ISSN 2278 – 0211 (Online)

Simulation of Impact of Change in Landuse on Water Yield of Upper Manair Catchment

Hari Krishna B.
Department of Agronomy (Water Management), ANGRAU, Hyderabad, India
A. Mani
Department of Agronomy (Water Management), ANGRAU, Hyderabad, India
M. Uma Devi
Department of Agronomy (Water Management), ANGRAU, Hyderabad, India
V. Ramulu
Department of Agronomy (Water Management), ANGRAU, Hyderabad, India

Abstract:
Land use plays an important role in controlling hydrologic response of catchment, particularly in terms of the nature and magnitude of surface water and ground water interactions and surface water availability. The change in land use controls the water yield of surface streams and groundwater aquifers and thus the amount of water available in a watershed. Hence, the hydrological model SWAT has been applied to upper Manair catchment, Andhra Pradesh, India to determine the impact of land management practices and change in land use on water yield for sustainable use. The model was run for a period of 21 years, i.e.1992 to 2012. It was calibrated against observed reservoir volumes using Nash Sutcliffe criteria (0.85). To obtain sustainability of ground water resources in the watershed, it was tried to simulate the water balance components by reducing the area under paddy cultivation through three alternate cropping scenarios. The evaluation of three scenarios clearly demonstrated the impact of conversion of paddy (water intensive crop) on the hydrology of watershed. The base flow was reduced from 31.42mm to 6.21mm. The lateral flow through soil has decreased to 3.05mm from 3.92mm. The deep aquifer recharge has been reduced to 356.79mm from 464.51mm. Actual ET has been increased to 592.8 from 545.1mm due to more vegetation. It can be concluded that converting paddy area to dry land crops will enhance availability of surface water resources and decrease ground water resources.

1. Introduction

Globally, the quantification and evaluation of land use and cover changes on the hydrological status of river basins is a main concern. Understanding the implications of changes in land cover and land use is essential for sustainable land planning and development. On one hand, transformation of land cover and land use by human activities can affect the integrity of a natural resource system and the output of goods and services of the ecosystem. On the other hand, by careful planning, the development of new patterns of land cover and land use can enhance the well-being of people (Hadi Memarian *et al.*, 2013). Changes in land cover result in some proportional alterations in the basin condition and hydrological response. This is becoming one of the main contemporary land management issues.

Modeling tools have changed the scientific framework for analysis of land use systems, from one that is descriptive to one that is more quantitative which addresses both spatial and temporal dynamics. The impact of change in land use and land cover on water quantity and quality can be estimated very well with SWAT. There are many cases where SWAT models have been used to predict the impact of land use change on environmental cycles.

Yacob (2010) applied the SWAT model to identify the effect of land use and land cover change on runoff and sediment in Tikur Wuha watershed (706 km^2) of Ethiopia. The model predicted a strong relation between water yield and land use change during the calibration. Higher value of the surface runoff correlated with orthic luvisols soil type and bare and open shrub land use was observed.

Friedrich *et al.* (2012) adopted SWAT model to investigate the effect of dynamic land use on daily discharge, the total annual runoff and peak flow by adding "Land use Update and Soil Assessment" (LUPSA) in order to improve the overall SWAT abilities to handle land use changes in the Gedeb catchment (290 km^2), Ethiopia. LUPSA was applied during the period of 1973 to 2003 with yearly land use updates. There was a significant difference in the total discharge volumes observed which accounts for 2.9% of the total flow within the whole period of 30 years.

De Girolamo and Porto (2012) applied SWAT to develop possible land use and land management scenario that could constitute an alternative to the current watershed management in the Rio Mannu River Basin (Sardinia, Italy). The replacement of drum wheat with rapeseed (biofuel crop), could offer a margin of profit, but would have a negative impact on water quality due to increased nutrient losses.
The effect of different land uses on the water yield of the Kothakunta sub-watershed in India (550 ha) with varying soils, land use and management conditions over long period of time was quantified by SWAT (Vara Prasad, 2012). Reducing area under paddy cultivation and allocating the reduced area to irrigated dry crops
Yan *et al*. (2013) used the SWAT model to assess the impact of land use change on watershed stream flow and sediment yield for the Upper Du watershed (8973 km^2) in China. An integrated approach involving hydrological modelling and partial least squares regression (PLSR) was employed to quantify the contribution of changes in individual land use types to changes in stream flow and sediment yield. The results indicated that changes in grassland did not show a significant influence on either stream flow or sediment yield.
Hence, Soil and Water Assessment Tool (SWAT) model has been used to simulate the impact of change in landuse on water yield of Upper Manair catchmentof the upper manair dam.

2. Study Area

The Upper Manair Catchment (UMC) of Andhra Pradesh was selected for the study. The UMC is located between the latitudes 17.65^0 and 18.50^0 N and longitudes 78.15^0 and 78.85^0 E which comprises parts of the Medak, Nizamabad and Karimnagar districts of Andhra Pradesh. The catchment area is 2, 20,289.48 ha. Two rivers namely Kudlair river of Medak district and Manair river of Nizamabad are flowing through the catchment and contributing the flows to Upper Manair reservoir. The location map of the study area is shown in Fig .1.

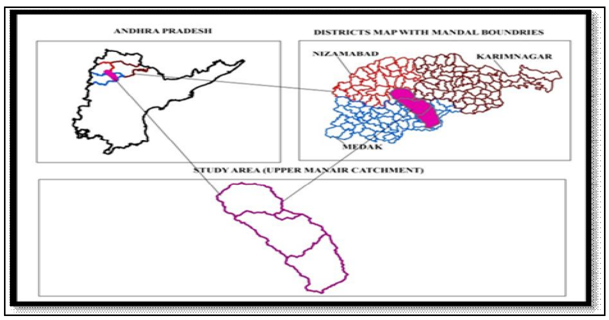

Figure 1: Location map of Upper Manair Catchment, Andhra Pradesh

The Upper Manair catchment consists of mainly two types of soils. Clay loam soils occupy an area of 92% in the catchment. Remaining 8% soils are Clay. Climate of the study area is semi-arid with distinct summer, winter and rainy seasons.
The average annual rainfall of 21 years from 1992 to 2012 was 777.8 mm. The highest amount of rainfall was recorded in 1995 as 1143.8 mm and lowest amount of rainfall was recorded during the year 2009 as 536.01mm.

2.1. Crops and Cropping Pattern of Study Area

The major cropping systems followed in the study area are paddy - paddy, maize-maize, paddy-maize, cotton-maize and maize-sunflower. The major crops grown during *kharif* and *rabi* are paddy, maize and cotton respectively. Sugarcane, sunflower and vegetables are also grown but not in significant area.

3. Model and Model Inputs

3.1. Soil and Water Assessment Tool (SWAT)

Hydrology simulation of a watershed in SWAT is separated into two major phases. Land phase controls the amount of water, sediment, nutrient and pesticide loading to the main channel in each sub basin. Water or routing phase controls the movement of water, sediments and nutrients through the channel network of the watershed to the outlet. SWAT has been applied to simulate the impact of changed land scenarios on water yield of the upper manair catchment.

3.2. Geospatial Layers

Geospatial layers namely, Digital Elevation Model (DEM), stream network and reservoir, land use and land cover and soil are required for hydrological modeling of the catchment area. The preparation of geospatial layers of the catchment area are explained below.

3.3. Digital Elevation Model (DEM) and Delineation of Watershed

The Digital Elevation Model was prepared by downloading Cartosat DEM of catchment area from Bhuvan web site provided by NRSC with a resolution of 30 m x 30 m. The Arc SWAT interface automatically generated stream network, flow direction and accumulation by taking into consideration the elevation values of DEM and masked area on the DEM. The outlet points have been added based on the flow from Kudlair River and Palvancha vagu (Manair River) reaching to Upper Manair reservoir. The delineation of watershed was completed based on the added outlet points. The reservoir point has also been set at the outlet of the watershed.

3.4. Land Use / Land Cover Map

The LULC was prepared for the study area of 2,20,289.5 ha using IRS P_6, LISS III image of December, 2011 and September, 2012. The information from LISS III image and toposheets were utilized for classification of land cover generation of training sets. Ground truth survey was carried out by walking around the field boundaries for two times (*rabi* 2011 *and kharif* 2012) during 2011 to 2012 using GPS. Major portion of the study area was covered with agricultural crops viz. paddy, maize and cotton. The areas of different land uses of the study area are presented in percentage in Table 1. and shown in Fig. 2.

S. No.	Land use	Area (ha)	Percentage (%)
1	Cotton	21069.9	9.57
2	Rice (*kharif)*	44170.6	20.06
3	Rice *(rabi)*	9479.8	4.31
4	Corn	53978.3	24.52
5	Rock	4331.0	1.97
6	Built up land	8641.0	3.92
7	Sugar cane	7619.6	3.46
8	Water bodies	7197.7	3.27
9	Forest	19236.2	8.74
10	Range lands	44448.7	20.19

Table 1: Land use pattern in Upper Manair Catchment

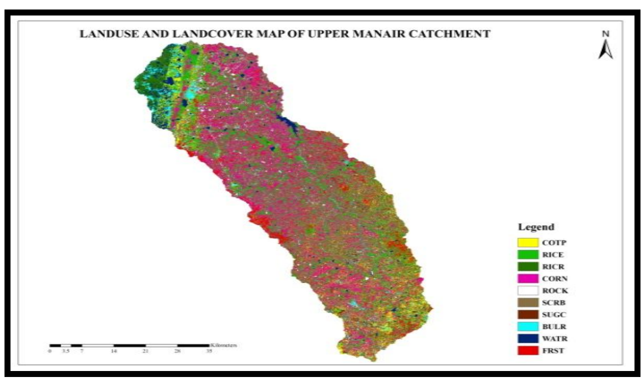

Figure 2: Land use and land cover map of Upper Manair Catchment

Note: COTP- Single crop cotton, RICE- Single crop paddy, RICR- Double crop paddy, CORN- Double crop maize, ROCK- Rock land, SCRB- Scrub land, SUGC- Sugarcane BULR- Built up land, WATR- Water bodies, FRST- Forest land

3.5. Soil Texture Map

The soil map (1.250,000) developed by NBSS & LUP has been taken as reference map and clipped to the catchment area. The soil textural classes were identified. One is clay loam soil and another one is clay soil. In addition to that the soil map prepared by SWAT group for India was also considered to ascertain the types of soils.

4. Application of SWAT Model

A base SWAT model has been created with the dataset of Upper Manair catchment and simulated total water yield, reservoir levels, reservoir discharge and reservoir volume for the period 1992 to 2012. It was also calibrated then validated to obtain accurate simulation since calibration and validation are important processes for any simulation model to understand its certainties, confidence levels and limitations. The model has been calibrated and validated for daily reservoir volume. The period from 2006 to 2012 has been chosen as the calibration period and 2001 to 2005 is taken as the validation period for the daily time step analysis. The simulated reservoir volumes match well with the observed values. The graph has clearly shown that the simulated values were on par with the observed values (Fig. 3). The results obtained in the present study were in good agreement with R^2 =0.85.

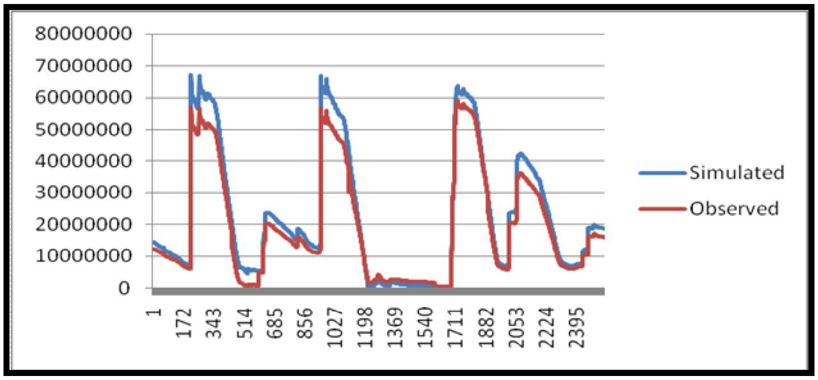

Figure 3: Comparison of observed and simulated reservoir volumes

5. Results and Discussion

Ground water is the major source for irrigation. Over exploitation through indiscriminate pumping of water has led to aquifer depletion and ground water contamination causing agriculture vulnerable in catchment area. Hence for the sustainability of ground water resources, three different cropping systems were proposed and the model was run to estimate the water yield. The first cropping scenario was proposed focusing mainly on reducing the area under paddy. The cultivation of paddy can't be stopped completely since it is against social interest. The area under double crop paddy (4.31%) has been reduced and that area has been assigned to Cotton. Thus Cotton area has been increased to 13.88% from 9.57%.

The second scenario is planned by reducing 14.31% area of paddy land use of catchment (double crop paddy area of 100% and single crop paddy area of 50%). The reduced double crop paddy area has been assigned to Maize - Sunflower. The 50% single crop paddy area has been allocated to cotton and maize equally.

Scenario-3 has been proposed by increasing the area under cotton and maize. The third scenario comprises 25 % less single crop paddy area in accordance with the present paddy grown area. The reduced area has been allocated to cotton. In addition to that double crop paddy area has been assigned to Maize-Sunflower. The rest of the land uses were not changed, namely, scrubland, forest and fallow land. The proposed alternate cropping scenarios were presented in the Table 2

S. No.	Land use	Existing (%)	Scenario-1 (%)	Scenario-2 (%)	Scenario-3 (%)
1	Cotton	9.57	13.88	14.48	14.51
2	Paddy	24.37	20.06	10.13	15.12
3	Maize-Maize	24.52	24.52	29.55	24.51
	Maize - Sunflower (Double crop)	-	-	4.31	4.31
4	Sugar cane	3.46	3.46	3.46	3.46

Table 2: Land use and percentage area coverage of different Scenarios

The model was run keeping all the other conditions namely, parameters of ground water, basin and soil same as in the existing land use of the watershed except the change in the areas of different cultivable crops. The LULC maps have been prepared based on proposed scenarios and the maps have been overlaid on the already prepared soil map and slope. The new HRUs were defined based on scenarios. The model was run using the already prepared database of watershed.

5.1. Average Monthly Basin Values

The monthly basin values for different components of water balance were presented in the Table 3. Generally, ET will be more during May to August in a year. However, ET was more even during the months of September and October. This is due to cultivation of *rabi* crops in the catchment.

There is considerable amount of surface runoff simulated in the months of July, August and September which is in accordance with the amount of rainfall received in those months. The maximum amount of runoff (32.51mm) was estimated in the month of August.

The similar trend was observed in the average monthly components of water balances of other two scenarios as discussed in the previous scenario-1.

5.2. Average Annual Basin Values

The average annual basin values of different components of water balance were also presented in the Table.4. The major share of the precipitation and irrigation was taken by actual evapotranspiration (592.8 mm) followed by total aquifer recharge (475.72 mm) and percolation (474.92 mm). Surface runoff and lateral flow contributed less in the scenario-1. By reducing the area under paddy and assigning the land to dry land crop increased the runoff and reduced the base flow and lateral contribution to stream flow. In addition to that, the ground water recharge also reduced. Attributed to its superior detention capacity, a paddy field typically has a much lower flood peak, about one third of a dry farm field (Ray Shyan Wu, 2001). Surface runoff and lateral flow contributed less in the scenario-2 compared to the existing land use and scenario-1. Even, the base flow contribution to the stream flow and total yield was also less since more area under paddy has been reduced. Surface runoff and lateral flow contributed less in the scenario-3. Actual Evapotranspiration (577.10 mm) is the significant component followed by percolation out of soil (480.0 mm) and total aquifer recharge (479.11 mm) in the basin. Overall water balance clearly shown a significant increase in runoff and a decrease in groundwater recharge when paddy fields are converted to other uses. Ray Shyan Wu *et al.* (2001) also investigated the effect of paddy fields in water retention and their conversion into dry land crops on runoff and confirmed the same.

Month	Rainfall (mm)	Surface runoff (mm)	Lateral flow (mm)	Water yield (mm)	Actual ET (mm)
January	10.57	0.66	0.29	1.71	40.41
February	4.80	0.04	0.24	0.76	38.91
March	17.42	0.28	0.21	0.59	42.86
April	14.35	0.11	0.18	0.35	44.08
May	13.98	0.15	0.16	0.34	49.93
June	83.20	1.11	0.15	1.24	44.72
July	183.57	11.23	0.20	11.36	52.98
August	207.94	32.51	0.32	33.68	56.62
September	142.77	20.66	0.38	23.10	62.95
October	79.74	9.99	0.40	13.07	67.71
November	17.14	0.77	0.35	3.38	51.19
December	2.46	0.08	0.32	1.98	41.44

Table 3: Average monthly basin values of different components of Water balance for scenario-1

	Average Annual Value (mm)		
Process	**Scenario -1**	**Scenario -2**	**Scenario -3**
Precipitation	777.8	777.80	777.80
Surface runoff	77.79	67.57	91.08
Lateral flow through soil	3.17	3.05	3.08
Groundwater	11.21	6.21	8.50
Capillary rise	21.55	24.45	23.51
Deep aquifer recharge	356.79	364.29	359.33
Total aquifer recharge	475.72	485.72	479.11
Total water yield	91.35	76.27	101.97
Percolation out of soil	474.92	484.99	480.00
Actual Evapotranspiration	592.8	577.10	556.40

Table 4: Average annual basin values of different components of water

5.3. Water yield from Different HRUs

The water balance components of different HRUs were presented in the Table.5. The ET of maize was 798.07 mm from clay soil indicating that it is more than all other land uses of the catchment. The above results indicate that the model has simulated very well the impact of soil type and land use on the yield of water.

The surface runoff, ground water contribution to stream flow was very high from sugar cane compared to other crops and non-cultivable area**.** ET was high in clay soils compared to clay loam soils in the catchment for maize and cotton crops. However, the ET was little less in clay soils compared to clay loam soils for sugarcane and paddy crops. Due to reduction of paddy area under cultivation, the actual evapotranspiration from rice fields was reduced from 784.6 mm to 599.7 mm. There was a little change in the ET due to variation with the soil type in the rice fields. The evapotranspiration ranged between 580 mm to 599.7 mm for the paddy fields. The surface runoff was more for sugarcane i.e. 402.66 mm in clay soils when compared to clay loam soils. It was followed by paddy, double crop maize and cotton respectively.

Ground water contribution to stream channel was poor from 0.12 mm to 39 mm in clay soils. It was 498.75 mm in sugarcane crop in clay loam soils. The ground water contribution to stream flow was showed highest for sugarcane followed by paddy, double crop maize and cotton respectively in clay loam soils. Application of irrigation water to paddy and sugar cane has contributed to increased ground water flow towards stream.

S. No	Land use	Type of soil	Available water content (mm)	Surface Runoff (mm)	Ground water contribution to stream flow (mm)	Actual Evapo transpiration (mm)
SCENARIO - 1						
1	Paddy	Clay loam	175.00	13.6375	70.7	599.72
		Clay	203.58	242.07	39.36	580.00
2	Double crop Maize	Clay loam	175.00	61.3225	11.48	780.68
		Clay	203.58	218.03	6.41	798.07
3	Cotton	Clay loam	175.00	84.31	2.85	714.47
		Clay	203.58	195.19	8.29	716.19
4	Sugarcane	Clay loam	175.00	110.10	498.76	755.94
		Clay	203.58	402.66	392.37	704.12
SCENARIO - 2						
1	Paddy	Clay loam	371.00	13.805	70.68	599.93
		Clay	203.58	242.07	9.38	580.00
2	Double crop Maize	Clay loam	371.00	61.38	10.77	782.40
		Clay	203.58	218.03	0.41	798.07
3	Double crop maize-sunflower	Clay loam	371.00	61.58	14.21	757.54
		Clay	203.58	219.11	0.38	765.47
4	Cotton	Clay loam	371.00	86.30	1.855	714.47
		Clay	203.58	195.19	0.28	716.19
5	Sugarcane	Clay loam	371.00	113.01	499.34	756.09
		Clay	203.58	413.85	398.9	704.67

SCENARIO - 3						
1	Paddy	Clay loam	353.5	13.93	54.44	600.34
		Clay	203.58	244.34	5.85	580.25
2	Double crop Maize	Clay loam	371.00	61.84	15.07	782.64
		Clay	203.58	219.96	0.41	797.9
3	Double crop maize-sunflower	Clay loam	371.00	62.01	13.77	757.45
		Clay	203.58	221.04	0.38	764.94
4	Cotton	Clay loam	371.00	86.465	3.70	713.99
		Clay	203.58	196.36	0.28	715.2
5	Sugarcane	Clay loam	371.00	112.301	511.26	764.94
		Clay	203.58	415.94	393.09	712.99

Table 5: Water balance components of different HRUs

Based on the proposed scenario-2, the values of different components of water balance from the HRUs have been presented in the Table 5. In the second scenario, the actual evapotranspiration was more for double crop maize ranged from 782.40 mm to 798.07 mm in clay loam and clay soils. Paddy crop has exhibited less evapotranspiration ranged from 580 mm to 599.93 mm since the area under paddy has been reduced.

Ground water contribution was high from sugarcane fields compared to other crops and the contribution from the sugarcane fields ranged from 398.9 mm to 499.34 mm. The surface runoff contribution from paddy, double crop maize-sunflower and double crop maize was moderate and ranged from 14.20 to 70.68 mm. Cotton had shown poor GWQ i.e. 1.85 mm.

Surface runoff was more in the sugarcane crop followed by paddy crop. The range of surface runoff simulated in sugarcane was 113 mm to 413.85 mm. In paddy crop, it was ranged from 33.80 mm to 242.07 mm in clay and clay loam soils. Double crop maize-sunflower contribution ranged from 61 to 219 mm in clay loam and clay soils followed by double crop maize. The contribution from cotton ranged from 86 to 195 mm in clay loam and clay soils respectively. The above results clearly showed the magnitude of variation based on type of soil and land use. The variation between water balance components of wet land crop and other irrigated dry crop was also clearly visible from the results. Hence it was thought of observing the magnitude of water balance components by allocating area to irrigated dry crops.

In the scenario-3, the paddy area was reduced by 25% and double crop paddy was converted to maize-sunflower, which in turn reduced both the evaporation from the stagnant water and evapotranspiration from crop. However, the evapotranspiration from the double crop maize in the scenario-3 has been simulated as 798 mm in clay soils which was greater than other field crops. The ET from paddy ranged from 580 to 600 mm in clay loam and clay soils.

The ET estimated for the sugarcane was ranged from 712 to 764 mm and the ET simulated in the double crop maize-sunflower ranged from 757 to 764 mm in clay loam and clay soils. Similarly ET noticed in the Cotton was 714 to 715 mm.

The surface runoff from sugarcane ranged from 112 to 415 mm followed by scrub land (137 to 311 mm) in clay loam and clay soils. The surface runoff was high for paddy followed by double crop maize-sunflower, double crop maize and cotton crop in clay to clay loam and clay soils respectively.

As usual, Sugarcane crop had shown high GWQ and it recorded as a 393.09 to 511.26 mm in clay and clay loam soil followed by paddy, double crop maize, double crop maize-sunflower and cotton in clay loam and clay soils respectively. Of all the field crops, cotton had shown less GWQ ranged from 3.69 to 5.28 mm in clay loam and clay soils.

5.4. Comparison of Different Scenarios

The ratio of allocation of precipitation in to different components of the water balance for existing and proposed alternate scenarios were furnished in the Table 6.

Ratio	Existing scenario	Scenario -1	Scenario -2	Scenario-3
Stream flow /precipitation	0.14	0.12	0.1	0.13
Base flow	0.33	0.16	0.12	0.11
Surface runoff	0.67	0.84	0.88	0.89
Percolation /precipitation	0.8	0.61	0.62	0.61
ET/precipitation	0.70	0.76	0.74	0.72

Table 6: Comparison of different components of the water balance for different cropping scenarios

The above results have clearly demonstrated the impact of change in land use on different components of water balance. However, the type of soil has shown little impact on yield of water.

From the above results, the following inferences were drawn. In the existing scenario, there was about 24.37% catchment area under rice and 3.27% area under sugar cane. Approximately one third of the catchment area has water intensive crops with high evapotranspirational losses which lead to the depletion of surface and ground water resources. On other hand deep aquifer recharge and base flow increased. Base flow reacted slowly to rainfall and associated with water discharged from groundwater storage (Eckhardt, 2008). Water that entered the deep aquifer is not considered in the future water budget calculations and can be considered lost from the system (Neitsch et al., 2005) since it flows towards stream and crosses the basin boundary.

Therefore, for the sustainable water resources in the basin, it was proposed to substitute the paddy with yielding, high water use efficient and low water consuming dry land crops like maize, sunflower and cotton for judicial use of water for sustainable production. Clearly, a significant increase in runoff and a decrease in ground water recharge occurred when a paddy field is converted to dry land crops. Even the base flow, lateral flow and total yield were reduced increasing the availability of water within the basin. All the three scenarios have exhibited the similar trend with the variation in magnitude coinciding the reduction in paddy area.

The scenario -2 was found to be better cropping system for sustainable water resources and economical crop production. The surface runoff is less and ground water recharge is less and hence water is available within the basin and not lost from the basin. On the other hand, crops distributed in this scenario shows predisposal conditions like less capillary rise leading to less green water loss. The yield from different crops particularly with more area under commercial crops will assure increased income to the farmers which will exactly meet the objectives of the watershed management. The stream flow was however less compared to existing cropping scenario. The stream flow reaches to reservoir and evaporation losses over a period of time will decrease the availability of water.

6. Conclusion

Quantification of water balance components using spatial data base definitely provide the insight about the influence of type of soil and land use on the availability of water resources. Reducing area under paddy cultivation and allocating the reduced area to irrigated dry crops will lead to sustainability of water resources. However, positive effects of rice paddy fields on runoff should be considered in making decisions about the reduction of rice cultivation. Detailed evaluations of different cropping scenarios with their extent are necessary to finalise the optimal cropping pattern for the catchment.

7. References

1. De Girolamo, A.M. and Lo Porto, A. 2012. Land use scenario development as a tool for watershed management within the Rio mannu basin. Land Use Policy.29: 691– 701.
2. DeFries, R and Eshleman, K. N. 2004. Land-use change and hydrologic processes: a major focus for the future. Hydrol. Process. 18, 2183–2186,.
3. Eckhardt, K. 2008. A comparison of base flow indices, which were calculated with seven different base flow seperation methods. Journal of Hydrology. 352: 168-173.
4. Food and Agriculture Organization of the United Nations (FAO). 2002. Land-water linkages in rural catchments, Land and water bulletin 9, FAO, Rome.
5. Friedrich, J.K., Griensven, A., Stefan, U., Sirak, T and Teferi, E. 2012. The effects of land use change on hydrological responses in the Choke mountain range (Ethiopia)-A newapproach addressing land use dynamics inthe model SWAT. Proceedings of the sixth bi annual meeting of the International Environmental Modelling and Software Society, Leipzig, 1-5July2012. International Environmental Modelling and Software Society, Germany. 3022-3029.
6. Hadi Memarian, Mohamad Tajbakhsh and Siva K Balasundram. 2013. Application of swat for impact assessment of land use/cover change and best management practices: a review. International Journal of Advancement in Earth and Environmental Sciences. 1(1): 36-40.
7. Miller, S. N., Kepner, W. G., Mehaffey, M. H., Hernandez, M., Miller, R. C., Goodrich, D. C., Devonald, K.K., Heggem, D.T and Miller, W.P. 2002. Integrating landscape assessment and hydrologicmodeling for land cover change analysis. Journal of American Water Resources Association. 38(4): 915929.

8. Neitsch, S. L., Arnold, J. G., Kiniry, J. R and Williams, J. R. 2005. Soil and Water Assessment Tool Theoretical Documentation, Version 2005. Temple, Texas USDA-ARS Grassland, Soil and Water Research Laboratory. http://www.brc.tamus.edu/swat/doc.html. Accessed 1 November 2006.
9. Ray Shyan Wu, Wen-Ray Sue, Chuan-Bin Chien, Ching-Ho Chen, Jia-Shien Chang and Kuei-Miao Lin. 2001. A simulation model for investigating the effects of rice paddy fields on the runoff system. Mathematical and computer modelling. 33 (6-7): 649 -658.
10. Vara Prasad. 2012. Modelling of blue and green water for sustainable water resources management in watershed. P.G Thesis. Acharya N G Ranga Agricultural University, Hyderabad, India.
11. Yacob, E. 2010. Evaluating the impact of land use land cover change on soil erosion and runoff using SWAT model at TikurWuha Watershed. M.Sc. thesis in Environmental science. P.G Thesis. Addis Ababa University.
12. Yan, B., Fang, N.F., Zhang, P.C and Shi, Z.H. 2013 Impacts of land use change on watershed streamflow and sediment yield an assessment using hydrologic modelling and partial least squares regression. Journal of Hydrology. 484: 26–37