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Effect of Agroforestry Development on Runoff Generation Over a Catchment

SWAMY R.K[1], Dr. ANAND. V . SHIVAPUR[2]

[1]M.Tech Scholar
Dept. of Water and land management
Visvesvaraya Technological University Belgavi, Karnataka India.

[2]Professor, Dept. of Civil; Engineering,
Visvesvaraya Technological University Belgavi, Karnataka State, India.

ABSTRACT
Land–use modification is one of the key drivers of variation in watershed hydrology. The effect of forestry related land–use variations (e.g. agroforestry, afforestation, deforestation) on water fluctuations depends on weather, watershed characteristics. The Soil and Water Assessment Tool (SWAT) model was calibrated, validated and used to simulate the influence of agroforestry on the runoff from Talikote sub watershed on Doni catchment of Upper Bheema water basin. Model performance was assessed by Nash-Sutcliffe Efficiency (NSE) and R2 Efficiency. The NSE and R2 values for calibration and validation were R2 =0.74 and NSE =0.6 and R2 =0.82 and NSE =0.65 respectively. Using the land-use refinement tab from HRU in SWAT (ArcGIS interface), various land use scenarios were generated to investigate the change in runoff due to increase in the extent of agroforestry. In the present study an attempt is made to increase the agroforestry area by converting the certain of percentage of cultivable land. Here the percentage increase in agroforestry is done in step of 20 percent i.e. each time an increase of 20 percent is done and a change in runoff from the catchment is evaluated. It has been found that the increase in agroforest results in decrease of runoff. Therefore, this aspect of reducing the magnitude of flood can be implemented to reduce the impact of flood on the region and it can also improve ground water recharge due to percolation at the same time it decreases sediment erosion from the land surface.
KEYWORDS: Land–use; agroforestry; SWAT model; hydrology.

Introduction.

The systems integrating trees and agriculture have been practiced for thousands of years, the term ‘agroforestry’ was first coined in 1977(H.W. Beall et al.,) [1] “Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants” (Lundgren et al., 1982) [2].. Forests offer a number of ecosystem facilities, such as, improving soil water infiltration conditions, soil erosion control and provision of wood–related products like timber and fuelwood (Ong et al., 2006) [3]. The fertility potential of soils under forests and the need to increase crop production makes forests a target for conversion to agricultural land through deforestation (Laurance et al., 2014) [4]. Therefore high competition for land between forests and agricultural production in some regions of the world, particularly in the tropics (Laurance et al., 2014). In such situations, agroforestry is seen as a compromise between agricultural production and provision of forest/tree–related benefits (Garrity, 2012) [5]. In agroforestry systems, trees in different forms of arrangements are integrated into agricultural land (Nyaga et al., 2015) [6]. The World Commission on Water estimates that demand for water will increase by approximately 50% over the next 30 years, and about half of the world’s population will live in conditions of severe water stress by 2025 (C. K. Ong et al.,2006) [3]. The urgent need to increase water productivity is of growing global concern by Julich H.M. (2015) reported that the increase in the agroforest will result in decrease in runoff. Therefore, increasing the agroforestry is one of the solution to reduce flood values on the catchment. After more than a century of forest hydrology, there are still several controversial issues or ‘beliefs’, which hamper rational decision-making regarding land use. Calder summarized that, Forests increase rainfall, Forests increase runoff, Forests regulate streamflow and increase dry-season streamflow, Forests reduce erosion, Forests reduce floods, Forests improve water quality, minimizes the Drought. There are less number of forest cover in Talikote sub watershed on Doni river catchment which is a part of Upper Bheema watershed in Bijapur district Karnataka state India. In order to understand the impact of improving agroforestry on runoff from the catchment a Doni river catchment is chosen in the present study. An attempt is reported here on the percentage reduction in runoff values for the percentage increase in agroforestry in the chosen area of the catchment.

Background study

The study area chosen in this work is more susceptible to flood with a record of once every two years. Agriculture is the main and the prominent land use management practice in the region. Due to the low water quality of the river, the community is not using the water for agriculture and also for drinking purposes. During floods it can harm the crop yield due to the salt minerals present in the catchment soil. In order to reduce the runoff generation from the catchment, an attempt is made by the authors by increasing the area of agroforestry on changing the land use pattern from cultivable land into agroforestry by certain percentage.

Study area

In the present investigation, authors have taken a Talikote sub watershed on Doni watershed which is the part of the Upper Bhima catchment of Krishna basin. The Doni watershed, Talikote catchment is having an area of 219.2 sq.km situated at latitude 160 31'54.94” N and longitude 76017'45.48” E. The river Doni originates on the east side of the Sangli District in Maharashtra, India. Though it originates in Maharashtra, the majority of its streams passes through Karnataka's districts of Belagavi, Vijayapur, and Gulbarga. It joins the Krishna river to the southwest of the Talikote.

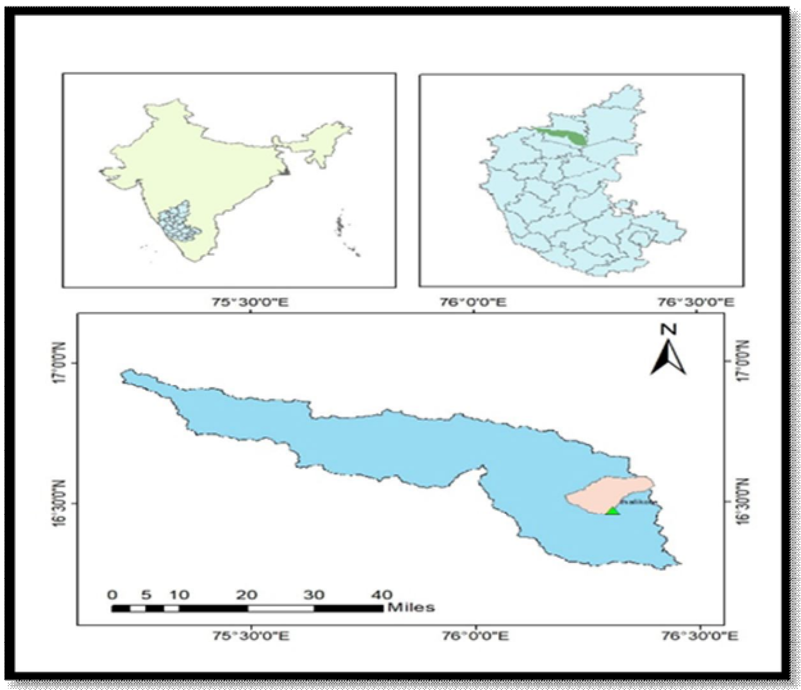

Fig. 1: Map of Talikote sub watershed on Doni river watershed.

watershed, situated in Bijapur region of Karnataka state in India which interpretates an attempt to examine the environment benefits, farmers willingness, runoff reduction, improvement fertility of soil and climate change of study area.

Data used.

The SWAT model requires data to physically depict the watershed [10], with topological DEMs was taken from Swat.tamu website, land use and soil maps are extracted from USGS website, and meteorological data all obtained (daily or monthly) from WRIS India website. The Table 1 below gives a brief description of different kinds of data and their sources. Tools like ArcGIS is used as supportive software to ArcSwat to provide input data like DEM, LULC, soil map, slope map. MS Excel is used for calculation and plotting. ArcSwat is used to implement the increase in extent of agroforestry and also to estimate changed runoff volume.

Methodology

SWAT is a physically based, semi-distributed, model, widely used for prediction of the impact of land management on water, sediment and agricultural yields. The main inputs of the model are: Digital Elevation Model (DEM), land-use, soil, and climate data. SWAT first sub-divides a watershed into sub-watersheds which are further partitioned into smaller Hydrologic Response Units (HRU) [4]. Each HRU in a sub-basin has unique land-use, soil type, and slope class combination. Simulation of agroforestry scenarios in this study was based on HRUs land units [4]. Climatic data was obtained from WRIS India website it is open source, monthly rainfall data of Talikote gauge station was used. Monthly data sets of the other climatic variables i.e. maximum and minimum temperature, were obtained from SWAT website. Talikote discharge gauging station data are obtained from WRIS India. The calibration of SWAT model in done by using the data of 1995 to 2000 and validation is carried for the period 2001 to 2004. The values of R2and NSE were determined in both the process to know the level of refinement in the values of runoff generated through SWAT. In this process model parameters are varied to achieved the desired level of acceptance.

Initially, the SWAT model is applied on the existing land use and land cover using the data of 1995 to 2005 . On calibration and validation of the SWAT model, three different land-use scenarios were simulated by increasing the agroforestry by 20 percent each time over the existing agroforestry area. Using the land-use refinement tab from HRU in SWAT (ArcGIS interface), various land use scenarios were generated to investigate the change in runoff due to increase the extent of agroforestry. Agriculture land was further split using the Land Use Refinement menu tab which subdivides land in each subbasin by the agroforestry percentages entered as by user-defined. The agricultural land was split into the agroforestry with the percentage of 20%, 40%,60% respectively and after every run, the change in runoff was estimated. The small area of the Doni catchment called Talikote sub catchment is selected to implement the idea of increasing the agroforestry is taken here. [7]

The aspect as suggested Julich H.M. (2015) [7]. is considered in the present study to reduce the flood values in the region. Which will also help to improve ground water recharge and to decrease sediment erosion from the land surface.

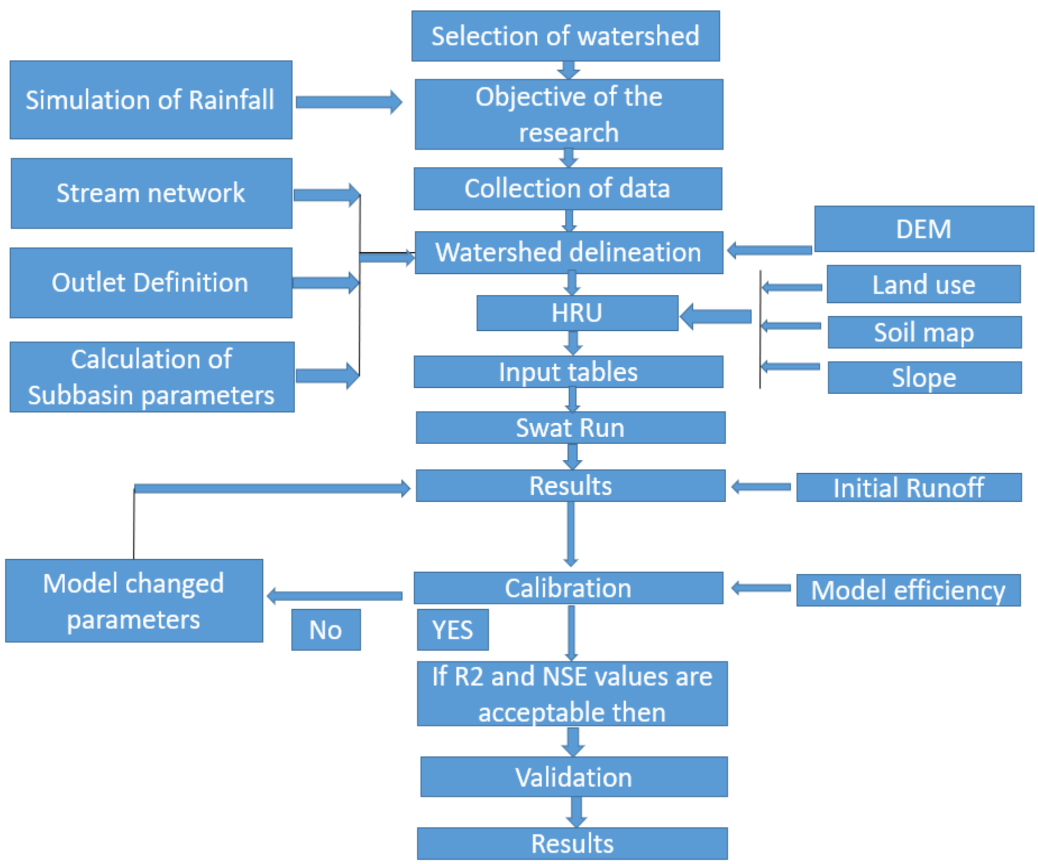

Fig. 2: Flowchart of Swat Run process

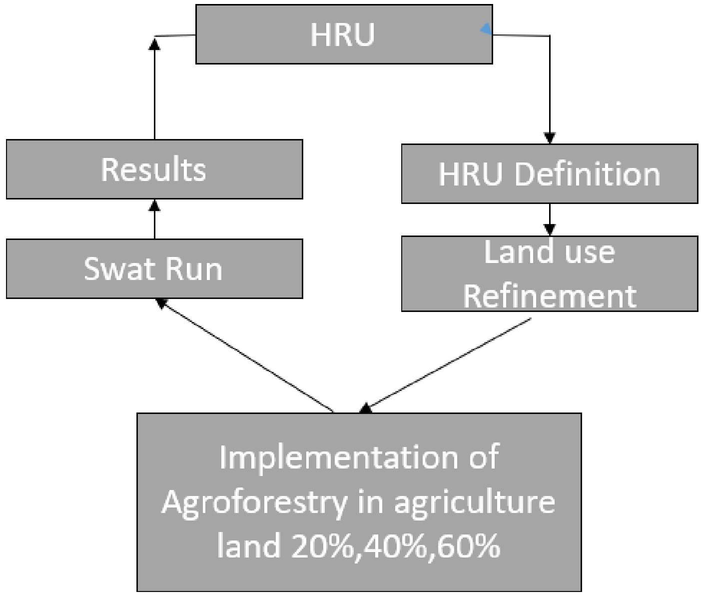

Fig. 3 :implementation of Agroforestry in Swat

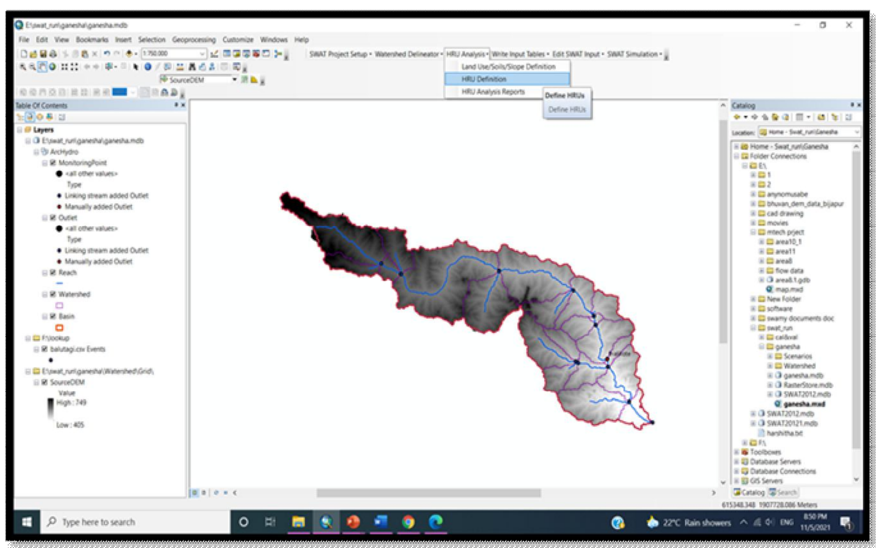

Fig. 4: Snapshot of implementation of Agroforest using HRU option

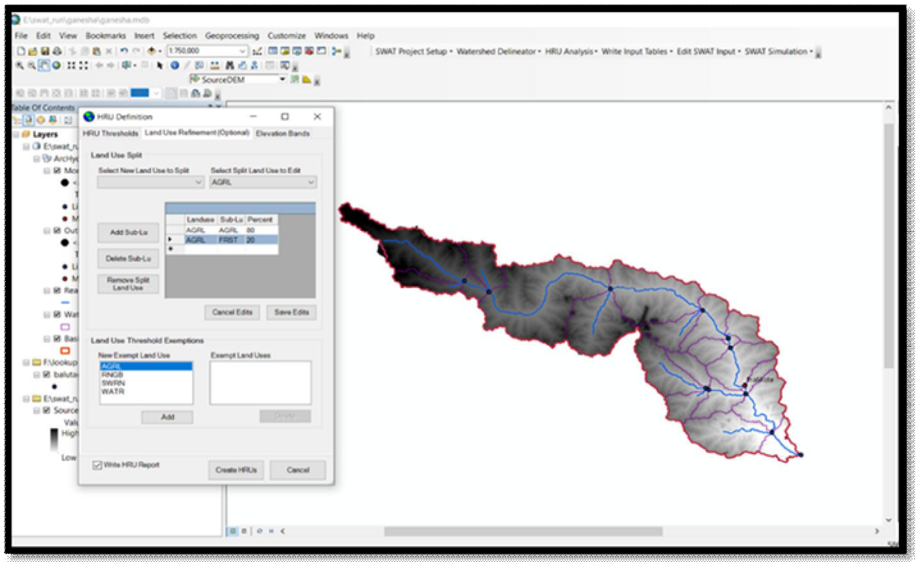

Fig. 5: Snapshot of implementation of Agroforest 20% on study Area

Results and Discussion.

The SWAT model is used to estimate the runoff using the data set of 1995-2000 for calibration and 2000-2005 for validation [8]. The sensitivity parameters found during validation are shown in Table 2. The performance efficiency of calibration and validation can be known through the estimation of R2 and NSE [9]. The results obtained for the present case are shown in Table 3.

Table 2: Sensitive parameter of the Model

Sl. No.	Parameter	calibration	Validation
1	CN_2	77	83
2	ESCO	0.85	0.95
3	EPCO	0.9	1
4	SURLAG	1	2

Table 3: Performance indicators

Sl.No	Process	R^2	NSE
1	Calibration	0.740	0.6
2	Validation	0.822	0.65

In order to know the effect of increasing the agroforestry [3] on runoff from the catchment the period from 1995 to 2005 is considered. The small area of the Doni catchment called Talikote sub catchment is selected to implement the idea of increasing the agroforestry is taken here. The SWAT model is run.by adopting the change in scenario of increasing the agroforestry by 20 percent over the existing area each time. The results due to this are compared with the SWAT results for the existing LULC is plotted on graph (Figures 2 to 4).

The results of the analysis indicate that there is a decreasing trend in flood values with the increase in agroforestry area. Therefore the effect of flood can be reduced by improving the agroforestry on the catchment which intern increase in ground water through greater infiltration and improve soil fertility due to increased tree roots holding the soil.

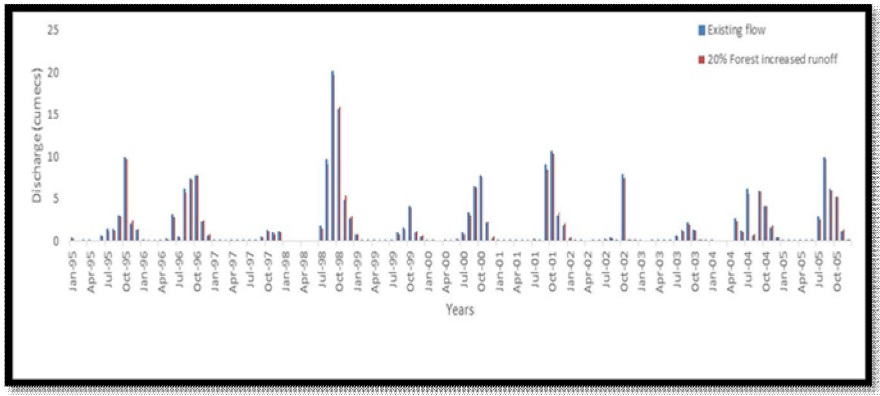

Fig. 6: Comparison between runoff from the existing LULC and for an increase of 20% area in agroforestry.

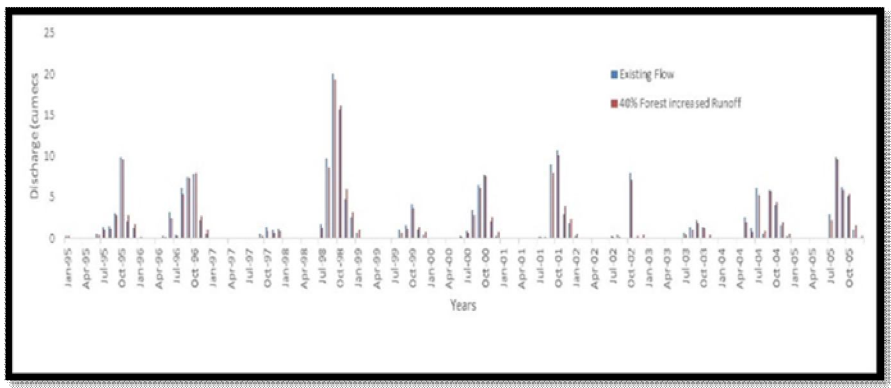

Fig. 7: Comparison between runoff from the existing LULC and for an increase of 40% area in agroforestry.

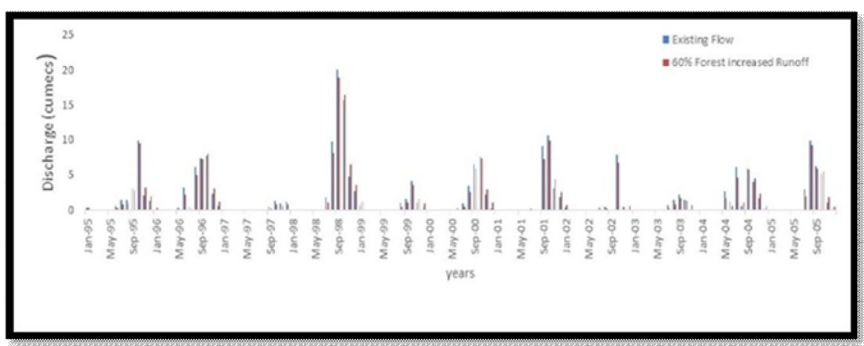

Fig. 8: Comparison between runoff from the existing LULC and for an increase of 60% area in agroforestry.

The study on the impact of increasing the agroforestry by 20 percent, 40 percent and 60 percent over the existing agroforestry area shows a decreasing value of runoff by 1.1%, 2.1%, 3.2% respectively. The average runoff values corresponding to various scenarios are shown in Figure 5.

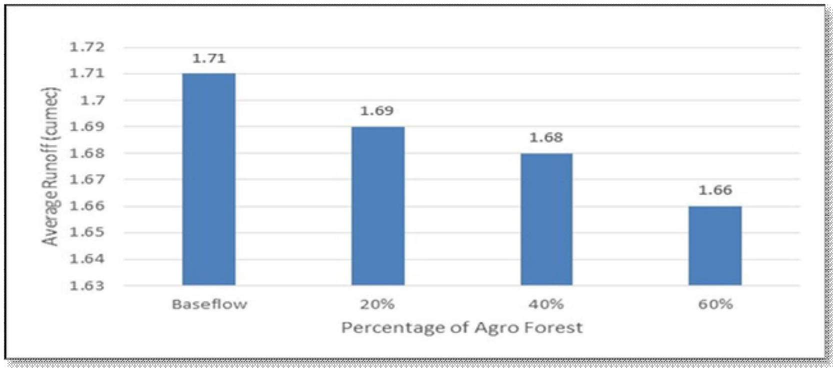

Fig. 9: Graph showing a comparison of Runoff between Baseflow and Forest implementation.

The present investigation demonstrates the impact of increasing agroforestry on runoff from the catchment by considering a conversion of the cultural land into agroforestry land over small part of the Doni catchment, Talikote catchment. Hence by adopting this approach over the entire catchment, the flood can still be reduced. In addition to other advantages can also be obtained as highlighted in the earlier paragraphs.

Conclusion.

The flood can be reduced by increasing the area of agroforestry of the catchment. The present investigation demonstrates the same. In this work it is estimated that with increase of agroforestry by 20 percent, 40 percent and 60 percent over the existing agroforestry area decreases runoff by 1.1%, 2.1%, 3.2% respectively.

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