates on water yield. The depth of drained water in wet and dry year without irrigation for 1 m deep drain was 298 and 59mm respectively. This indicates that the 1 m deep drain removed nearly five times more water from the area during wet climate as compare to the dry climate. On other hand when 16 ML/ha-annum irrigation was applied, the 1 m deep drains removed 312 mm of water during dry climate. Another interesting result can be seen in Table 5 is the amount of water yield by 2 m deep drain without any irrigation application in wet and dry climates. This was 623 and 337 mm in wet and dry climates respectively. This result indicates that 2 m deep drains were yielding sufficient water from the area even in dry climate. The amount of water yield by 1 and 2 m deep drains during dry climate without irrigation application was 59 and 337 mm. Its mean by increasing the depth of drain from 1 to 2 m the amount of water yielded was nearly five and a half times more during dry climate.

Conclusions

The water yield during wet, average and dry weather without drains from the irrigated catchments shows that there is a great risk of flooding and water logging in the down stream if a water management (storage and diversion) is not in place. The study found that the wet weather (above average annual rainfall) will significantly increase the water yield and flooding risks to areas surrounding the creeks network. The wet climate will produce extreme flooding events. On the other hand the dry climate is unlikely to produce any significant water yield.

With the installation of 1 and 2 metres deep drains, the water yield of the irrigated catchments was increased to five fold. This shows that the drains in the irrigated areas can produce a significant water yield which can be managed by storing or diverting it into the aquifers for future use if the water quality is favorable. In the absence of management plan, there is a great risk of overland flow, over spilling, flooding and waterlogging in the downstream of the irrigated catchments.

References

Ali, S. M. 2007. Climate Change and Water management Impact on Land and Water Resources. PhD Thesis submitted to the Curtin University of Technology, Western Australia.

Danish Hydraulic Institute, 2007. Working with MIKE SHE Part 1 and 2, and Technical Manual with User Guides Volume 1 and 2. Danish Hydraulic Institute, Denmark.

McFarlane, D.J. and Cox, J.W., (1992). Management of excess water in duplex soils. Aust. J. Exp. Agric., 32: 857-864.

McFarlane, D.J., Wheaton, G.A., Negus, T.R. and Wallace, J. F., (1992). Effect of waterlogging on crop growth and pasture production in the Upper Great Southern, Western Australia. Tech. Bull. No. 86, Western Australia Department of Agriculture, South Perth.

Nulsen, R.A. and Henschke, C.J., (1981). Groundwater systems associated with secondary salinity in Western Australia. In: J.W. Holmes and T. Talsma (Editors), Land and Stream Salinity. Elsevier, Amesterdam, pp. 173-186.