Environment and Ecology 38 (4) : 950—957, October—December 2020
ISSN 0970-0420

Interaction of Forest and Water in Upper Tungabhadra Sub Basin, Karnataka, India

Santhosh Kumar T.M, K.L. Prakash.

Received 5 October 2020, Accepted 4 November 2020, Published on 24 December 2020

ABASTRACT

Catchmentis a complex structure of living and non-living components. Land use changes in catchment have serious consequences on change in rainfall pattern, availability of water and soil erosion. Upper Tungabhadra sub basin in Krishna basin is experiencing such changes. Rainfall and water inflow data of three decades were collected and forest cover changes were collected using Landsat Thematic mapper. By using ERDAS Imagine 9.3 changes in forest cover were assessed and computed. Rainfall data analysis was indicated that the continuous decrease in annual rainfall in both Western Ghats and Semi-arid catchments in the catchment. Chitradurga district has recorded a highest rainfall return (500-1000 mm) of 83% followed by Koppal (76%) and Bellary (76%) districts. Forest policy changes attributed to decrease in forest area in the catchment by -0.07 % as compared to forest cover of 2006 to 2016. Water inflow of Bhadra, Tunga and Varada rivers in the forest catchment has insignificant changes and a significant variability was observed in water inflow at Tungabhadra reservoir comes under non-forest catchment of 21,487 Sq.Km. Thus, climate resilience pushed the catchment towards lower rainfall rate, forest area and increased in sedimentation rates due to over grazing, deforestation and loss of vegetative cover in the non-forested catchment. An effective catchment area treatment is the most appropriate measure to control for soil erosion problems with enhanced livelihood opportunities.

Key Words: Tungabhadra River, Catchment treatment, Land use and land cover, Deforestation, Soil erosion.

Santhosh Kumar T.M*, K.L. Prakash
Department of Environmental Science, Bangalore University, Jnanabharathi Campus, Bangalore - 560056, Karnataka, India.
*Corresponding Author Email : senenvi@gmail.com

INTRODUCTION

Catchment is a complex structure of various land uses such as forest, agriculture, barren land, etc. A change in land use pattern in the catchment has resilient impact on hydrology and soil resources. As per the recent statistics, the forest cover of India has increased from 21.54 % in 2017 to 21.67 % in 2019 and whereas the forest cover of Karnataka has increased to 20.1% (2019) from 19.60% (2017) amidst several developmental activities (MoEF & CC, 2019). At the same time, land degradation, soil erosion, sedimentation of reservoirs has increasing at the alarming rate. Most of the Indian rivers originate in forest areas and forest management practices plays crucial role in water availability and sediment flow apart from climate change resilience and rainfall pattern. Due to forest areas, organic matter with fallen and dead leaves often protects the soil properties. During rainy season, water gets filtered and flows to the catchment without any sediment. Forest management practices such as thinning shall increase the water yield moderately for few years and due to the forest fire the availability decreases with lesser water quality (Koraly and Kara, 2018). Sylvicultural practices such as selective logging plantation was responsible for increasing the water yield and slowly increasing trends can be observed as the year's progress (Bren, 2015).Manipulation of vegetation structure in the forest catchments and several change in policies in India lead to serious implications on forest hydrology (Krishnaswamy *et al*., 2014).

Many watershed programs have been implemented under various programs of State and Central Governments in Karnataka by the Watershed Development Department. Studieson assessment of these programs revealed that, the implementation of the programs was not as per the guidelines prescribed for the intended purpose and lacks consultation process at the local level. The plantation activities undertaken were completely failed and the structures built under the programs were not qualitative. Therefore, the failure of watershed programs has tendency to increase the sedimentation in non-forest areas and this needs to be re-verified with respect to Tungabhadra dam (Lele *et al*., 2009). The approach towards treating the watershed for different land uses should be same as indicated in Integrated Watershed Management with synchronized tactic.

The support of construction of check dams as part of catchment area treatment revealed that, effective in tumbling the sediment trapping yield and frequency of flows over a time. Further, check dams reduces the flow velocity thereby control erosion and degradation of lands and potential to increase base flow in arid lands (Luan *et al*., 2010, Xu *et al*., 2013 and Norman *et al.*, 2015).In contradiction, several researchers observed that, check dams are least effective during heavy rains and these are helpful only to arrest sediment load upto 50% and helps in recharging the ground water. The upstream areas of dams are more vulnerable for erosion and causing infiltration into the reservoirs (Polyacov *et al*., 2014).Negative effects on water flow due to increasing percolation rate and reduction in water availability to reservoirs were also observed which in turn affects the downstream users as well (Reddy, 1993). Thus, it is necessary to have better understanding of interactions of forests and water. Forests also use more water and tree canopies reduce stream flow through interception of precipitation, evaporation and transpiration from foliage (Calder *et al.*, 2007).Whereas, watershed restoration activities and forest management practices have positive benefits to water availability. But, it should be quantified with a cost and benefits with a due consideration to downstream users (Podolak, 2015). In the present study,effects on rainfall and forestry interventions on water availability over last three decades were investigated.

MATERIAL AND METHODS

Study Area

Krishna basin in South India has eleven sub basins. Upper Tungabhadra sub basin in Karnataka is one among them and spread across 29,116 sq.km. The sub basin has major tributaries such as Tunga, Bhadra, Varada, Kumadvati, Karla Halla, Dodda Halla, Vadaghatte Halla and Hire Halla. All these rivulets in the name of Tungabhadra finally joins river Krishna at Sangameshwaram village in Kurnool District of Andhra Pradesh.Upper Tungabhadra sub-basin is spread acrossnine districts in middle Karnataka namely Shivamogga, Uttara Kannada, Chikamaglur (Western Ghats Districts) Haveri,Chitradurga, Davanagere, Gadag, Koppal and Bellary (semi-arid Districts).The basin receives an average annual rainfall of about 2,300 mm in Western Ghats with an annual average temperature of 24 °C. Agricultural landscape covering 64 % of the basin followed by forest landscape covering 26 % and built up areas covering 2% in the basin. Tungabhadra sub basin is suffering with tail end problems in the downstream due to improper water management, soil erosion and sedimentation. On the other hand, deteriorated water quality, deforestation, excess use of fertilizers, lack of integration for use of irrigation, etc aggravated the problems. Study area map is shown in Fig (1).

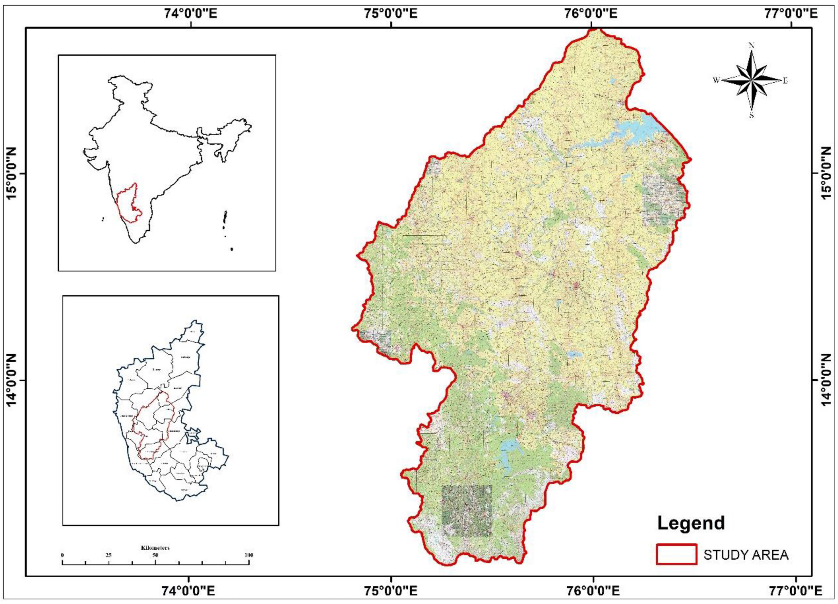

Fig 1. Study Area Map.

Methodology

Rainfall data of last three decades (1989-2018) were collected from rain gaugestations of Indian Meteorological Department and Karnataka State Disaster Monitoring Centre. Missing data were accessed from WRIS and Indian Water Portal and computed using Arc GIS platform for understanding spatiotemporal variability of rainfall in the catchment. Statistical analyses were done for Standard Deviation, Coefficient of Variation andreturn period. Satellite data were procured from Landsat Thematic mapper to analyze changes in forest areas over a period of time and pre-processed using ERDAS Imagine 9.3 and Arc GIS tools. Toposheets of the study area were mosaicked and sub-setting of images was carried out before geo-rectification. By using visual and digital interpretation of supervised and unsupervised classification, homogeneous and detached sections of the images were done. Finally, ground truthing of images was carried out to ensure the correctness data by taking geographical coordinates at specific locations such as major junctions, forest boundaries, railway junctions, etc. Data on forest management practices in the study area were collected from forest working plans and other published literature. Similarly, inflow data of Bhadra River at Bhadra Dam, Tunga River at Shimoga gauging Station and Varada River at Marol gauging station and Tungabhadra River at TB Dam gauging station were collected from Water Resource Department and WRIS website for three decades. Finally, rainfall variations, changes in forest area over a period of time and water availability were correlated to understand the impacts of each other.

RESULTS AND DISCUSSION

Rainfall variations

Variation in the rainfall pattern over a period of three decades was analyzed. Mean annual average rainfall of 2391 mm (Table 1) were observed in Western Ghats districts. Uttara Kannada (SD 406) and Shimoga (SD 298) districts showed decline in rainfall during 1999-2008. However, Chikkamagaluru district shows continuous decline in rainfall in all the three decades with SD 281. The variation of decreasing trend in rainfall is mainly attributed due to orographic influence of winds on leeward side of the Western Ghats (Venkatesh and Jose, 2007). Studies of Ramachandra

Table 1. Annual Average Rainfall (mm) variations.

Sl.No	District	1988-1998	1999-2008	2009-2018	Mean	SD	CV
Forest Catchment							
1	Uttara Kannada	2019	2579	2807	2469	406	0.16
2	Shimoga	2270	1905	2495	2223	298	0.13
3	Chikkamagaluru	2429	2101	1870	2133	281	0.13
Semi-arid Catchment							
4	Davanagere	1373	898	713	995	341	0.34
5	Chitradurga	872	693	603	723	137	0.19
6	Haveri	1891	1153	772	1272	569	0.45
7	Gadag	1206	813	541	854	334	0.39
8	Bellary	758	603	547	636	109	0.17
9	Koppal	774	619	554	649	113	0.17

et.al.,2014 also confirmed that there was a decrease in rainfall trend in central western Ghats when compared to northern and central Western Ghats.

In semi-arid districts, there is a continuous decline in rainfall were observed in all the districts for all the decades (CV 0.17-0.45). This trend is alarming and having direct influence on the availability of water in the catchment. Spatially, rainfall between the ranges of 1700-2400 mm was appreciable in decade-1 (Fig 2) and subsequently in decade -2, the extent of previous ranges has reduced and occupied with 1500-1700 mm in the basin. The exponential increase in area of <1000 mm was observed in decade -2. Similarly, the larger area in the basin has occupied by lower rainfall (<1000 mm) leaving uncertainties in all other ranges of rainfall in the basin.

Rainfall return period refers to the return of events over a period of time. Higher the rainfall return period indicate the higher accrued rainfall and vice-versa (Rich Ybanez, 2013). In Western Ghats districts, highest rainfall (>2500 mm) return period is about 30% followed by the rainfall ranging between 2000-2500 mm is 40% and 26% of rainfall corresponding to 1500-2000 mm(Fig3). Whereas in case of semi-arid districts, rainfall in the order of 1500-2000 mm was returned only in two districts in the basin viz., Haveri (20%) and Davanagere (6%). Maximum rainfall returns occurred in the range between 500-1000 mm and 1000-1500 mm respectively in the basin (Fig 4). Chitradurga district has

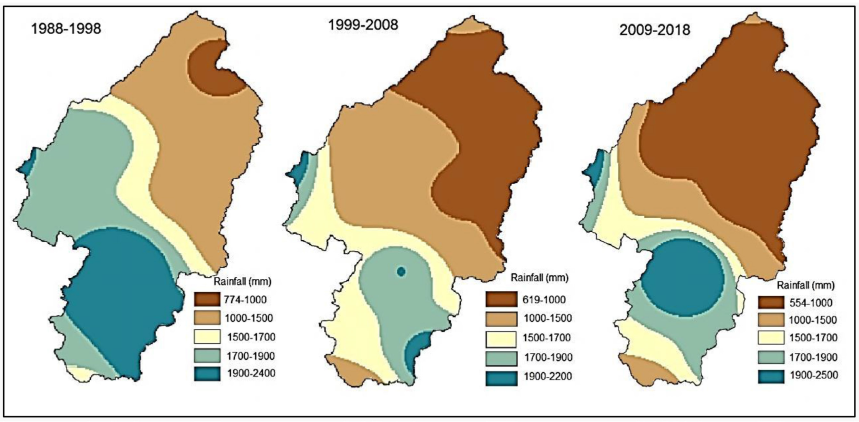

Fig 2. Rainfall Distribution in the study area

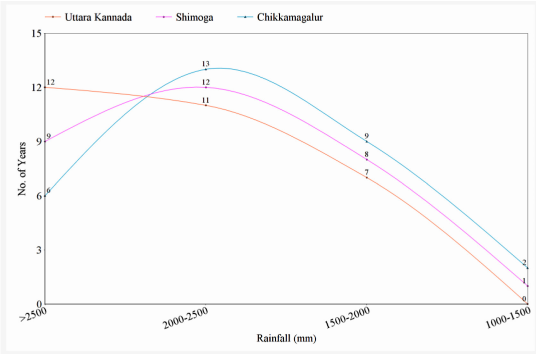

Fig 3. Rainfall Return period in Forest Catchment.

recorded a highest rainfall return (500-1000 mm) of 83% followed by Koppal (76%) and Bellary (76%) districts. These variations in semi-arid districts are very common due to climate change resilience and lack of vegetative cover.

Forest management interventions

Prior to 1980, forests were mostly treated as 'production' units for various anthropogenic needs such as fire wood, ply wood industries, matchwood industries, paper and pulp industries, railway sleepers, timber, etc. The era of 1980 in the Indian forest history was a golden period where the 'conservation' replaced the production. There are two prominent programs were

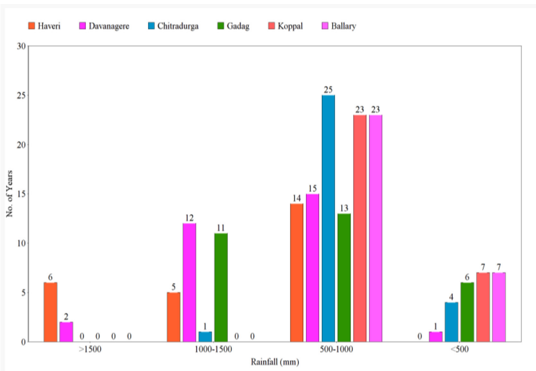

Fig 4. Rainfall Return period in Semi-arid Catchment.

launched and one among them was enactment of Forest (Conservation) Act, 1980 to prevent deforestation. Restrictions have been imposed on use of forest land for non-forestry activities with prior approval from Central Government. Another was introduction of social forestry program where large scale massive afforestation works has been undertaken in the country. During 1980-1985, 4.66 million ha and 8.85 million ha (1985-90) of forest and waste lands were afforested as against 3.556 million ha during 1951-1980 in the country. Even then, tree felling in natural forests was in practice for various purposes which were causing much more damage to forests in the study area. Karnataka Forest Policy, 2013 emphasized that there will be no tree felling in natural forests and collection of dead and fallen trees are allowed only in deciduous forests (Deepak Sarmah,2018).In the study area, plantations were often leased to Paper and pulp industries. There is a decreasing of trend in plantations were observed in the study area constituting 1778.87 Sq. Km in 1996 which was slightly increased to 1933.85 and drastically reduced to 587 Sq. Km (Fig 4).

Another important step undertaken by Karnataka Forest Department was to expand the protected area network declared under Wildlife (Protection) Act, 1972 where not even a single 'stick' is allowed to take outside. Presently, 25% of the total forests of Karnataka are under protected area network. In the study area, 11 protected areas were declared viz., Kudremukh National Park, Bhadra Tiger Reserve, Shettihalli Wildlife Sanctuary, Rangayyanadurga Antelope Sanctuary, Bankapura Peacock Conservation Reserve, Kappathagudda Conservation Reserve, Ranebennur Black buck Sanctuary, Gudavi Bird Sanctuary, Basur Amruth Mahal Kaval Black buck Conservation Reserve, MagadiKere Conservation Reserve and Ankasamudra Lake Bird Conservation Reserve constituting 24 % (1873.52Sq.km) of the total forest area in the sub basin.

Change in forest cover

The evergreen forests are present in the core area of the Western Ghats which is undisturbed and have high protection; human entry and other developments are strictly prohibited. Hence, the forest area remains almost same from 1996-2006 (Table-2). However,

Table 2. Forest covers (Sq. Km) status in the study area.

Sl.No	Year	1996	2006	% Change	2016	% Change
1	Deciduous Forest	2521.96	2447.43	-0.03	2552.30	0.04
2	Evergreen Forest	858.40	859.63	0.00	920.02	0.07
3	Grassland	231.08	229.70	-0.01	265.09	0.15
4	Mixed Forest	1227.86	1198.63	-0.02	2428.07	1.03
5	Plantations	1778.87	1933.85	0.09	587.17	-0.70
6	Scrubland	1569.39	1550.74	-0.01	876.03	-0.44
	Total	8187.55	8219.97	0.003	7628.68	-0.07

due to declaration of protected areas, policy interventions on prohibition of developmental activities and prohibition of removal of trees in the evergreen forest has led to the increase in area by 0.07% from 2006-2016 (Fig4). Scrub lands (forest) cover was decreased by 0.01% from 1996-2006 and 0.44% from 2006-2016. Scrub forests are present outside the Western Ghats which are surrounded by human settlements and also human interventions are very common in these areas in order to fulfill their basic livelihood needs and feed their domestic animals. Hence, the demand on the Scrub land is more. As per the Forest Department records, the scrub land trees are being used by local people for fuel wood, fodder for cattle and thorny species are being used for fencing. The Mixed forest was decreased with 0.02% from 1996-2006 and increased with 1.03% from 2006-2016. The Deciduous forest cover was decreased by 0.03 % from 1996-2006 and gradually increased by 0.04% from 2006-2016. The deciduous forest types encroached by local people for fast growing species, coffee and other plantations. Government policies on rehabilitation and resettlement of people from Tiger core protected areas also contribute for increase of evergreen forest cover in the study area. Overall, the forest area status reduced from 8187.55 Sq. Km (1996) to 7628.68 Sq. Km (2016).

Water availability

The water inflow studies of Tunga, Bhadra, Varada and Tungabhadra Rivers shows that the deviation trend of water inflow for Bhadra, Tunga and Varada rivers are not significantly varied. This is mainly due to the origination of the tributaries of Tungabhadra such as Tunga, Bhadra, Varada, Kumadvati, Karla Halla, Dodda Halla, Vadaghatte Halla and Hire Halla in Western Ghats (Fig 5-6). Bhadra River has forest catchment of 1968 Sq. Km up to Bhadra reservoir having annual average water inflow of 104842 Mcft for the period between 1988-2018. Similarly, Tunga river has 2831 Sq. Km forest catchment with an annual average inflow of 170578 Mcft at Tunga reservoir site and whereas Varada river has 4902 Sq. Km forest catchment with an annual average inflow of 67305 Mcft at Marol gauging station. Tungabhadra reservoir has non-forest catchment of 21487 Sq. Km and annual average inflow at Tungabhadra reservoir site is 279417 Mcft. Hence, larger parts of non-forest area contribute more towards soil erosion and sedimentation of the reservoir.

CONCLUSION

Climate resilience has pushed the annual rainfall to a lesser extent of days. But, nevertheless, there are no significant changes in the mean annual rainfall pattern. The entire yearfull rainfall occurs in a span of two to three months causing heavy devastation and damage led to severely on soil strata and enhanced rate of sedimentation. Conversion of forest land into crop plantations or ranches was noticed in the Tungabhadra sub-basin which disturbs the patterns of the water cycle (Ramachandra, 2014). A significant rainfall return was noticed in semi-arid districts such as Chitradurga, Koppal and Bellary due to climate change resilience and lack of vegetative cover. Deforestation and overgrazing activities observed in the study areawhich is asignificant factor indirectly effectson water inflow of the rivers (Saroha, 2017). A significant increase in inflow of water in Tungabhadra River was observed which comes under non-forest area (Fig 5-6). Land use changes especially forest cover leads to low flows in the rivers (Peel *et al.*, 2001 and Brownaetal., 2005).

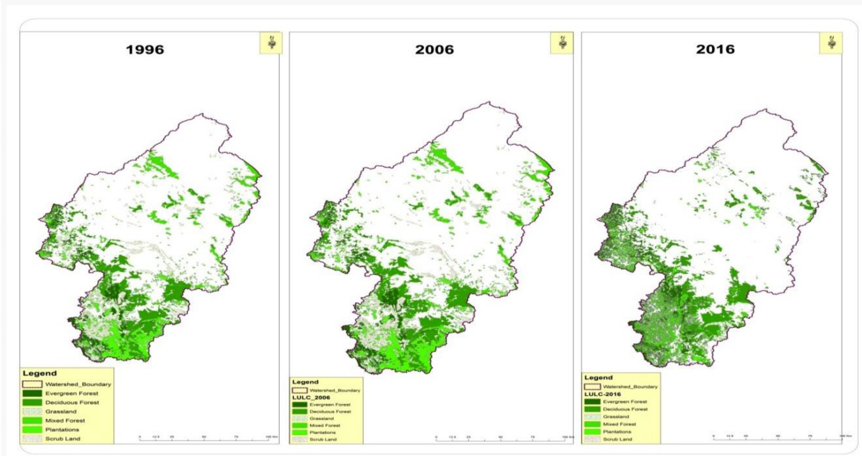

Fig 5. Water inflow (Mcft) in the study area.

Overgrazing is also an important factor leading to soil erosion in the study area. This attributes for increase in sedimentation rate in the Tungabhadra dam and reduces the dam water storage. This has led to socio-ecological and geopolitical changes in the catchment area (Coe *et al.*, 2009). Loss of vegetative cover for livelihood opportunities increases the risk of soil erosion due to accelerated run off (Bhattacharyya et al., 2015).Around 60 % of the Tungabhadra river basin constitutes for water accountability in the catchment area. The trees were removed to produce good yield agricultural lands and however the rain water leads to low infiltration capacity of soil, loosening of top soil, flood and soil erosion. An Effective catchment area treatment is suggested to reduce the soil erosion and also increases the water infiltration capacity in the region.

ACKNOWLEDGMENT

The authors are thankful to Department of Environmental Science, Bangalore University, and Bangalore for the support.

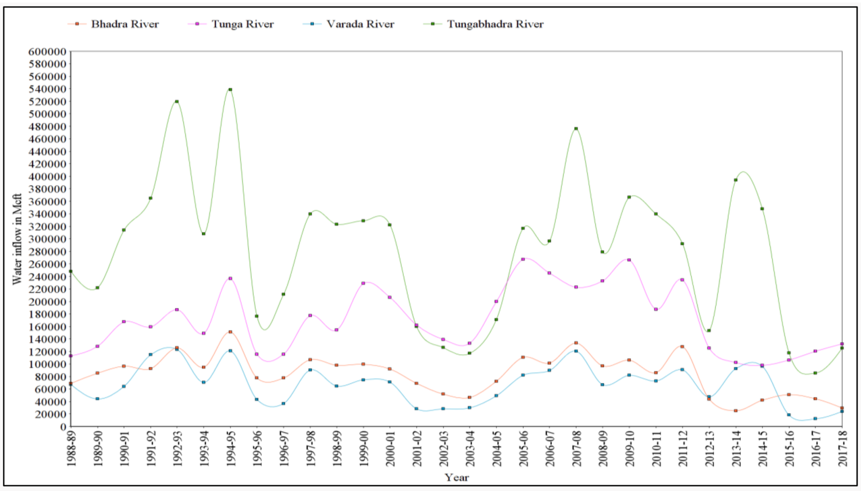

Fig 6. Water inflow (Mcft) in the study area

REFERENCES

Alice E. Browna, Lu Zhangb, Thomas A, McMahonc Andrew, W. Westernc, Robert A. Vertessyb 2005. A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *Journal of Hydrology,* 310 : 28—61.

Calder I, T Hofer, S Vermont, P Warren (2007) Towards a new understanding of forests and water, FAO.

Deepak Sarmah (2018) Forestry in Karnataka – A Journey of 150 years.Unity Printers, Bangalore. 1—309.

FSI. 2019. India State of Forest Report - 2019. Forest Survey of India, Uttarkhand, India.16 (1): 1—222.

Jitender Saroha (2017) Soil Erosion: Causes, Extent and Man agement in India. *International Journal of Creative Research Thoughts,* 5 (4) :1321—1330.

Krishnaswamy J, R John, S Joseph (2014) Consistent response of vegetation dynamics to recent climate change in tropical mountain regions. *Global Change Biology*, 20 : 203—215.

Leon Bren (2015) Forest hydrology and Catchment Management: An Australian Perspective. Springer, New York, London.DOI 10.1007/978-94-017-9337-7.1-276.

Michael T, Coe Marcos, H Costa, Britaldo S, Soares-Filho (2009) The influence of historical and potential future deforestation on the stream flow of the Amazon River – Land surface processes and atmospheric feedbacks. *Journal of Hydrology,* 369 : 165–174.

Necla Koralay, Omer Kara (2018) Forestry Activities and Surface Water Quality in a Watershed. *European Journal of Forest Engineering,* 4 (2) : 70—82.

Norman L. MF Brinkerhoff, E Gwilliam, DP Guertin, J Callegary, DC Goodrich, P.L Nagler, F Gray (2015) Hydrologic response of streams restored with check dams in the Chir icahua Mountains, Arizona, *River Research and Applications,* 32 : 519–527.

Peel MC, McMahon TA, Finlayson BL, Watson FG (2001) Identi fication and explanation of continental differences in the vari ability of annual runoff.*Journal of Hydrology,* 250 (1-4) : 224—240.

Podolak K, D Edelson, S Kruse, B Aylward, M Zimring, N Wob brock (2015) Estimating the Water Supply Benefits from Forest Restoration in the Northern Sierra Nevada. An unpub lished report of the Nature Conservancy prepared with Eco system Economics. San Francisco, CA.

Polyakov VO, MH Nichols, MP McClaran, MA.Nearing (2014) Effect of check dams on runoff, sediment yield, and retention on small semiarid watersheds, *Journal of Soil and Water Conservation,* 69 (5) : 414—421.

Ramachandra TV (2014) Hydrological Responses at Regional Scale to Landscape Dynamics.*Journal of Biodiversity,* 5 (1,2): 11—32.

Ranjan Bhattacharyya, Birendra Nath Ghosh, Prasanta Kumar Mishra, Biswapati Mandal, Cherukumalli Srinivasa Rao, Dibyendu Sarkar, Krishnendu Das, Kokkuvayil Sankarana rayanan, Anil. Manickam Lalitha, Kuntal MouliHati, Alan Joseph Franzluebbers (2015) Soil Degradation in India: Challenges and Potential Solutions. *Sustainability,* 7: 3528—3570.

Rich Ybanez, Understanding Rainfall Return Period. Project NOAH Open File Reports. 2013. 1. ISSN 2362 7409.3-4.

Sharachchandra Lele, G Madhavi Latha, Shrinivas Badiger, Anand Vadivelu (2009) Watershed Development in Karnataka : A large scale assessment of processes, sustainability and impacts. Centre for Interdisciplinary Studies in Environment and Development (CISED), Bangalore, Karnataka. 1—44.

Venkata Reddy M (1993) Catchment Area Treatment in Major Irrigation Projects: Problems and Issues, Institute for Social and Economic Change, Bangalore - 560072, India.

Venkatesh B, Mathew Jose.(2007) Identification of homogeneous rainfall regimes in parts of Western Ghats region of Karnata-ka. *Journal of Earth System Science*, 116 (4): 321-329.

Xu YD, BJ Fu, CS He (2013) Assessing the hydrological effect of the check dams in the Loess Plateau, China by model simu-lations. *Hydrol. Earth Syst. Sci,* 17: 2185–2193.

Zhang Luan, Shi Changxing, Zhang Hao (2010) Effects of check-dams on sediment storage-release in Chabagou Watershed. *Transactions of the CSAE,* 26 (2) : 64—69.