Influence of Change in Tree Density Under Selected Land use Land Cover System on Runoff Generation in Parts of Western Ghats, Karnataka

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Abstract **- Sustainable management of land and water resources of catchment requires the information on water availability which is in turn depends upon the loss of water mainly through runoff. However, relationship between tree density under different land use system on runoff was poorly understood in Areangadi regions of Honnavar block Karnataka. Vegetation survey results shown that total stand density per ha was maximum of 5047.12 and 4962.75 per ha under natural forest. However, this was reduced 50.55 and 50.55 percent at Acacia plantation and 88.05 and 88.84 per cent in degraded forest during 2009-10 and 2010-11 respectively. The runoff under degraded watershed has given maximum as expected in comparison with Acacia and natural forest. During 2009-10, the percent of runoff was 46.23, 52.80 and 60.33 under natural forest, acacia and degraded watershed respectively. However, this was an increase of 5.58%, 8.71% and 11.52% under natural forest (NF), Acacia (AaP) and degraded (DF) watersheds during 2010-11. The specific discharge and specific peak discharge were observed maximum in the forested watershed followed by degraded and minimum in Acacia. However, peak specific discharge values are almost equal with respect to temporal variation in the entire watershed. Relationship between stand density, total runoff, specific discharge and peak specific was found increasing trend with the decrease of tree density in both degraded (DF) and Acacia (AaP) watersheds. However, in natural forest, except runoff, higher specific and specific peak discharge values are higher with the increase of tree density.**

Keyword: Land use systems, rainfall runoff, stand density

INTRODUCTION

Sustainable management of land and water resources of a catchment requires the information on water availability which is in turn depends upon the loss of water mainly through runoff. The runoff response of watersheds is essentially influenced by the geomorphology and type of land use system especially density of vegetation cover. There have been no clear evidences that the reduction of forest cover increases water yield and increases the higher flow volumes (Bruijnzeel's et al., 2006). However, the paired catchment experiments elsewhere (Bosch and Hewlett, 1982; Hamilton, 1988; and Bonell, 1993) suggested that the increase or decrease in the stream flow is much depended on the local conditions and more of the location specific. Bruijnzeel's state-of-knowledge review (1990) was focused mainly on the tropics and reported that there is an increase in the higher flow volume due to degradation of forest cover either through the selective harvesting or complete harvesting. Further, few studies indicated a significant role of tree physiognomy such as tree density, leaf litter, canopy cover and presence of grass partition into the various components of the hydrological cycle (Negi et al. 1998, Madrid et al. 2006, Pathak et al. 1989 and Martin Armbrusteretal et al. 2004). However, such types of studies are limited in India and especially in the Western Ghats region of India. The Western Ghats form head water catchment of many peninsular rivers and millions of people are depending on the eco-hydrological services provided by Western Ghats. From, recent study reports an increase in the frequency of quick and higher flow as the percentage of degradation of forest increases (Pradeepkumar and James, 2006; Krishnaswamy et al., 2012). However, relationship between treedensity under different land use system on runoff was poorly understood and needs a thorough comprehensive analysis to evaluate the impact of tree density on the hydrologic regime of a watershed. In order to understand the relationship, three experimental watersheds covering the dominant land cover of the region, such as natural forest, degraded forest and acacia, close to Areangadi village near Honnavar town, Karnataka, India are selected. The field experiments was taken up to address the following issues, (i) rainfall-runoff response of these small watershed especially with reference to variation in the tree density and (ii) effect of tree density on peak flow and quick flow under selected land covers.

STUDY AREA

The Western Ghats, locally called as 'Sahayadri Mountains", is a range of mountains in the peninsular India running approximately parallel to its West Coast and home to the largest tracts of moist tropical forests in the country. The coastal district of Uttara Kannada, Karnataka State straddles the Ghats, which are at their lowest here (<600m) and are about 20-25 km inland. East of the crest line of the Ghats are rolling hills with forested slopes and shallow valleys with cultivation.

Climate, Geology and Hydrology

The region has a tropical climate with mean monthly temperatures ranging from 27° to 29° C. The average annual rainfall is 3900 mm with significant intra-annual variability. About 70-80% of the rainfall is received between June to September due to the south-west monsoon phenomenon, while the remaining rainfall is spread over remaining eight months. The number of rainy days during monsoon season (June to September) is about 100-110. The geology of the area mainly consists of Archaen-Proterozoic-Dharwar schist and granitic gneisses, meta-volcanic and recent sediments (Bourgeon, 1989). Many of the upper geological sequences of the region are lateraliged due to their exposure to suitable climatic conditions over a prolonged period. Their thickness ranges from a few cm to as much as 60 m in depth (Geological Survey of India, 2006). The soils in both the coastal and mainland basins are deeply weathered similar to the description of Putty and Prasad (2000). In the absence of any deep drilling in the basins, however no detailed soil descriptions down to bed rock exist. Exposures in hill sand stream banks do suggest that soils extend well beyond 2 min depth. Further no detailed mapping of soil pipe occurrence (Putty and Prasad, 2000a,b) was undertaken, although we have observed soil pipes in the forested catchments in the region and there was evidence of vertical macro-pore flow in soil exposures (Krishnaswamy et al., 2012).

MATERIALS AND METHODS

Experimental Sites

The micro watersheds selected for rainfall-runoff studies with respect to change in vegetation density under different land use system are located on the leeward side of the mountains (Fig. 1) in Honavar block of Uttarakannada district, Karnataka. Three watersheds, one each under homogenous land covers of acacia plantation (7 ha), degraded forest (7 ha) and natural forest (23 ha) were selected. The Latitude and longitude 3 watersheds are as follows and the morph metric characteristics of these watersheds are given in Table1.

Gauging station	Lad Use type	Latitude	Longitude
TottalGundi	Natural Forest	14^0 20' 21.59"	74^0 30' 19.86"
Areangadi	Acacia Plantation	14^0 19' 50.09"	74^0 29' 53.61"
Nilkod	Degraded Forest	14^0 20' 04.93"	74^0 28' 28.98"

Rainfall record: an automatic rain gauge (tipping bucket) station established close to the *Acacia auriculiformis* watershed (AaP) in the area is assumed to representative for all the three watersheds. The measurements were collected from 2009 to 2011.

Flow Measurement: The discharge in these watersheds was measured using the current meter. Additionally, a stage level and automatic water level recorder is installed to measure the water levels at sub-hourly time step. The current meter readings were used to develop a relationship between the water level and discharge (stage-discharge curve). This relationship is used to convert the observed waters levels to discharge and is used in the study. Peak flow was obtained from the highest discharge of the hydrograph obtained from stage level recorder.

Vegetation Sampling: A Stratified random sampling method was adopted for vegetation analysis study and 0.1% percent area was selected for vegetation survey and laid with the size of 20 X 20 m transact for enumerating tree density (considered only sapling/ poles, trees and stumps with more than 15 cm girth). Further, a nested plot size of 5X 5m was used for regeneration study. With the help of Excel (MS office software), the average stand density was calculated and stand analysis was carried out to know the effect of stand density on total discharge, specific discharge and specific peak discharge in each land use system.

$$Dv = \frac{\Sigma s}{\Sigma nq} \quad \text{---1}$$

Dv: Vegetation density,
s: Total Number of Individuals of a species in all quadrates
nq: Total number of quadrate studied

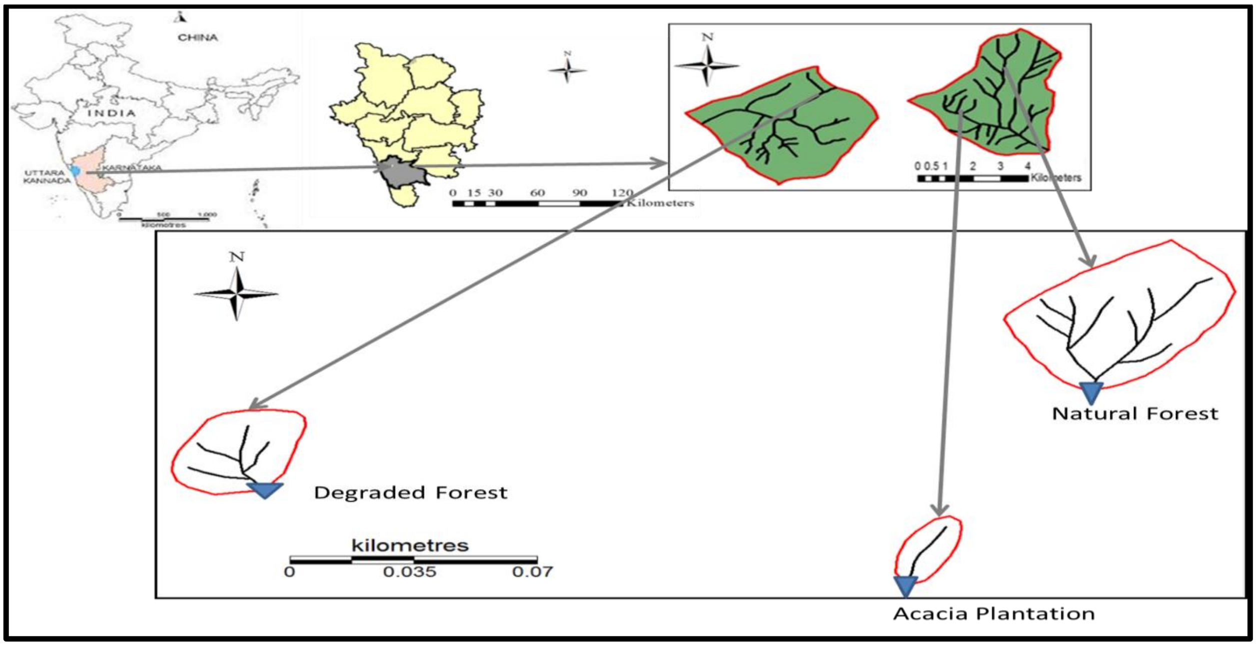

Fig 1. micro watershed of different land use systems in Honavar block, Karnataka

TABLE 1. Marphomatrics characteristic of experimental micro watersheds in Honavar block, Coastal Karnataka

Characteristic	Natural forest (NF)	*Acacia auriculiformis* Plantation (AaP)	Degraded forest (DF)
Arial Aspects			
a) Catchment area (km^2)	0.23	0.07	0.07
b) Watershed shape factor (Rs)	54.24	70.028	29.14
c) Average elevation (mt)	255.3	112.25	52.71
d) Average slope (%)	17.16	15.23	10.38
e) Drainage Density (D) in km/km^2	13.56	7.08	21.04
f) Stream frequency (F) No/km^2	39.13	14.28	57.1
Linear Aspects			
a) Catchment perimeter (C) in meter	2504.22	773.90	834.5 mt
b) No of streams in various order			
i) First order (N1)	6	1	3
ii) Second order (N2)	2	0	1
iii) Third order (N3)	1	0	0
iv) Forth order (N4)	0	0	0
Total number of all order streams (N)	9	1	4
c) Length of streams of various order			
v) First order (L1)	1.747	0.4956	0.860
vi) Second order (L2)	1.313	0	0.613
vii) Third order (L3)	0.060	0	0
viii) Forth order (L4)	0	0	0
d) Total length of all order streams (L) km	3.119	0.4956	1.473
e) Length of Mainstream in meter (Lm) mt	735.6	495.6	613.3
Other			
Soil type	Red laterite, Clayey, kaolinitic, Ultisol (UsticKandihumults)	Red laterite, Clayey-skeletal, kaolinitic, Ultisol (Petroferric Haplustults)	Red laterite, Clayey, kaolinitic, Ultisol (UsticKandihumults)
vegetation cover and land management practices	• Natural semi evergreen forest with high density and thick canopy cover. • Collection of NTFP and chopping of leaf.Conserved under reserve forest by forest department and spiritual by local community	• Monoculture plantation with regular spacing of 2 X 2 mt spacing and sparsely distribution of native tree species. Canopy cover is medium. • Harvesting of poles/ timber leaf letter collection, Burning of leaf litter • Soil and water conservation structure like D-barrow	• Bushy vegetation with open canopy, fairly distribution of cashew nut trees. • Intensive Grazing Harvesting of poles/ timber, firewood collection, leaf letter collection, burning of grass. • Trenches for soil and water conservation along the catchment border

RESULTS AND DISCUSSION

Vegetation Analysis:

Vegetation survey results shown that, total stand density was found maximum of 5047.12 and 4962.75 plants/ha under natural forest. However, this was reduced by 50.11 and 50.55 percent in Acacia plantation and in degraded forest by 88.05 and 88.84 percent during 2009-10 and 2010-11 respectively. While, tree density in natural forest are shown maximum followed by acacia and minimum was found in degraded forest. The increased stand density in natural forest and acacia was mainly due to presence of seedling / ground cover and in acacia plantation, planting of seedlings at regular spacing and utilisation of maximum area. With respect to stump, Acacia watershed stands highest number followed by degraded and minimum was in Natural forest. As compared to previous year, during 2010-11, the percent increase in number stumps was 19.4, 17.3 and 10.1 in acacia, degraded and natural forest watersheds respectively. The increasing trend of stump density in acacia showed dependency of local community shifted from Natural forest to Acacia for woody biomass.

TABLE 2. Vegetation study under different land use system in Areangadi regions of Honnavar block, Karnataka

Average stand density No/ha	AaP		DF		NF	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Tree	534.5	498.32	380.45	360.3	851.67	845.5
Stumps	250	310.34	122.5	148.15	60.45	67.25
Seedlings	1733.3	1645.22	100	45.5	4135	4050
Total Stand density	2517.8	2453.88	602.95	553.95	5047.12	4962.75

Runoff Analysis:

i. Monthly variation in runoff under different land cover,

Monthly rainfall-runoff under different land use systems was depicted in figure 2. Graph indicates that the degraded watershed (DF) has given maximum runoff as expected in comparison to that of the other two land-use watersheds. The watershed covered with *Acacia auriculiformis* plantation (AaP) is smaller than in degraded watershed and the least discharge was observed in the Natural forested watershed (NF). However, flows continue till December to May during both the hydrological year 2009-10 and 2010-11 in forested watersheds. The reduction in runoff and extended flows during water stress period (December - May) in the forested watersheds are mostly due to the fact that presence of high stand density and organic matter reduce surface flow and supports forest soils to hold greater capacity of water and release slowly during post monsoon in comparison to the soil in degraded watersheds. However, small quantity of runoff was also observed during May month in both Acacia and degraded watershed. This may be due to sudden small rise in the summer rainfall amount and decreasing trend of vegetation density (Table 2) lead to enhanced surface runoff. Similar observations were also made under different land use system in costal and mid Ghats regions of Uttarakannada district by Jagadish et al. (2012) and Venkatesh et al. (2011).

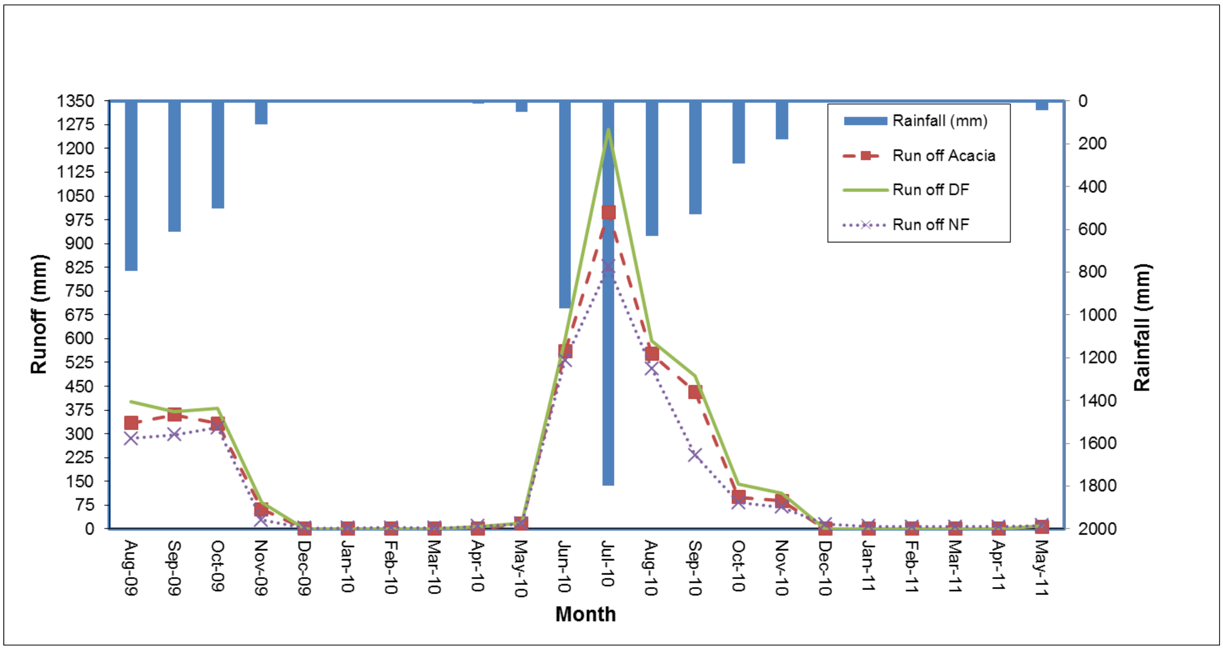

Fig 2. Monthly distribution of Rain-runoff under different land use systems (2009-11), Areangadi region of Honnavar Block, Karnataka

ii. Variation of run-off across the different land covers

The salient features of the observed rainfall runoff characteristic from different land-use watersheds are shown in Table 3. Also it can be seen from the results presented in the Table 3 that the percent of runoff is lowest in forested watershed followed by acacia watershed and in degraded forest watershed yielded the highest percentage of runoff. For 2009-10 hydrological year, 46.23, 52.80 and 60.33 percent runoff is observed under forest, acacia and degraded watershed respectively. However, this is an increase of 5.58, 8.71 and 11.52 percent under forest (NF), acacia (AaP) and degraded forest (DF) watersheds respectively during 2010-11 hydrological year as compared to previous year. The percentage of runoff reduction under forested watershed may be due to higher the stand density which acts as barrier to surface flow as compared to acacia and degraded forest. Similar findings were reviewed and compiled by Venkatesh et al. (2011) from one of study conducted in India. In another study by Kurniatun Hairiah et al. in the year 2004, observed that forest conversion has lead to 6 to 10 times increase of the overland flow and accelerated soil loss particularly in the first two to four years after land clearing. Madrid et all 2006 and Martin et all 2004 noticed the annual discharge of a fictional beech stand at Schluchsee is 7 to 14 percent higher compared to spruce and he suggested practical forestry will favourably establish mixed beech–spruce rather than pure beech stands.

TABLE 3. Rain runoff characteristics under different land-use type for (a) year 2009-10 and (b) year 2010-11 in Areangadi regions of Honnavar block, Karnataka

Particulars	AaP		DF		NF	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Rainfall (mm)	2095.2	4451	2095.2	4451	2095.2	4451
Runoff (mm)	1106.22	2737.84	1261.53	3199.37	968.64	2306.23
% Runoff	52.80	61.51	60.33	71.85	46.23	51.81

iii. Specific and specific peak discharge with respect to change in land cover

The highest specific discharge and the specific peak discharge were observed in forested watershed followed by degraded watershed but whereas it is minimum in acacia watershed. However, peak specific discharge values are almost equal with respect to temporal variation in the all the watersheds, except natural forest. It indicates movement of water (cubic meter/ sec) contributing to surface runoff than the infiltration in both the degraded and Acacia watershed during 2009-10 and 2010-11. But in forested watershed the movement water per second per cubic meter area contributing to the infiltration, soil moisture and base flow than the surface runoff (reduce in percent of runoff and increase delayed flow from table 3 and Fig 2). On an average 60 percent increase in the specific discharge in all the watersheds and peak specific discharge by 6 percent in acacia, 22 degraded and 35 percent forested watershed as compared to 2009-10. This increase in specific and peak discharge during the year 20010-11 may be attributed to a change in tree density cover and increase of rainfall by 53 percent to that of rainfall in 2010-11. Similar observations are reported by Rowe (2003) and Hewlett and Hibbert, (1967) for some of the watershed in New Zealand and United states of America (UAS) respectively. Ford/UNESCO (2007) has reported that in western Ghats of India specific and specific peak discharge are highest in natural forest watershed as compared to degraded watershed due to change in land use.

TABLE 4. Specific and peak Discharge under different land-use type for (a) year 2009-10 and (b) year 2010-11 in Areangadi regions of Honnavar block, Karnataka

Particulars	AaP		DF		NF	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Rainfall (mm)	2095.2	4451	2095.2	4451	2095.2	4451
Specific Discharge (Cum/s)	0.128	0.3169	0.146	0.370	0.390	0.928
Specific Peak Discharge (Cum/ha/s)	0.0090	0.0096	0.0120	0.0154	0.0175	0.0271

iv. Variation of peak flow across the various land cover

The peak flows obtained are presented in the Fig. 3. The analysis indicates that, there is an increase in the peak flow upto 54 and 129 percent in *Acacia auriculiformis* plantation and 33 and 61 percent in degraded watershed in comparison with that of the forested watershed during 2009-10 and 2010-11 respectively. Irrespective of rainfall amount, comparison among the peak flows from all three watersheds shows that a maximum peak flow of 103.55 mm per hector and 132 mm per hector for degraded watershed to 168 mm and 204.2 mm rainfall during august 2009 and 2010 respectively. However, for acacia and forested watershed for the same event was observed only 44.39 and 34. 48 mm per hector during 2009 and during 2010 it was 43.4 mm and 71 mm per hector. It indicates that there is high temporal variability of the peak flow within each of the watersheds. Since the peak flows is function of intensity and duration of rainfall in addition to land use specially density of trees. There have been evidences that, the change in land-use have resulted in increasing the peak flow magnitude. For example, storm runoff from a 70ha forested basin in the lesser Himalaya was consistently higher than for a nearby agricultural basin of 55ha (Bruijnzeel, 1990). Here in the present case, the comparison is made between the watersheds under different land-uses under the same rainfall regimes. The same has been reported from the experimental basin from humid and temperate regions (Hewlett, 1982; Hamilton and King, 1983; Bonell, 2005).

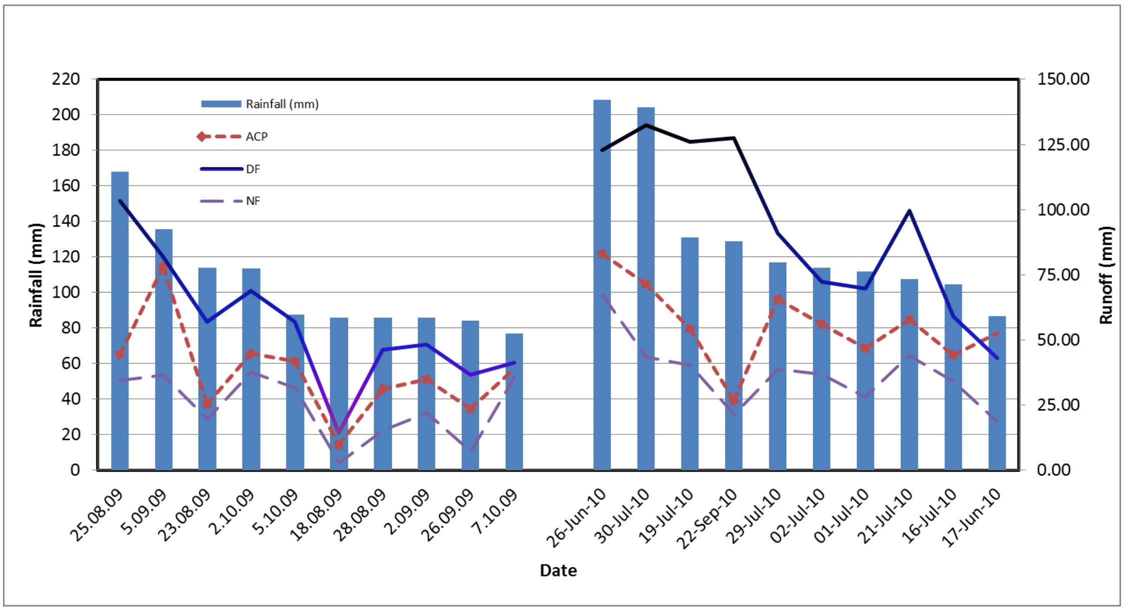

Fig 3. Peak flow of selected rainfall events in watershed with different land use systems in watersheds in Areangadi region of Honnavar block, Karnataka

v. Study on relationship between the stand density and discharge

Figures 4, 5 and 6 represents relationship between stand density, total runoff, specific discharge and peak specific discharge under various land use system in Areangadi region of costal Karnataka. Irrespective of land use system temporally total runoff, specific and peak specific discharge was found increasing trend with the decrease of tree density in all the three land use system. With respect to different land pattern, except natural forest, total runoff, specific and peak specific discharge increase with decreasing of stand density. The decrease in total runoff with higher stand density in natural forest may be due higher rate of infiltration, soil moisture and arresting the flow by vegetation. However increase in specific and specific peak discharge in the natural with higher density may be due to contribution base flow after soil saturation.

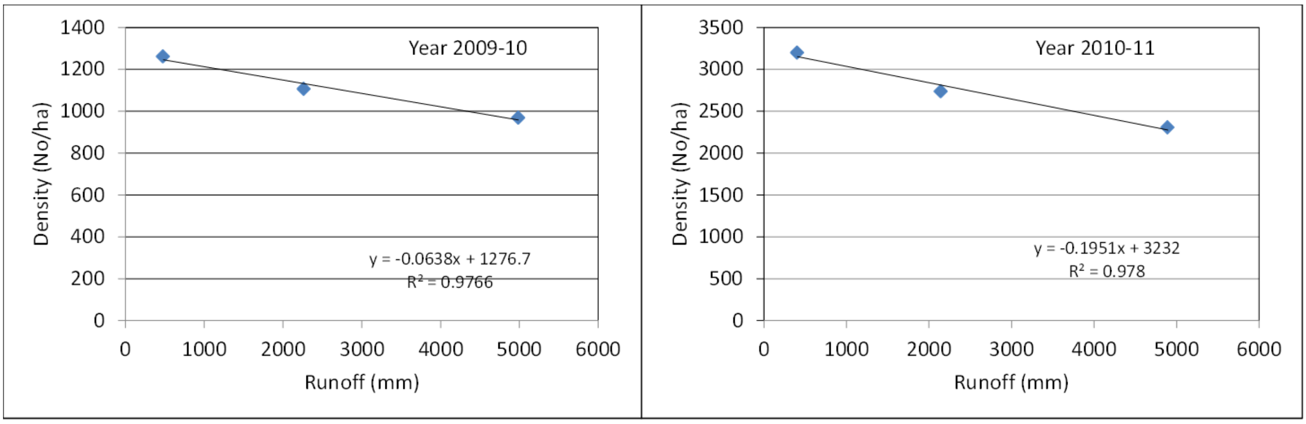

Fig 4. Stand density Vs total discharge relationship under different land use system in Areangadi regions of costal Karnataka (2009-11)

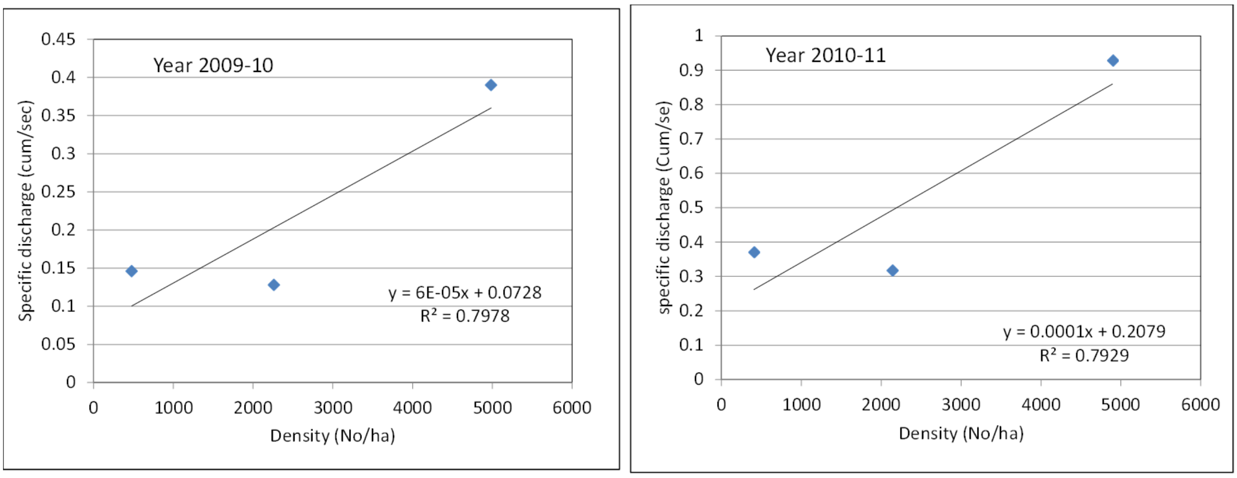

Fig 5. Stand density vs specific discharge relationship under different land use system in Areangadi regions of costal Karnataka (2009-11)

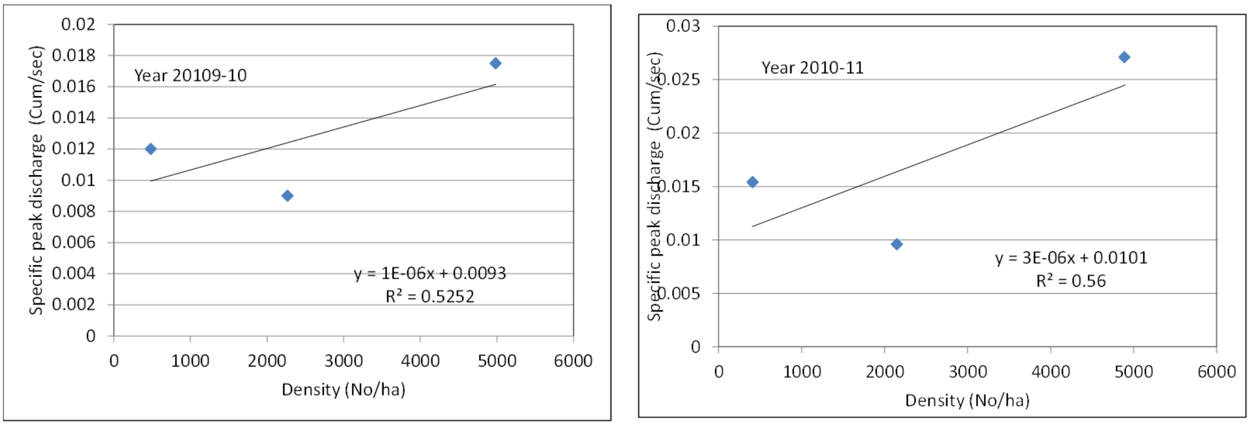

Fig 6. Stand density Vs specific peak discharge relationship under different land use system in Areangadi regions of costal Karnataka (2009-11)

Conclusions:

The rain-runoff including peak flow under different land use cover and management practices clearly indicated that the land cover under natural forest (NF) reduces average runoff by 25 percent as against 14 percent in comparison with degraded (DF) and acacia (AaP) watersheds. However, contribution to stream flow during post monsoon in the watershed having substantial area under natural forest is primarily by subsurface flow. Irrespective of land use pattern, distribution of stand density in each land use system found important and played a significant role in total discharge, specific discharge and peak specific discharge.

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