



Hydrological Response of the Imphal River on the Impact of Landuse/ Landcover and Rainfall Patterns

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Abstract

The river regime is one of the important parameters in studying the physical attributes in a region. The influence of a river passing in a region is immense. The nature of the stream reflects the natural and cultural set up of the surrounding areas. For instance soil factors, Land use/Land cover and vegetation, habitat, settlements, etc. Everywhere land use/ land cover is often altered during the process of economic and social development and eventually, the morphology and structure of river systems are unconsciously or consciously influenced along with the land-use change. The changes in land use/ land cover have a large amount of impact on the nature of runoff and associated hydrological characteristics. Availability of remotely sensed data has made convenient and accurate to map and monitor the Spatio-temporal variation of land use/ land cover at regional or local scales. The present paper highlights the changing of land use pattern in the Imphal River catchment. To identify the changes, Landsat 5 TM and Landsat 7 ETM+ obtained in 2005 and 2016 have been used and categorize the images into 16 major land use/ land cover. It has been found that over the periods both rural and urban built-up area has increased more than 24 Km² and decreased in forests cover area by more than 113 Km². Further, the study also focused on the rainfall-runoff response through regression analysis. The integration of the analyses demonstrates the effect of land use/ land cover change on discharge characteristics of the study area.

Keywords: discharge, land use/ land cover, regression, run-off, soil, soil factors

Introduction

Land use/land cover patterns depend on human usage in terms of natural and socio-economic development through space and time (Hua Kean Ang, 2017). Changes in land use pattern affect the land cover in one way or the other. The same is true in case of land cover changes. The relationship between land use and land cover and the hydrological response of watersheds are becoming highly scrutinized in science, management, and public policy. (Timothy L. Negley and Keith N. Eshleman, 2006). Changes in land cover may have significant consequences for atmospheric composition and air quality (S. Wu et. al., 2006). The conversion of vegetation such as tropical forest or savanna to grassland disrupt the hydrological cycle of a drainage basin by altering the balance between rainfall and evaporation and, consequently, the runoff response of the area. (Marcos Heil Costa, 2003). Additionally, the flow pattern of a river

reflects socio-economic conditions and pattern of land resource utilization. The subsequent impact of urbanization to the environment, especially land cover change, now occurs on scales that significantly affect hydrologic variations (K.A. Kiriwongwattana & Vaibhav Garg, 2012). It has been and still changing, through human activities, creating variability in hydrological cycle besides being linked to water quantity through relevant hydrological processes (Alfred Awotwi et. al, 2014). Human-induced land-use changes such as deforestation, afforestation, and agricultural and urban development within the river basin can affect the hydrological cycle (Santosh Babar and H. Ramesh, 2015). Moreover, an account on rainfall variation is still significant. Studies rainfall-runoff processes in hydrology are also an active and deep area of research with continually emerging new understanding (David G. Tarboton, 2003). All these events cannot be fulfilled without mentioning the effect of rainfall.

Thus, a quantitative assessment of hydrologic response on the changing land use/ land cover is essential to be highlighted. As degrading land use/ land cover pattern accelerate the flow rate of a river causing serious grievances like floods and droughts. This is particularly more concerned with the degradation of forests. It always leads to runoff exceeds infiltration on slopes which shortened the on-set of flood and drought. It is important to highlight the changes made by individual categories and their respective contribution to flow characteristics.

Since the last twenty years, there is an apparent change in the forest cover over the catchment area. The study also reveals that more than 113 Km² of forests land has been reduced during the period from 2005 to 2016. An anthropogenic activity may be one of the main triggering forces that large part of the

forests covered areas has been reclaimed by the process of expansion of both rural and urban built-up areas and also increasing rate of shifting cultivation. In fact shifting cultivation widely practices agricultural system in the entire hilly region of Manipur which accounts for approximately 90 % of the geographical area of the state. The result of land use/ land cover study provides in the required assessment on the changing flow behaviour concerning rainfall characteristics. Finally, the results are integrated to obtain a rainfall-discharge- land use/ land cover relationship over the years. The present paper highlights the temporal land use/ land cover changes of Imphal River catchment.

Study area

The Imphal River is one of the main rivers draining Imphal valley or the central plain which is a part of the main study area. With an extension 24°38'57" N to 25°14'21" N and 93°55'15" E to 93°56'56" E, it has a total catchment area of 560 km² up-to Ironglchil. It originates from the northern hills of Karong in Senapati District. Further downstream towards the south it is joined by Iril River at Lilong thereafter known by the name Manipur River. The Imphal River also belongs to 6th order stream formed by around 715 numbers of small and larger streams. During the monsoon season, the catchment receives an average annual rainfall of above 1500 mm at Kangpokpi station. Being a rain-fed region along with the ever-increasing population surrounding it, the over-expansion settlements are commonly accompanied by different land uses. Such changes have triggered unnatural and deteriorating effects on the hydrological response of the river. This results in witnessing flash floods, particularly in the low lying valley. This calls for a thorough analysis to check and mitigate such problems in future.

Data sources and methodology

The study begins with the assigning of different land use/ land cover categories based on visual interpretation of Landsat 5 TM and Landsat 7 ETM+ in the year 2005 and 2016, from Manipur remote sensing and application centre, Imphal. Thereafter a similar month each for two years having the same rainfall amount with different run-off are selected to find out the effect of land use/ land cover on discharge characteristics. By selecting such years will eliminate the effect of rainfall variations which will automatically highlight the effect of land use/ land cover change. Since only the land use/ land cover images of 2005 and 2016 were available for all catchments, the rainfall years selected were of the closest times to these temporal images so that the time gaps will not affect the results. The equal rainfall years chosen is 2004 and 2011 in July for each year. Despite similar rainfall, the water level during these two years came out to be 782.81m and 782.94m at Minuthong station. It can be seen that the water level has increased a bit over the years which may indicate the increased discharge rate in these particular years could be the result of the change in land use/ land cover over the years. Further, the effect of rainfall on discharge (Flood Management Circle, Imphal) was taken into account. A linear regression analysis was conducted in Microsoft Excel to find out the relationship between rainfall and discharge. It is then followed by analysis between the observed discharges, estimated discharges and major land use/ land cover change categories. Thus a comprehensive result could be obtained by integrating the analysis. Further, empirical pieces of evidence have been gathered by personal visits in and around Imphal city to identify the places affected by the overflow of Imphal River.

Results and Discussion

Land use/ land cover change detection

One of the most common applications of

change detection is determining urban land-use change and assessing urban sprawl (Innocent Ezeomodo and Joel Igbokwe, 2013). Study of land use/cover is an important aspect in analysing flood as changes in land cover can also influence the occurrence and frequency of floods by changing the responsiveness of river flows to rainfall (Bulus L.Gadiga and Alfred D. Mshelia, 2015).

All these classifications made above are sub-divisions derived from parent/mainland use/ land cover categories due to which a brief account to illustrate in this regard is deemed to be necessary. Consequently, Forests, Built-Up, Wasteland, Water bodies/wetlands, Agricultural Lands, Grass/ grazing lands are principal divisions upon which various other subdivisions have been categorised. The FESEDC, FESEO, FSF, FFP and FFB are typed as forest while WR/SP and WL/PP are classified under Water bodies/ Wetlands. Likewise, Agricultural Land includes AGCLKC, Plantation Agriculture, Shifting Cultivation and Fallow Land. Subsequently under the category of wasteland include the sub-categories of WSOS and WSDS and Abandon shifting Cultivation (ASC).

It was found that the BUR was generally concentrated in the southern and central low lying plains in 2005. However, a noticeable increase of 18 km² is seen in recent years. With the increase in population, it spread to such an extent that it covers almost the entire catchment along with the expansion of agriculture from 136.05 km² to 175.78 km². This nature of growth of BUR and agricultural land (AGCLK) is similar to those of the Iril River where spreading occurs along the river valley. Areas cultivated with rain-fed crops such as cereals, vines and olives are mainly restricted to hilly lands with shallow soils, very sensitive to erosion (C. Kosmas et al.1996). The degradation of soil structure, due to either

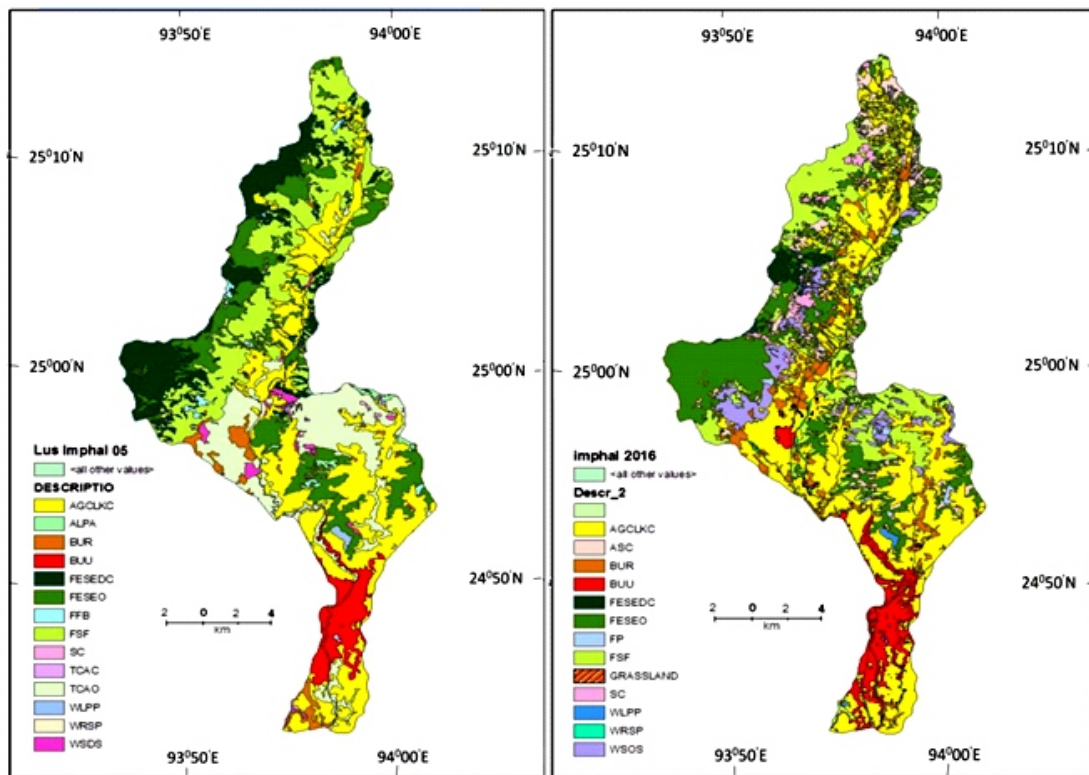


Figure1. Land use/Land cover of Imphal river catchment (2005 and 2016)

Source: Manipur remote sensing application centre (MARSAC), Imphal

The land use/ land cover categories found in the region consists of the following 16 categories. They include

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|---|---|
| 1. Water bodies Lakes/ Ponds Perennial (WL/PP) | 9. Agricultural Land Cropland Kharif Crop (AGCLKC) |
| 2. Wasteland Scrubland Open Scrub (WSOS) | 10. Forest Evergreen Semi-Evergreen Dense Closed (FESEDC) |
| 3. Water bodies River/Stream Perennial (WR/SP) | 11. Tree Clad Area Open (TCAO) |
| 4. Wasteland Scrubland Dense Scrub (WSDS) | 12. Agricultural land Plantation (ALPA) |
| 5. Built-Up Rural (BUR) | 13. Shifting Cultivation (SC) |
| 6. Built-Up Urban (BUU) | 14. Forest Plantation (FFP) |
| 7. Forest Evergreen Semi-Evergreen Open (FESEO) | 15. Forest Blank (FFB) |
| 8. Forest Scrub Forest (FSF) | 16. Abandon Shifting Cultivation (ASC) |

Table 1: Landuse/Landcover Change in Imphal river catchment from 2005 to 2016

Sl.No.	Land use/ land cover category	Area 2005 (km ²)	% of the total area in 2005	Area 2016 (km ²)	% of Total Area in 2016	Area of change (2005 to 2016) (km ²)	% of Change in Area (2005 to 2016)	Annual rate of change (%)
1	WLPP	1.55	0.30	2.1	0.41	0.55	0.10	0.01
2	WRSP	4.41	0.86	5.42	1.06	1.01	0.19	0.02
3	BUR	11.58	2.26	29.58	5.79	18	3.52	0.38
4	BUU	25.16	4.92	31.7	6.20	6.54	1.28	0.14
5	FESEO	77.03	15.07	95.84	18.75	18.81	3.68	0.40
6	FSF	102.83	20.12	95.87	18.76	-6.96	-1.36	-0.14
7	AGCLKC	133.09	26.04	175.78	34.39	42.69	8.35	0.92
8.	FESEDC	65.64	12.84	8.97	1.75	-56.67	-11.09	-1.22
9.	SC	0.60	0.11	7.77	1.52	7.17	1.40	0.15
10.	TCAO	73.17	14.43	0.00	0.00	-73.76	-14.43	-1.58
11.	FFB	4.72	1.68	0.00	0.00	-4.72	-0.92	-0.10
12.	TCAC	1.18	0.23	0.00	0.00	-1.18	-0.23	-0.23
13.	ALPA	2.96	0.58	0.00	0.00	-2.96	-0.57	-0.06
14.	WSDS	6.48	1.27	0.00	0.00	-6.48	-1.26	-0.13
15.	WSOS	0.00	0.00	26.48	5.18	26.48	5.15	0.57
16.	FP	0.00	0.00	2.89	5.5	2.89	0.56	0.06
17.	Grassland	0.00	0.00	1.25	0.24	1.25	0.24	0.03
18.	ASC	0.00	0.00	27.34	5.35	27.34	5.35	0.59
	Total	510.99	100	510.99	100			

WLPP- Water bodies Lakes/ Ponds Perennial; WRSP -Water bodies River/Stream Perennial; BUR - Built-Up Rural; BUU- Built Up-Urban; FESEO- Forest Evergreen Semi-Evergreen Open; FSF- Forest Scrub Forest; AGCLKC- Agricultural Land Cropland Kharif Crop; FESEDC- Forest Evergreen Semi-Evergreen Dense Closed; SC - Current Shifting Cultivation; TCAO - Tree Clad Area Open; FFB- Forest Forest Blank; TCAC- Tree Clad Area Closed; ALPA - Plantations; WSDS-Wasteland Scrubland Dense Scrub; WSOS- Wasteland Scrubland Open Scrub; FP- Forest Plantation; Grassland; ASC- Abandon Shifting Cultivation

Source: Manipur Remote Sensing Application Centre(MARSAC), Imphal

arable or grazing intensification, can lead to a reduction in soil infiltration rates and available storage capacities, increasing rapid runoff in the form of overland flow (Heathwaite et al., 1990; Bronstert et al., 2002; Carroll et al., 2004). Besides, the BUU is also spreading northwards along the river valley particularly on the western side. Most of the BUU is concentrated on the south-western region of the lowland. A continuous growth rate of around 0.14% per annum since the last decade has led to the escalation of BUU by 6.5km².

The zone covered by FESEDC has decreased drastically by 11% since 2016 where most of which is transformed into FESEO and FSF. However, the total degradation of Tree Clad Area, FFB, ALPA and WSDS are evident

accompanied by the prevalence of WSOS, ASC, Grassland and FP. Regarding the WSDS few patches of it has been converted to agricultural land and FESEO. Despite the minute changes occurring within the land use/land cover types, it is significant to mention that the total forest cover has been decreased from 324.57 km² to 211.34 km² resulting in rapid runoff and overland flow in the low lying regions. The effect can be aggravated due to increasing built-up areas both the BUR as well as the BUU. Besides above all the factors, the increase in the area covered by wasteland could further enhance the condition. The area of wasteland was 6.48 km²but a phenomenal rise occurred in the recent past by 53.62 km².

Effect of rainfall on run-off

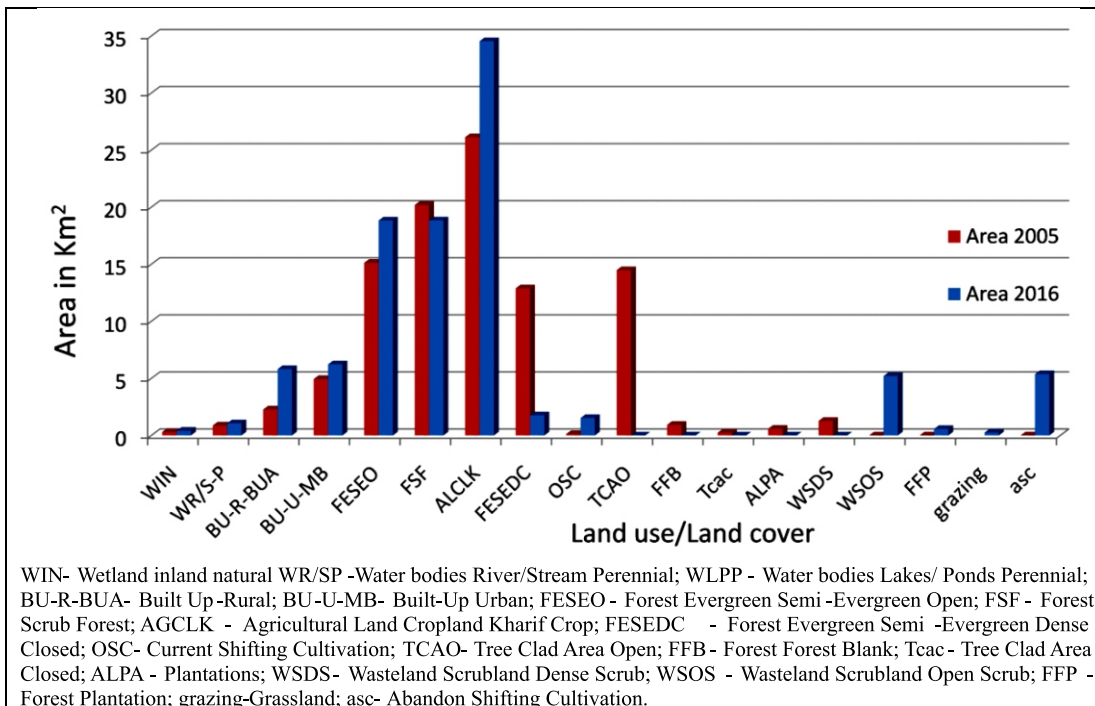


Figure2: Land use/ land cover changes in Imphal river catchment from 2005 to 2016

The Imphal River belongs to 6th order stream and formed by around 715 small and larger streams. It constitutes 354, 154, 86, 36, 51 and 34 1st, 2nd, 3rd, 4th, 5th and 6th order streams respectively. The catchment receives heavy to moderate rainfall. However during the lean season especially during winter months the region experience low rainfall. The variability of rainfall is also quite high with a range of around 2195 mm over the past 17 years. The linear regression analysis on the impact of annual maximum discharge by annual rainfall for the past 17 years is given in table 2. It is found that the estimated discharge is directly proportional to the amount of rainfall in the region and is quite significant.\

A clear picture of the relationships between different variables with land use/ land cover and discharge in particular is shown in Fig.3. The variables include land use/ land cover change in %, observed discharge, estimated

discharge obtained through regression analysis and rainfall. An increase in built-up (BUR/BUU), agricultural land (AGCLKC/ALPA), wasteland (WSDS/ WSOS) and grassland result in higher observed discharge as against the estimated discharge. The overall decrease in forest cover from 324.57 km² to 211.34 km² caused rapid runoff and overland flow in the low-lying region. The effect was aggravated due to increasing Built-up areas both the BUR as well as the BUU. One of the major impacts of both increase BUU and decrease in FESEDC is the frequent occurrence flash flood. At the same time, the impervious surface coverage in the Imphal City and its adjoining areas has increased with rising urbanization in the recent past. The frequency and magnitude of flood in the city area may be attributed to the reduced infiltration and speedy run off which effectively reducing the lag period discharge. There are also various

Table 2: Rainfall-Discharge Relationship of Imphal River.

x	X ²	y	Y ²	xy	y cap
1995	3980025	568.430	323112.7	1134018.0	401.7454
1996	3984016	412.390	170065.50	823130.4	404.0984
2000	4000000	503.840	253854.70	1007680.0	413.5101
2003	4012009	263.510	69437.52	527810.5	420.5689
2004	4016016	457.510	209315.40	916850.0	422.9219
2005	4020025	243.360	59224.09	487936.8	425.2748
2006	4024036	250.000	62500.00	501500.0	427.6277
2007	4028049	631.060	398236.70	1266537.0	429.9807
2008	4032064	334.390	111816.70	671455.1	432.3336
2009	4036081	400.000	160000.00	803600.0	434.6865
2010	4040100	562.930	316890.20	1131489.0	437.0395
2011	4044121	290.683	84496.61	584563.5	439.3924
2012	4048144	387.840	150419.90	780334.1	441.7453
2013	4052169	290.683	84496.61	585144.9	444.0983
2014	4056196	493.120	243167.30	993143.7	446.4512
2015	4060225	528.740	279566.00	1065411.0	448.8042
2016	4064256	702.950	494138.70	1417147.0	451.1571

Source: IFCD, Imphal and Personal calculation

$X_{\text{mean}}=2007.2941$, $Y_{\text{mean}}=430.6727$, $X_{\text{mean}^2}=4029229.7$, $Y_{\text{mean}^2}=185479$
 $(X_{\text{mean}}^2)*17=68496904$
 $(Y_{\text{mean}}^2)*17=3153143$,
 $b=0.05681$, $a=333.27$.

methods to evaluate the weakness or vulnerability of an area, but since the last ten years, the qualitative approach of vulnerability in flood risks became more important (B. Barroca, 2006). A qualitative analysis based on field studies has been conducted in the study. Based on field observation and survey conducted on the spot the region witnesses different types of flood based on their location. The flooding in the urban areas mostly the municipal areas are more prone to urban floods which are a result of lack of proper sewerage system and engineered methods of constructions. The areas surrounding the municipal areas are vulnerable to riverine floods. Large areas within and outside the Imphal city namely, Lamphel, Uripok, Sagolband, Yaiskul, Singjamei, Kakwa, etc. experience frequent temporal floods due to overflow of Imphal River. Kyamgei, Arapti and Urup experience overflow of Imphal River inundating houses and fields. The overflow is

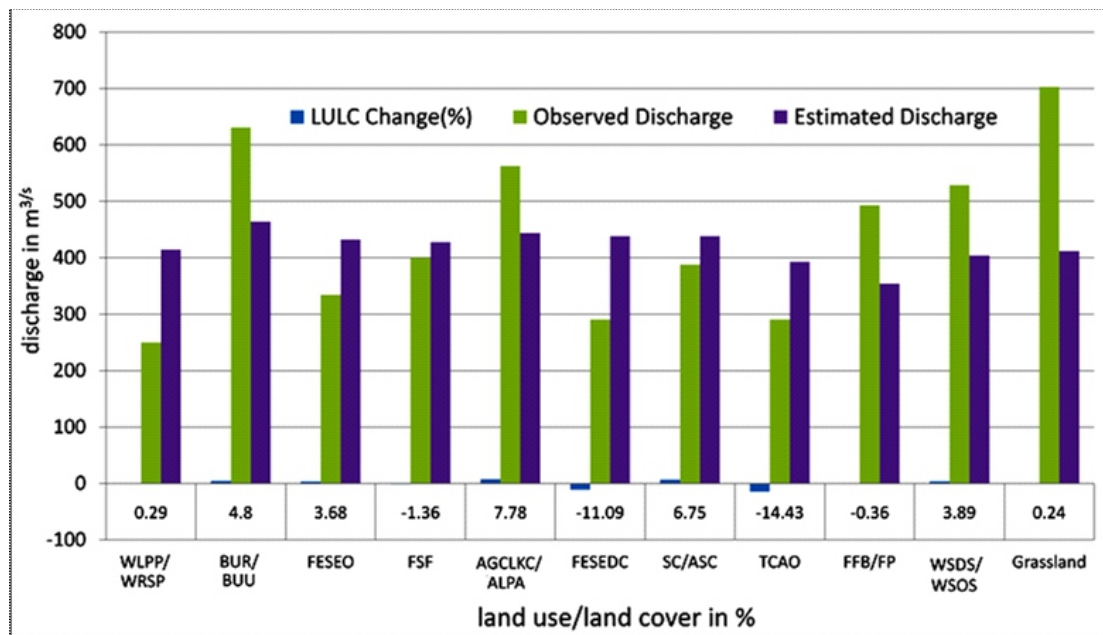


Figure 3: Variability between estimated and observed discharges at different land use/ land cover of the Imphal river

generally accompanied by breaching of the embankment at certain locations during heavy rainfall. Since the region is situated between Imphal and Iril River the region is prone to flooding. The water depths generally exceed knee length and the areas remain waterlogged for about a month. On the other hand, a small increase in FESEO by 3.68% indicates a lesser magnitude of observed discharge than the estimated discharge which is shown in figure 3.

Conclusion

To identify the hydrological response of Imphal River land use/land cover analysis has become the indispensable task. For this analysis, Landsat 5 TM and Landsat 7 ETM+ have provided useful statistics of 16 major categories of land use/land cover of the study area. An increase in built-up (BUR/BUU), agricultural land (AGCLK/ALPA), wasteland (WSDS/WSOS) and grassland result in higher observed discharge as against the estimated discharge. The overall decrease in forest cover from 324.57 km² to 211.34 km² caused rapid

runoff and overland flow in the low-lying region. The effect was aggravated due to increasing Built-up areas both the BUR as well as the BUU. On the other hand, a small increase in FESEO by 3.68% indicates the lesser magnitude of observed discharge than the estimated discharge which is shown in Table 1. Land use/ land cover as a whole has little effect on rainfall patterns in the area. However, there are significant pieces of evidence that the land use/ land cover change in the region greatly impacted the discharge characteristics. For instance, despite having a similar rainfall amount in the year 2004 and 2011 in the same month (July) of each year the water level has increased in 2011.

Thus it is seen that the increasing pattern of peak flow and the decreasing pattern of low flow values are the results of land use/land cover change.

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