CHAPTER 8

CONCLUSION AND SUGGESTIONS

Crop diversification refers to the competition among the growing crops in a region. The keener the competition the higher the magnitude of crop diversification, and lesser the competition, greater will be the trend towards crop specialization or monoculture farming, where emphasis is on one or two crops (Singh, 1976). According to Petit and Barghouti (1972), crop diversification has emerged as an important alternative to attain the objectives of output growth, employment, generation and natural resources sustainability in the developing countries. The recent experiences in Asia, particularly southeast Asia, Middle East and North Africa indicate that policy makers and planners are increasingly focusing on crop diversification to promote agricultural development.

The farmers all over the world, especially in the developing countries, try to grow several crops in their land holdings in an agricultural year. The level of crop diversification is largely depends on the geo-climatic conditions, and socio-economic conditions and the level of technological development in a region. It is generally considered that higher the level of agricultural technology, lesser the degree of diversification and vice versa. Moreover, rich farmers prefer to specialize in agricultural enterprise, while the poor and subsistent farmers are generally more interested in crop diversification.

Punjab-Haryana plain is situated in north-west of India. It comprises two states namely Punjab and Haryana. Total area of the study region is
94,572 sq km, which accounts 2.88 per cent of the total reporting area of India. This region is flanked by the states of J & K in the north-west, Himachal Pradesh in the north, Uttrakhand in the northeast, Uttar Pradesh and Union Territory of Delhi in the east and Rajasthan in the west and southwest. It forms international boundary with Pakistan in the northwest. According to 2001 census, its total population is 4,55,03,563 persons, out of which 2,44,48,998 are males and 2,11,54,565 are females. Punjab-Haryana plain is considering as the food basket of India and it produces 38.19 million tons of food-grains, which comprises 18.30 per cent of India’s total food grains production in 2001-2002. It contains 38 districts.

The study in hand has selected five objectives, to identify the cropping patterns and changes their in; to demarcate the crop diversification regions and changes their in; to highlight the factors responsible for changes in crop diversification regions; to know the effects of crop diversification on environment; to make suggestions for the future patterns of crop diversification.

For achieving the above mentioned objectives, the present study has tested the proposed four hypotheses, relief affects decisively on the cropping pattern of a region which often leads to variations in crop diversification; development of water resources leads to adoption of new agricultural technology which generally leads to crop specialisation; Introduction of high yielding varieties of seeds leads to changes in cropping patterns and crop diversification regions; levels of magnitude of crop diversification and levels of environmental degradation are positively co-related.
The present study is empirical in nature. District is taken as unit of study. It is based on secondary sources of data. Data of three time periods i.e. 1965-66, 1985-86, and 2005-06 is collected. For deriving the results, statistical techniques are applied and for mapping the results, cartographic methods are selected. The present study is based on secondary sources of data which is collected personally by the researcher from various State Offices, Libraries, etc. Data is collected from the following secondary sources which contains both published and unpublished sources.

The present study is divided into 8 chapters namely, Introduction, Physical Environment, Socio-Economic Environment, Land Use Patterns and changes therein, Cropping patterns and changing therein, Crop Diversification Regions and changes therein, Impacts of crop diversification on environment, Conclusion and suggestions. Following observations are made from the present study.

Chapter first defines the statement of the problem, review of literature, study area, objectives, hypotheses, methodology, sources of data and tentative chapter scheme.

Chapter second deals with physical environment of the study region. In it the researcher has found that relief of the study region is highly varied. The gradient of the land is from north-east to south-west. It is steep in the north-east, gentle in the central parts and irregular in the south and south-western parts. From physio-graphic point of view, the study region is divided into six landform regions namely Shiwalik hills, Piedmont plains, Flood plains, Upland plains, upland plains with frequent occurrence of sand dunes and Rocky surface. Climatic conditions are ideal for growing number of crops throughout
the year, because the mean minimum temperature in December and January is above 6°C, which is threshold temperature for germination of crops (Schimper, 1903). Maximum temperature in the study region is 48°C whereas the minimum temperature some times comes down to less than freezing point. The mean annual rainfall ranges between 140 cm (Sujanupr) in the northeast to 22 cm (Abohar) in the south-west. The coefficient of variability in annual rainfall is found between 22 per cent in north-east to 64 per cent in south-west. A great variety is recorded in the soils of the study region. Eight prominent types of soils are found namely, Shiwalik Soils, Piedmont Soils, Loamy Soils, Light Loam Soils, Sandy Loam Soils, Sandy Soils, Silty Clay Soils and Rocky Soils. These soils are suitable for a variety of crops like wheat, maize, rice, pulses, bajra, sugarcane, etc. Major problems of soils of the study region are soil erosion, salinity, alkanity, acidity, etc. There are four major perennial rivers namely, Ravi, Beas, Satjuj and Yamuna. All these rivers are dammed and their water is used for irrigational and generating of hydro-electric power purposes. Leaving aside these four rivers, there is one seasonal river namely Ghaggar and numerous seasonal torrents, which are knowing as choes in local dialect. The aquifers of subsoil water along the Shiwaliks are inadequate and deep which is beyond the economic reaches of the poor farmers. Whereas in western and southern parts aquifers of subsoil water are saline and alkaline and are not suitable for drinking and irrigational purposes. But central parts have rich aquifers of fresh water which are fit for irrigational purposes and as a result large numbers of tubewells are sunk. Thus, from crop farming point of view physical environment is highly suitable.
Chapter third deals with socio-economic environment. In it, population characteristics, irrigation, agricultural workers, consumption of chemical fertilizers, market, transport network, size of landholdings, land tenure system, government policies, etc. are discussed. According to 2001 census, the study region has an average density of population of 481 persons per km$^2$. But the rural density of population is recorded 325 persons per km$^2$ which varies between 192 persons per km$^2$ in Sirsa district to 475 persons per km$^2$ in Gurgaon district. Agricultural workers constitute 34.85 per cent of the total workers. It is found that spatial distribution of agricultural workers is not uniform which ranges between 20.23 per cent in Ludhiana district and 67.31 per cent in Fatehabad district. The ratio between cultivators and agricultural labourers is noted of 64.74:35.26 per cent. The number of cultivators is high in those districts, which are socio-economically backward, and mostly these are found in the southern and western districts of the study region, whereas the low number of agricultural labourers again is found in these districts, because these are lacking of major urban centers and have small size of landholdings, which on average are less than 2 hectares. It is also found that out of 24,55,739 land holdings, 12 lakhs are less than 2 hectares and only 1.3 lakhs are above 10 hectares. In respect of land tenure system, there are 3 types of cultivators i.e. owners lessees and tenants-at-will. It is observed that 92 per cent are owner cultivators, 6 per cent are lessees and 2 per cent are tenement-at-will. The study region is enjoying 90.62 per cent of extent of irrigation, which is quite comfortable from agricultural point of view. It varies between 54.55 per cent in Gurgaon district to 100 per cent in about seven districts of the study region like Amritsar, Ludhiana, etc. Major sources of
irrigation are canals and tubewells, which comprise more than 99 per cent of the irrigated area. The study region has an average density of 283 tubewells/000’ hectares of net sown area. The density of tubewells is recorded highest of 499/’00 hectares of net sown area in the districts of S.A.S. Nagar and lowest of 60/’000 hectares of net sown area in Bhiwani district. The density of tubewells in the study region depends upon the quality and adequacy of aquifers of subsoil water. Punjab-Haryana plains have consumed average chemical fertilizers of 368 kg/hectare of net sown area, whereas, it is recorded highest of 672 kg/hec in Karnal district and lowest of 105 kg/hec in Bhiwani district. It is found that high consumption of chemical fertilizers in the study region is owing to well developed sources of irrigation and emergence of wheat-rice and wheat-cotton crop rotation in major parts of the area under present investigation. It is also recorded that on an average, each regulated market serves 426 sq. km area, which is very significant from agricultural point of view. It has 250 regulated markets and 696 sub-yards, which provide excellent marketing facilities to the farmers. A well developed road network is noted which is evident from the facts that there are 94 km road length per 100’ sq. km of area and 184 km road length per lakh of population. It is also found that almost all the villages in the study are having link roads. Their number varies from 97.8 per cent in Rupnagar district to 100 per cent in 22 districts. Thus, the above-mentioned facts show that the study region has well developed socio-economic environment for agriculture.

Land use pattern and changes therein are discussed in chapter fourth which shows that in 2005-06, area under forest land is 3.51 per cent of total cropped area while land not available for cultivation comprises 10.59 per cent,
area under cultivable waste land is 0.90 per cent. Whereas current fallow land has 2.80 per cent and the net sown area contains 81.84 per cent of total reporting area. It shows that there is little scope for further increase in net sown area. Area under forestland was 1.90 per cent in 1965-66, which had increased to 3.68 per cent in 1985-86 and further it decreases to 3.51 per cent in 2005-06. Land not available for cultivation had 11.56 per cent of the total reporting area in 1965-66. It has declined to 9.35 per cent in 1985-86 and has increased to 10.95 per cent in 2005-06. Cultivable wasteland had experienced decline. It was noted 3.50 per cent, 1.90 per cent and 0.90 per cent in 1965-66, 1985-86 and 2005-06 respectively. A fluctuating trend in current fallow is noted. It was recorded 6.44 per cent in 1965-66, 2.02 per cent in 1985-86 and 2.80 per cent in 2005-06. However, overall decline of 3.64 per cent is noted in current fallow. Net sown area has increased from 76.19 per cent in 1965-66 to 83.77 per cent in 1985-86 and it declines to 81.84 per cent in 2005-06. Above facts show that the forestland and net sown area have recorded positive volume of change during 1965-66 to 2005-06 whereas during this period, the land not available for cultivation, cultivable wasteland and current fallow land have recorded negative volume of change. All this have been happened due to the introduction of green revolution technology.

Chapter fifth deals with spatio-temporal variations in cropping pattern of 1965-66, 1985-86 and 2005-06. In 1965-66, it is recorded that wheat was the leading crop with 22.98 per cent area followed by fodder crops, pulses, bajra, maize, oilseeds, rice, sugarcane, others and vegetables with per cent share of 20.15 per cent, 17.84 per cent, 11.39 per cent, 7.20 per cent, 5.74 per cent, 5.19 per cent, 5.18 per cent, 1.85 per cent, 1.59 per cent and 0.90 per cent
respectively. But in 1985-86, the over all cropping pattern of the Punjab-Haryana plain had wheat, rice and fodder as leading crops with 36.90 per cent 15.30 per cent and 14.61 per cent of the total cropped area respectively. Next in order were pulses, bajra, cotton oil seeds, maize, others, sugarcane and vegetable crops which had 8.43 per cent, 6.81 per cent, 6.04 per cent, 4.34 per cent, 3.01 per cent, 1.58 per cent, 1.52 per cent and 1.45 per cent of the total cropped area respectively. Where as the cropping pattern in 2005 – 06 for the study region is having wheat of 40.21 per cent, rice of 25.34 per cent, fodder with 11.33 per cent, cotton with 7.07 per cent, oil seeds with 5.58 per cent, bajra with 3.99 per cent, sugarcane with 1.52 per cent, pulse with 1.48 per cent, vegetables with 0.27, maize with 1.14 per cent, and others with 1.07 per cent. It is also observed that in 1965-66, the spatial variation, in wheat cultivation was varying between 1.16 per cent in Bhiwani district to 33.90 per cent in Gurdaspur district of the total cropped area. It shows great variations in its distribution. It is also found that southern and southwestern districts were having low proportion of wheat cultivation, whereas northern and central districts were having high per cent share in wheat cultivation in 1965-66. there were only ten districts in the study region which had more than 10 per cent of the total cropped area under rice cultivation. Again, it was negligible in southern and western parts of the study area. High percent share in case of maize was observed along the Shiwalik hills, whereas bajra was predominant in southern districts of the study region, cotton was only significant in the western districts of the study region, oilseeds were important in southern districts. Pulses were also having 17.84 per cent of total cropped area under their cultivation, but their share was noted over 20 per cent in southern and
western districts. Fodder was also an important crop of the study region because majority of the district were having more than 20 per cent area under their cultivation. Sugarcane, vegetables, and other crops were having less than 2 per cent area under their cultivation. It is also observed that sugarcane was having more area under its cultivation in Punjab than Haryana. Overall cropping pattern of 1965-66 was recorded highly diversified. No crop had registered over 40 per cent area under its cultivation in any district of the study region whereas during 1985-86 wheat crop had captured overall 36.90 per cent of the total cropped area. But 18 districts had recorded more than 40 per cent of the total cropped area. Whereas in southern and south-western districts area under wheat cultivation was below 30 per cent. It was recorded lowest of 0.85 per cent in Bhiwani district. It was very interesting to note that rice had emerged second ranking crop in overall cropping pattern with 15.30 per cent of total cropped area. It was emerged as a major kharif crop in central parts of the study region whereas in southern and western parts, its share is less than 10 per cent. The third crop in ranking order was recorded fodder with 14.61 per cent of total cropped area. Again, its per cent strength was high that is over 15 per cent in Northern and Southern parts, while central parts were having low fodder cultivation. Pulses were ranked fourth with 8.43 per cent area under its cultivation. Its cultivation was predominant in Southern and Western districts, where the geo-climatic conditions were highly suitable for pulses cultivation. Bajra with 6.81 per cent was largely confined to 10 districts, due to emergence of rice and consequently area under its cultivation had reduced to 1 per cent. Oilseeds were having 7th position in the overall cropping pattern with 4.34 per cent area though oilseeds were grown
throughout the study region yet their predominance was confined to Southern districts. Sugarcane from spatial point of view was a significant crop with over 3 per cent area in the districts of Gurdaspur, S.A.S. Nagar, Ambala, Panchkula, Karnal, Panipat, Sonipat and Jhajjar. In respect of vegetables it is found that their cultivation had reduced ranging between 1.02 per cent in Jalandhar district and 2.01 per cent in Hoshiarpur district which shows vegetables were not having a predominant place in the cropping pattern of any district of the study region. Other crops, which include barley, jower, fruits, etc., were having only 1.58 per cent of the total cropped area. Their spatial distribution was also almost uniform from areal strength. In 2005-06, wheat and rice crops have emerged as main crops in majority districts of the study region. Expect 9 districts, wheat is having more than 40 per cent of the total cropped area and has emerged undisputed leading crop of the study region and follow by rice with 25 per cent. Rice has also more than 40 per cent area in 10 districts of the study region. It is also worth noting that rice cultivation is insignificant in southern and south-western districts where its share is less than 10 per cent. Moreover, it is insignificant in case of Gurgaon, Jhajjar, Rohtak, Rewari, Mahendragarh, Hisar, Bhiwani and Sirsa district with less than 7 per cent. Maize is only confined to the areas lying along the Shiwalik hills which covers the district of Hoshiarpur, Rupnagar, S.A.S. Nagar and Panchkula whereas bajra is predominant in Southern and south-western districts like Rohtak, Jhajjar, Gurgaon, Rewari, Mahendragarh, Bhiwani and Hisar. All these districts have more than 10 per cent of the total cropped area. Cotton was significant crop in the districts of Firozpur, Faridkot, Muktsar, Bathinda, Mahendragarh, Faridabad, Jind, Hisar, Fatehabad and Sirsa,
whereas it ranges between 0.28 per cent in Faridkot district to 28.49 per cent in Sirsa district. Oilseeds have registered their predominance in districts of Jhajjar, Gurgaon, Rewari, Mahendragarh, Bhiwani, Hisar and Sirsa where their share between 12.12 per cent in Sirsa district to 40.23 per cent in Mahendragarh district, which shows that oilseeds are favourite crop in arid parts of the study region where irrigation facilities are inadequate. Pulses have recorded only 1.48 per cent of the total cropped area. Their cultivation was only predominant in the districts of Rohtak and Bhiwani where these are having more than 5 per cent area. Most of the districts have recorded less than 1 per cent area under pulses, which shows that in major parts of the study region, irrigation facilities are well developed. Though Sugarcane has 1.52 per cent of the total cropped area under its cultivation, yet it is very significant crop in the districts of Gurdaspur, Hoshiarpur, Yamunanagar, Nawanshahr, Jind, Sonipat and Rohtak, where it ranges between 4.0 per cent in Nawanshahr district to 18.92 per cent in Yamunanagar district. In the remaining districts, the cultivation of sugarcane is insignificant. Vegetables have emerged significant crop in case of Kapurthala and Jalandhar districts where more than 5 per cent area under their cultivation is recorded. More than 15 per cent of the total districts are having less than 1 per cent of area under its cultivation. All this shows that introduction of green revolution technology and developments in agricultural infrastructure have led to the cultivation of few crops by the farmers. In central parts of the study region, the choice of farmers has fallen on wheat and rice while during rabi and kharif season respectively cotton cultivation has confined to western districts of the study region which has sandy soil, low rainfall, saline and alkaline sub-soil water
and developed canal irrigation. But maize is dominant in comparatively high rainfall areas along the Shiwalik foothills. Whereas the cultivation of bajra and oilseeds are having comfortable position in southern part of the study region which is arid zone with less irrigational facilities and less developed agricultural infrastructure.

Due to the adoption of Green Revolution technology in mid sixties, development of agricultural infrastructure, organizational reforms, government policy etc. have affected the changes in cropping pattern of the study region during the present investigation period. It is observed that area under wheat cultivation had increased drastically from 22.98 per cent in 1965-66 to 36.90 per cent in 1985-86 and has further increased to 40.21 per cent in 2005-06. In case of rice cultivation, area under rice cultivation was 5.74 per cent, 15.30 per cent and 25.34 per cent in 1965-66, 1985-86 and 2005-06 respectively and recorded positive volume of change of 9.56 per cent during 1965-66 to 1985-86 and 10.04 per cent during 1985-86 to 2005-06. In this way, rice has experienced overall positive volume of change of 19.60 per cent during 1965-66 to 2005-06. Fodder cultivation had 20.15 per cent area under its cultivation in 1965-66 which had decreased to 14.61 per cent in 1985-86 and recorded a negative volume of change of 5.54 percent. Further it has been decreased to 11.33 per cent in 2005-06 and registered negative volume of change of 3.28 per cent from 1985-86 to 2005-06. Whereas an overall negative volume of change of 8.82 per cent is recorded during 1965-66 to 2005-06. While the cotton cultivation had recorded declined from 7.20 percent to 6.04 per cent during 1965-66 to 1985-86 and registered a negative volume of change of 1.16 percent. But cotton has experienced increase from 6.04 per cent to 7.07
percent from 1985-86 to 2005-06, and noted positive volume of change of
1.03 per cent. Overall negative volume of change of 0.13 percent is recorded
during 1965-66 to 2005-06. The cultivation of maize crop has also
experienced negative volume of change during the study period. It had
declined from 5.18 per cent in 1965-66 to 3.01 per cent in 1985-86 and
recorded 2.17 per cent of negative volume of change. It has further declined
from 3.01 per cent to 1.14 per cent during 1985-86 to 2005-06 and noted 1.87
per cent negative volume of change. But overall negative volume of change of
4.04 per cent has experienced during study period. Next crop is bajra which
had covered 11.39 per cent in 1965-66 and 6.81 per cent during 1985-86 and
recorded negative volume of change of 4.58 per cent. It has further declined
to 3.99 per cent in 2005-06. But it has experienced overall negative volume of
change of 7.40 per cent. Next significant decline from 17.54 per cent to 8.43
per cent during 1965-66 to 1985-86 was recorded under pulses cultivation
with negative volume of change of 9.11 per cent. While pulses have
experienced negative volume of change of 6.95 per cent during 1985-86 to
2005-06. Overall negative volume of change of 16.06 per cent is recorded.
Oilseeds had declined from 5.19 per cent to 4.34 per cent and noted negative
volume of change of 0.85 per cent during 1965-66 to 1985-86. Its cultivation
has experienced increase in 2005-06 and consequently positive volume of
change of 1.24 per cent is noted from 1985-86 to 2005-06. Whereas overall
positive volume of change of 0.39 per cent in oilseeds cultivation is recorded
during the 1965-66 to 2005-06. Sugarcane cultivation in the study region has
also experienced overall negative volume of change of 0.33 per cent, but
during 1965-66 to 1985-86 the decline was 0.33 per cent whereas no change
is noticed under its cultivation during 1985-86 to 2005-06. The area under vegetables in the study region had increased from 0.90 per cent to 1.45 per cent but further it has declined to 1.27 per cent during 1965-66 to 1985-86 and 1985-86 to 2005-06 respectively. Thus, an overall positive volume of change of 0.37 per cent is recorded. Therefore, it is found that wheat and rice crops are the major gainers where as bajra, pulse, maize and sugarcane are the major looser crops.

Demarcation of crop diversification regions are made in chapter sixth. For delineation of crop diversification regions, three techniques are taken which are Gibbs & Martin’s technique, Bhatia’s technique and Singh’s technique. According to Gibbs & Martin’s technique great variation in the values of crop diversification is noted for 1965-66 which ranged from 0.67 to .83. Whereas the average value for the study region was is found 0.79. In case of Bhatia’s technique derived index values range from 17.07 per cent to 28.22 per cent. While index values of Singh’s technique were found between 15.31 to 23.36 for 1965-66. In 1965-66 after Gibbs & Martin’s technique, the regions of high crop diversification was found in the Eastern and South-Western parts. While the region of low crop diversification was confined to Southern parts which comprise the districts of Bhiwani, Mahendragarh and Rewari. The region of moderate crop diversification had contained central parts of the study region which was a continuous belt. It is also worth noting that major parts of this belt were confined to Punjab state. But according to Bhatia’s technique, 25 districts of the study region comprised the region of high crop diversification. The region of low crop diversification was confined to the districts of Bhiwani, Mahendragarh and Rewari as it was in the case of
Gibbs & Martine’s technique. But the areas of moderate crop diversification covered only 10 districts and was found in 3 separate belts covering the districts of Amritsar, Tarn Taran, Moga, Muktsar, Bathinda, Sangrur, Mansa, Rohtak, Jhajjar and Gurgaon. Whereas Singh’s technique had 23 districts in high category of crop diversification, but the belt of low crop diversification was the same as it was in the case of “Gibbs & Martin’s technique and Bhatia’s technique. The category of moderate crop diversification had mainly confined to South-Eastern parts covering the districts of Jind, Panipat, Sonipat, Rohtak, Jhajjar, Gurgaon and Faridabad. Another belt of moderate category was found in districts of Moga, Faridkot, Muktsar and Bathinda. When these three maps were compared some similarities were found between all the techniques, but more similarities are seen in case of Bhatia’s technique and Gibbs & Martin’s technique. It is also observed that areas of high crop diversification covered about 2/3rd of the total occurrences in all the techniques, whereas great variation was found in moderate category. But the category of low crop diversification was noted same in all the maps prepared by these three different techniques which covered the districts of Bhiwani, Mahendragarh and Rewari. Here, low crop diversification was the result of less developed agricultural infrastructure and arid climate which had compelled the farmers to grow only bajra, pulses and oilseeds.

During 1985 – 86, area of high crop diversification was found in the districts of Sirsa, Fatehabad, Hisar, Jind and Yamunanagar where as the area of low crop diversification was found in a continuous belt which ran from Amritsar district to Sonepat district covering the districts of Tarn Taran, Firozpur, Kapurthala, Jalandhar and Ludhiana. These are the areas where
wheat rice crop rotation had emerged. Moderate crop diversification was found in 3 different belts. One was lying along the Shiwaliks, second covered the Southern districts of the study region and the third comprised the districts of Moga, Faridkot, Muktsar, Bathinda and Mansa.

According to Bhatia’s technique the picture had remained almost the same. High category of crop diversification confined to the Sirsa, Fatehabad, Hisar and Jind districts. Low crop diversification had found in central parts where there was wheat and rice crop rotation dominance. And moderate category had contained the areas along the Shiwaliks, southern districts and western districts. Even the crop diversification regions after Singh’s technique were also found the same as these were in case of Gibbs & Martin and Bhatia’s techniques.

In 2005–06, according to Gibbs & Martin’s technique, the picture has become more clear and three distinct belts have emerged. The areas of low crop diversification covers central parts of the study region comprising the districts of Gurdaspur, Amritsar, Tarn Taran, Kapurthala, Jalandhar, Moga, Faridkot, Ludhiana, Sangrur, Fatehgarh Sahib, Patiala, Kurukshtetra, Kaithal, Karnal, Panipat and Sonipat. Whereas, the moderate category of crop diversification was found in two belts; one comprises the districts of Hoshiarpur, Nawanshahr, Rupnagar, S.A.S. Nagar, Panchkula and Yamunanagar. While the second belt covers the districts of Faridabad, Gurgaon, Jhajjar, Rohtak, Bhiwani, Hisar, Jind, Fatehabad, Sirsa and Firozpur. The high crop diversification is due to the growing of more crops during kharif season like maize, rice, oilseeds, fodder, etc. The category of moderate crop diversification has also two belts; one covers the districts of
Rewari and Mahendragarh and second comprises the districts of Mansa, Bathinda and Muktsar. But according to Bhatia’s technique, there is some change in moderate category which has gained two districts namely Firozpur and Faridkot in addition to Gibbs & Martin’s technique. While the areas of low crop diversification cover central parts. But the picture of crop diversification regions is quite different according to Singh’s technique. According to Singh’s technique, the major belt of low crop diversification, which covers central parts except the districts of Jalandhar, Kapurthala, Nawanshahr and Sonipat which have shifted to moderate category. The areas of high crop diversification are found along the Shiwalik hills in the north-east and the districts of Sirsa, Fatehabad, Hisar, Jind, Rohtak, Jhajjar and Bhiwani in the south-west. While the moderate category covers the southern districts namely Mahendragarh, Rewari, Gurgaon and Faridabad. But the main belt of this category lies in Jalandhar, Bathinda, Muktsar, Kapurthala and Mansa districts. Among these three maps of crop diversification, which are taken into account, more similarities one found in Bhatia’s technique and Gibbs & Martin’s technique. While Singh’s technique yields different results. It is also found that the results of Bhatia’s and Gibbs & Martin’s techniques are more authentic.

During 1965-66 to 2005-06 significant changes are found in crop diversification due to the adoption of Green Revolution technology, development of agricultural infrastructure, reforms in social institutions, organizational setup, favourable government policy towards agriculture, awakening among the farmers, etc. As a result, according to Gibbs & Martin’s technique, the average index of crop diversification was 0.79 in 1965-66 which had declined to 0.75 in 1985–86 and it further decreases to 0.71 in 2005–06
which shows that the trend of crop diversification was from high to low and it remained consistence during the study period. Even the categories of crop diversification were over 0.80 per cent (high), 0.75 per cent to 0.80 (moderate) and less than 0.75 (low) in 1965-66 but in 1985-86 the categories were remained the same. Whereas in 2005–06, the categories of over 0.70 (high) 0.65 to 0.70 (moderate) and less than 0.65 (low) have emerged. Even, the category of high crop diversification in 2005-06 is also over 0.70 whereas in 1965-66 and 1985-86, these were over 0.80 which shows the trend from high crop diversification to low crop diversification. In respect of Bhatia’s technique, which indicates that higher the index, lower the diversification and vice versa. According to his approach, in 1965-66 the index of high crop diversification was less than 22 and for low crop diversification was over 24. But it was less than 20 for high crop diversification and over 26 for low crop diversification in 1985-86. It has further changed to less than 30 for high crop diversification and over 35 for low crop diversification in 2005-06. These figures again indicate the trend from high crop diversification to low crop diversification. Even the minimum index value according to Bhatia’s method in the study region was 17.07 and highest was 29.00 in 1965–66 but it was recorded lowest of 15.68 and highest of 39.26 in 1985–86 whereas it has further changed to lowest of 17.88 in Hisar district and 44.01 in Moga district in 2005–06. Again, it shows that trend is from high crop diversification to low crop diversification. The average index value of crop diversification in 1965-66 after Singh’s technique was recorded 18.07 for the study region and lowest of 15.31 and highest of 23.36, which shows highly diversified cropping pattern. But these figures changed in 1985-86 when study region’s average index
value was 20.73 and the lowest value of 15.32 in Fatehabad district and highest of 29.86 in Kaithal district. But in 2005-06, the region’s average index value has become 46.06, whereas the lowest value of 16.00 in Sirsa district and highest of 32.04 in Patiala district. It again shows that region’s agriculture has become specialized in 2005-06 from highly diversified in 1965-66.

Thus, from the derived results, it is found that the overall picture of the crop diversification of the study region is from high crop diversification to low crop diversification. Secondly the category of high crop diversification which contained more than 60 per cent of the total districts in 1965-66, presently is having only 25 per cent of the total occurrences. While the category of low crop diversification has expanded which is evident from the figs. 6.1 to 6.9. Thirdly, it is observed that among the three techniques which are used, the results of Gibbs & Martin’s and Bhatia’s techniques are closer as compare to Singh’s technique. But it is further found that Gibbs & Martin’s technique is more scientific because according to it, all crops are taken into account for calculating the index of crop diversification. Whereas in Bhatia’s technique, only those crops are taken which are having 10 per cent or above of the total cropped area. And according to Singh’s technique, only those crops are taken which have 5 per cent or more of the total harvested area.

Impacts of crop diversification in environment are discussed in chapter seventh. Cropping pattern of the study region was highly diversified in 1965-66 and the major crops grown were wheat, gram, maize, bajra, pulses, oilseeds, fodder, cotton, etc. This type of crop pattern was adopted by farmers because of poor irrigation facilities, lack of agro-chemicals, indigenous variety of crop seeds, etc. But with the development of tubewells irrigation,
particularly in central parts of the study region and excessive canal irrigation in south-western and western parts particularly in the districts of Firozpur, Muktsar, Faridkot, Bathinda, Mansa, Sirsa and Hisar, certain changes in the sub-soil water table has taken place in central parts of the study region, sub surface water table had gone down whereas in south-western and western parts due to excessive canal irrigation water table has come closer to the surface which caused water-logging conditions. Thus, the adoptions of wheat-rice crop rotation and wheat-cotton crop rotation in major parts of the study region have led to low degree of crop diversification. Thus, these change, in crop diversification have effected the environment particularly subsoil water and soil resources.

Sub-soil water resources are effected by two ways, firstly, water depth and secondly contamination of sub-soil water. The depth of the sub soil water in central parts has gone down from 5 meters to over 30 meters, whereas in the western and south-western parts, it has come closer to the surface which has caused water-logging. Secondly, owing to excessive use of agro-chemicals, the subsoil water has been contaminated when farmers use agro-chemicals and then provide watering to the fields which become responsible these agro-chemicals for percolation of agro-chemicals with the water into the aquifers of sub-soil water and contaminated it. As a result, the concentration of sulphate, chloroide, sodium, potassium and magnesium has caused rise in the sub-soil water table particularly in the districts of Firozpur, Moga, Faridkot, Muktsar, Bathinda, Mansa, Hisar, Sirsa, etc. Bajwa et al (2003) have determined high concentration Nitrogen Nitrate in Punjab’s sub-soil water. The presence of arsenic in ground water in western districts of the study
region varies from 8.92 to 11.13 (Ppb) which is very dangerous. It is all owing to changes in crop diversification in the study region.

The second impact of changes in of crop diversification is noted on the soil of the study region. Due to highly intensive use of land, there is depletion of macro and micro nutrients of soil. Thus, the soils of the study region have become deficient in nitrogen, zinc, iron, potassium, phosphate, etc. Secondly, owing to rice cultivation the upper layer of soil has become harder in areas where rice cultivation is predominant. Even the use of chemical fertilizers, pesticide, weedicide insecticide, etc. has also contaminated the soils of the study region. Moreover, changes in crop diversification have created air and noise pollution. The agricultural operations right from sowing, growing, harvesting and transporting the product from field to market and from market to warehouses have created both air pollution and noise pollution. The burning of paddy and wheat straw has added more to air pollution.

Proposed objectives are achieved by studying the cropping pattern, crop diversification region, factors responsible for changes in the cropping pattern and crop diversification and have found environmental effects due to crop diversification. Thus for the achievement of above mentioned objectives, proposed four hypotheses are tested and these proved valid.

In case of first hypothesis it is found that areas with steep gradient, undulating and dissected topography or with sand dunes or remnant of Araveli hills have high crop diversification, whereas areas with flat topography and clayey or loamy soils have experienced moderate to low crop diversification which shows the validity of first hypothesis.
In second hypothesis, positive correlation between extent of irrigation and density of tubewells and density of tractors is found 0.82 and 0.87 respectively. A coefficient of correlation is also drawn between the density of tractors and magnitude of crop diversification, density of tubewells and magnitude of crop diversification. In both cases a positive correlation of 0.88 and 0.91 respectively is observed. In case of third hypothesis, a positive correlation of 0.83 between area under high yielding variety of seeds and magnitude of crop diversification is found and in fourth hypothesis, correlation is drawn between magnitude of crop diversification and depth of sub soil water, which is found 0.77. A correlation between magnitude of crop diversification and pH value of soils is also drawn which yields positive correlation of 0.69. Thus, the entire proposed hypotheses are tested and are proved valid.

Suggestions
For making region’s agriculture sustainable the following suggestions are made:

1. Stress should be given on those crops, which require less water and are suitable to region’s environment, which ranges from subtropical semi arid to arid type.
2. About 30 per cent area from wheat rice-crop rotation should be diverted to crops like maize, fodder, vegetables, pulses and oilseeds so that the water resources and soil health can be saved.
3. The use of chemical fertilizers should be minimized by using alternative manures like green manure, cow dung and bio-fertilizers.
4. Flood irrigation should be avoided and in its place spring irrigation and drip irrigation should be encouraged particularly along the Shiwaliks which are having undulating and dissected topography supplemented with steep gradient, southern and western districts where either the remnants of sand dunes or rocks exist.

5. More agro-based industries should be installed e.g., vegetables processing plants, fruit processing plants, milk plants, sugar mills, chain of cold storage, etc. so that study region’s agriculture can be diversified from highly specialized.

6. Dry air ports in the region should be established at major urban centers so that fresh vegetables, fruits and milk can be exported to the Middle East and European countries which will help the farmer to diversify their cropping pattern.

Thus, if above-mentioned suggestions are incorporated to region’s agriculture by the government planners, farmers, etc., then region’s cropping pattern can be made sustainable. These suggestions are very vital for region’s agriculture because of its being food bowl of India.