Summary and Conclusions
Summary and Conclusion

Integrated remote sensing and GIS techniques with image processing techniques (band ratioing, PCA analysis, generation of FCC) and visual interpretation of Landsat ETM+ image of Imphal valley and its surrounding area in Manipur, helps in delineating the geological units and structures (faults, lineaments), geomorphic units (hills, valley, alluvium fan deposits, lakes and other water bodies, swampy areas), differentiating soil signatures, drainage textures and modification, slope determination and urbanization extent mapping etc.

The urban sprawling map obtained through Landsat imageries during 1979, 1990 and 2000 give the areal extent of the Imphal city as 4.29km\(^2\) in 1979, 19.02 km\(^2\) in 1990 and 27.04 km\(^2\) in 2000 and the corresponding population of the Imphal city was 431773 in 1971, 711261 in 1991 and 833312 in 2001. There is an also significant change in areal extent of the open water body of the Loktak Lake. The areal extent of the open water body of the Loktak Lake obtained through Landsat in 1979 is 51.29 Sq. Km. But the areal extent water body increased to 65.57 Km\(^2\) in the 1990 and 71.73 Km\(^2\) in 2000.

This increase in the extent of the water body is due to the transformation of Loktak Lake into a permanent reservoir since the commissioning of LHPP (Loktak Hydro Electric Power Project) in 1983. The impoundment of water in the Loktak Lake resulted in the spread of water to over larger areas. It leads to the inundation of large area of cultivable and cultivated land, about 20,000-80000 hectares around Loktak Lake, especially on its eastern side.

The land-use pattern change in the valley area suggests that the expansion of settlement and related activities in the formerly marshy areas and swamps through reclamation without proper planning is creating not only ecological imbalance but also unleashed a slew of health related problems in the form of many water and air borne
communicable diseases like acute diarrhea, acute respiratory diseases and malarial diseases. Prevelence rate is higher in the Thoubal and Bishenpur districts as compared to Imphal district in the Imphal valley. This is because majority of the people in these two districts are engaged in agricultural activities and fishing from Loktak Lake and many other smaller lakes and swamps that are scattered in these two districts. Thus people here suffer from the edge effects of living in the vicinity of many scattered marshy and swampy areas. These marshy and swampy areas act as hosts for the disease carrying vectors. Also, womenfolk are engaged in handloom cottage industries which increase the chance of respiratory diseases through cotton and silk dust.

Jhum cultivation in the hills surrounding the Imphal valley affects the study area. Jhum cultivation entails large scale deforestation through slash-and-burn of the forests and vegetation covers. This leads to the erosion of the precious top soils of the barren hills due to the splash forces generated by the rain drops during rainfall, down stream sedimentation of the beds of important rivers and streams of the Imphal valley which originate in the hills and siltaion of bottoms of Loktak Lake and other smaller lakes.

Due to deforestation, rainwater flows down without any barriers as the absence of trees and forest cover in the hills prevents the seepage of rainwater underground. This causes floods during the rainy seasons due to the lack of regulation of the rain water through natural processes of storage and conservation facilitated by the forests and trees. The frequency and intensity of floods are increasing and the whole of Imphal valley is prone to them.

Sediments which are further carried away by the rivers reached the Lokkat Lake and its surrounding area and deposited in and around the lake, making the area surrounding the lake swampy and waterlogged and made conducive conditions for the outbreak of vector and water-borne diseases. Cultivated and cultivable lands surrounding
the lake are also submerged under the expanding lake water, affecting the food production. Sedimentation and siltation of the Loktak Lake bottom also affects the proper functioning of the LHPP. Thus, both the ecological balance and hydrological cycle are disturbed.

The results of the analysis of 25 surface water samples collected from rivers and ponds (community and private) from different locations in the study area show that water from rivers have greater average pH, Hardness, HCO₃⁻, CO₃²⁻, Mg²⁺, Na⁺, and TDS than the water samples collected from ponds. On the other hand, samples from ponds have greater average concentration of SO₄²⁻, Cl⁻ and K⁺. This may be explained by the different, lithology, hydrodynamic conditions and anthropogenic activities prevailing in the sources of both the groups of sample.

Samples collected from two different rivers from Kakching (S15) and Phoudel (S25) show comparatively higher concentration of Hardness, Calcium, Sodium, TDS along with higher pH due to the local effects like dumping of solid wastes from the market domestic wastes.

The average ion chemistry shows the order of anion abundance as CO₃²⁻>HCO₃⁻>Cl⁻>SO₄²⁻ and that of cation abundance as Ca²⁺>Na⁺>Mg²⁺>K⁺. The percentage of various anions is 46% CO₃²⁻, 36% HCO₃⁻, 18% Cl⁻ and negligible for SO₄²⁻ and the percentage of various cation is 54% Ca²⁺, 21% Na⁺, 15% Mg²⁺ and 10% K⁺. The nature of the hydrochemistry of the surface water samples collected from the study area suggests that the water in the area is dominated with Ca²⁺ and CO₃²⁻. The facies of the water in the study area belong to Ca type and no dominant type cation facies and HCO₃ type anion facies. Monsoonal rainfall effected changes the ionic abundance order from HCO₃⁻>CO₃²⁻>Cl⁻>SO₄²⁻ and Ca²⁺>Na⁺>K⁺>Mg²⁺ of pre-monsoon (March-April) to CO₃²⁻>HCO₃⁻>Cl⁻>SO₄²⁻ and Ca²⁺>Mg²⁺>K⁺=Na⁺ of post-monsoon (October-November).
Spatially, all major ions except sulphate show southward increasing trend in their concentrations. Sulphate concentration is very low.

Concentration analysis for trace elements, Fe, Mn, Cr, Ni, Co, Zn and Cu were done. Seasonal monsoonal rainfall dilutes the concentration of Fe but enriched Cr in both the rivers and ponds.

Most of the trace elements show southward increasing trend in their concentration.

The analyses for major ions and trace elements of the surface water samples show that the average concentration of all the major ions and trace elements except Fe and Cr are well under permissible limits set by BIS (1991) and WHO (1993) for drinking purposes. Average concentration of Fe at twelve locations and Cr at one location are above their respective permissible limits. Although high concentration of Fe is rather more of aesthetic and taste significance than health consideration, higher concentration of Cr has the risk of causing mainly skin infection.

The water in the study area was also assessed for irrigation use. The water falls under good water for irrigation and can be used for most of the crops and in most of the soils.

The major ion concentrations are mainly contributed by rock weathering of the Disang Formation. Also, agricultural use of fertilizers and other anthropogenic activities along with the scattered presence of brine springs in the study area contributed to the ionic concentration.

Fe and Cr concentration in the study area is mainly contributed by the leaching from the Disang shales. Some contributions were also made from the agriculture use of pesticides and herbicides.
The hydro-geochemical study of the surface water was also conducted for assessment of the various geochemical factors responsible for the surface water chemistry. The results suggest that the surface water in the study area is dominant of carbonate weathering processes along with minor contribution from the silicate weathering. Chemical weathering is contributed mainly by H\(^+\), which is supplied in the environment by the CO\(_2\) release by biochemical and geochemical reactions.

The grain size analysis was also carried out for twenty-two (22) bed sediments samples collected from the rivers and standing water bodies (SWBs) consist of ponds and lakes to find out the bed sediment characteristics and decipher the hydrodynamic conditions of the surface water bodies. The result shows that the bed sediments from rivers are mostly medium sand but at some places the bed sediments are fine to coarse sand. The bed sediments of the SWBs are medium sand. But there is significant difference in the kurtosis and skewness of the bed sediments from the rivers and SWBs. However in both the groups, the bed sediments do not show any significant difference in sorting. It may be due to the low energy conditions of the drainage system in the valley.

Trend analyses of the study area in the Imphal valley were carried out for the important weather elements, temperature, rainfall, evaporation and sunshine hour for the period, 1969-1998. The trends of the daily maximum temperature and daily minimum temperature of study area indicated increasing trends as are the cases with both the Indian (national) and north-east Indian (regional) trends. However, the rate of increase is smaller than the increase rates of both the all India and north-east India. The overall increasing trend of temperature in the Imphal valley is contributed by increase in the minimum temperature unlike that of the all India and north-east India, where rise in temperature is contributed by rise in the maximum temperature, because, the rate of increase in the daily
minimum temperature in the study area is greater than the rate of increase in the daily maximum temperature.

The rainfall trend of the study area exhibited increasing trend unlike that of regional and national trends, which show decreasing trend. One common feature of rainfall trends in the national, regional and that of the study area is the decreasing low intensity rainfall spread over long period and increasing high intensity rainfall concentrated in short period of time. The high intensity rainfall is the cause of frequent flash floods in the study area. Increasing trend in high intensity rainfall is observed consistently since 1981. The pre-1981 data do not reveal any definite trend for this parameter.

The trend lines for daily evaporation and daily sunshine hour show decreasing trend. The analysis shows that for the period, 1969-1980, the trend lines for both these parameters exhibit increasing trend but after 1980, for the period, 1981-1998, the trend lines for both these parameters show definite increasing trends. These observed trends for the various climatic parameters indicated the local effect of global warming phenomenon which brought about climatic change all over the globe.

Manipur in general and Imphal valley in particular, face water quantity and quality concerns even though the place receives ample amount of rainfall. Most of this rain water is lost as surface runoff. In terms of quantity, the state needs to tap the potential ground water and rain water through rain water harvesting method in order to meet the rising needs of the ever increasing population. In terms of quality, even though the chemical contamination of surface water is found to be not at alarming stage, findings of my study included, biological contamination of surface water—the main source of drinking water, due to the reckless disposal of human and animal wastes also contributes to the spread of water borne diseases which are very common in the study area. Since, more than 60% of the
people of the state do not have access to safe drinking water, authority should take up necessary measures to address this problem. The government also needs to develop proper waste disposal facilities. Recent major projects like, the centralize Imphal Sewerage Project and plan to develop the first landfill site in the Imphal district are welcome developments in this direction.

Land-use/land-cover change in the form of encroachment on the marshy and swampy areas should be avoided and discouraged so that ecological degradation and its attendant consequences facing the population in the study area like, outbreak of communicable and other diseases due to the edge effect, development of water logging condition in new areas as flood water diversion area get converted for different land-uses etc. can be checked.

Flood, which is the most frequently occurring and damaging, of all the geoenvironmental hazards in the study area, is mainly due to the anthropogenic intervention. Flood in the Imphal valley is mainly due to the land-use/land-cover change in the hills which surround the valley. Most of the main rivers draining the valley originate from these surrounding hills and they lie in the catchments areas. Shifting cultivation is done extensively in these hills. Since shifting cultivation entails large scale deforestation, the hills are cleared of forest. This deforestation made the hills barren and reduces the infiltration of rain water into the ground. So during the rainy season, there is large scale runoff which causes flood in the valley. Thus, shifting cultivation not only disturbs the hydrological cycle but also causes various geoenvironmental problems, like soil erosion, landslides etc. Authorities should discourage geoenvironmentally damaging shifting cultivation practice by actively encouraging the cultivators to opt for other viable, more productive and environmental friendly cultivation practices. This can be achieved through creating geoenvironmental awareness and providing incentives to the farmers.