SUMMARY AND CONCLUSIONS
The present study has examined the spatio-temporal changes in rice cultivation in Punjab-Haryana plain during the period 1960-63 to 1999-02. The study is based on district level data. It is generally suggested that changes in cropping pattern in favour of water intensive crops often leads to the problem of land degradation. Rice is a water intensive crop, and therefore, in this study an attempt has been made to explore the magnitude and nature of the problems of water depletion, water logging and soil salinity/alkalinity in the plain as a consequence of spread of rice cultivation.

Punjab-Haryana plain is one of the major geographical regions of India. It is situated in the north-west of the country. The Punjab-Haryana plain extends from 27°39' N to 32°30' N latitudes and 73°51' E to 77°36' E longitudes. It may be noted that for the present study the administrative divisions of the two states - Punjab and Haryana have been taken into account. The total area of the plain thus is 94574 sq. km., accounting for 2.9 per cent of the total geographical area of the country.

In terms of administrative division, the plain comprises of two states namely Punjab and Haryana. On the basis of language, these two states came into existence on November 1, 1966 after the re-organization of composite Punjab state.
Except some hills of the Siwaliks in the northeast and Aravalli system in the south, the study area is basically a plain area. The northern part of the plain generally slopes imperceptibly from the northeast to the southwest. But the southern and south-western part is undulating due to Aravalli system and sand dunes. They provide slope towards north and north-east. Height of Siwalik hills vary from 400 to 700 metres above mean sea level. Excepting Siwalik and Aravalli system, the whole plain forms an integral part of the great Indo Gangetic plains. This alluvial plain lies between 200 to 300 maters above sea level. The plain is one among the most fertile lands of the country. Plain with sand dunes are located in south-western part of the plain. Sand dunes of this part break the continuity of the great alluvial plan. The sand dunes in the south-western part vary in height from 200 to 220 maters above sea level.

The Ravi, the Beas, the Satluj and the Yamuna are the main rivers that flow through the plain. Along with these there are several smaller order river channels namely Ghaggar, Saraswati, Markanda, Sahibi, Indora etc. Which flow though this plain. In addition there are number of seasonal streams (locally called ‘choes’) which drain the plain particularly during the rainy season.
The climatic conditions vary from arid in the south-west to semiarid type in the rest of the plain. The climate of this region is basically a part of the entire system of the Indian climate. The location of the plain helps to bring metamorphic change in the temperature conditions. Normally, temperature of the plain starts rising slowly from the month of February. The hottest month of the plain is June. From July, when the monsoon rain starts the temperature subsides and starts falling. The winter season is extremely cold and is spread over the months of January and December. Some areas in the region even experience frost like situation during winter, the durations of which may spread over a week.

The amount of rainfall in the plain varies from 25 cm. to more than 110 cm. The highest rainfall is recorded near the Siwalik Hills in the north while the lowest to the extreme south-western part of the plain. In other words, rainfall received decreases from north-east to south-west direction. From July to September over 70 per cent rainfall of the plain is received. The rainfall of the plain is highly variable in time as well as in space. The region also receives some rainfall during winter season in the wake of western disturbances.
The Punjab-Haryana plain can be divided into three climatic zones namely, less hot and humid northeastern zone, hot and semidry central zone and hot and dry southwestern zone.

The soils of the plain are primarily formed of alluvial debris brought from the mountains by the Ganges and the Indus River systems. These soils are grouped into Nehri, Barani, Khadar, Bhangar, Rehi, Naihi Chachhra, Bagar, Tibba etc. Broadly the soils of the plain can be categorized as soils of sub-mountainous areas in northeastern parts, alluvial soil in central parts and desert soil in southwestern parts of the plain.

According to the latest figures of 2001 census the total population in the study area is 4,53,72,285, which amounts to 4.42 per cent of the total population of the country. According to the size of population, Punjab and Haryana states rank 15th and 16th respectively amongst 28 states of the country. The urbanization level of the plain is 31.48 per cent, which is quite high as compared to the nation’s average. The density of population in the plain is 480 persons per sq. km. as against 324 for the country. The female-male ratio in the population of the plain works out to be only 868 (females per 1000 males). This is the lowest female male ratio not only in India but also perhaps in the whole world. In addition,
the recent past has witnessed further decline in the ratio. Literacy rate in the plain is 69.27 per cent in comparison to 65.38 per cent in the country as a whole as per 2001 census. The work participation rate in the plain is however, on a lower side than national average of 38.7 per cent.

The economy of Punjab and Haryana plain appears to be balancely poised. The plain has taken a big lead in increasing industrial production. Planned industrial activities, promotion of new enterprise and peaceful environment contribute to the present achievement in high level industrialisation in the plain. Today this plain occupies an enviable position on the industrial map of India. At present there are 22,588 registered working factories in the region. The location of industries in the plain exhibits a strong preference along the entire length of G.T. Road between Amritsar in Punjab and the national capital of Delhi. The main industries in the region are largely agro based.

Agriculture too has undergone a rapid transformation in the plain. There has been significant increase of area, production and productivity in agriculture. A significantly higher proportion of the land in the region has already been brought under cultivation. It is only in the two districts namely Panchkula in Haryana and Roop Nagar in Punjab where the cultivated area accounts for less than 60 per cent of the total reporting
area. It is because of the fact that a larger part of land in these districts is the extension of Siwaliks ranges. On the whole about 82 per cent of the total geographical area in the plain is already under cultivation. As such there is very limited scope for further expansion in the cultivable area in the plain.

Nearly 78 per cent of the population in the plain depends either directly or indirectly, upon agriculture and its allied activities. As per latest available statistics, about 45 per cent of the net domestic product of the plain comes from agriculture and its allied activities alone. This region is rightly considered as the ‘food basket’ of the country.

Wheat and rice are the two dominant crops in the region. Both the crops are produced in surplus quantity. Area under these crops is on the increase at the cost of other crops. During the year 2000-01, 41 per cent of the total cropped area was under wheat, while 26 per cent was under rice. From the time green revolution began in the country, the cropping pattern has undergone significant change with the accent on diversity and cash crops. The main aim of green revolution was to augment wheat production in the country. Wheat commands the largest area followed by rice. The benefits of green revolution were shared by only rich and big landlords while the conditions of small and marginal farmers have further
worsened. Small marginal farmers could not derive any benefit due to their poor economic conditions and lack of access to new input technology.

Green revolution also brought about change in Work culture. Farmers of the region stopped doing manual farm work. They began to depend heavily on migrant labour. Heavy agricultural machinery and implements have become the symbols of status for big farmers in the region.

Irrigation played a vital role in the agricultural development of Punjab and Haryana plain. Irrigated areas have almost reached its farther limit in the region. During 1970-71 to 2000-01 the percentage share of net irrigated area has increased from 57 per cent to 89 per cent. Tube wells and canals are the main source of irrigation. During the period tube-well irrigated area has increased by about 107 per cent, where as canal irrigated areas have recorded a growth of 34 per cent. There is a well developed network of canals in the plain. But the distribution of irrigation network is not uniform across the region everywhere. The network is mainly concentrated in northeastern and central parts of the plain. As the, south western parts are the tail points for canal irrigation, they are not served well by canals for irrigation. At the same time, the ground water in
these areas is largely saline hence tubewells do not provide substitute. Tube wells are largely concentrated in the northern and eastern belts where ground water is fresh.

Today, this region ranks very high in India in terms of per hectare consumption of chemical fertilizers. It is estimated that about 70 per cent of growth in agricultural production can be attributed to increased application of fertilizers. During the period of 30 years, i.e. 1970-71 to 2000-01, consumption of fertilizers in the region has gone up by about 693 per cent. The area covered by pesticides has also increased very significantly. The area under high yielding varieties of seeds has continuously increased in the plain. In case of wheat more than 95 per cent of the total area under the crop is based on H.Y.V. seeds. In case of rice the corresponding figure was about 79 per cent in 2000-01.

At present the agricultural practice in Punjab-Haryana plain is totally mechanized. Whole cultivation work is done with the help of machines. Manpower is used only where machines fail to operate. Adoption of mechanization in the plain is higher than in the rest of the country.

In India, the eastern, north-eastern and southern states are the traditional rice growing states. These states contribute a major share in
area under rice. But during the post green revolution period most of the traditional rice growing states have experienced decline in the relative strength of area under rice vis-à-vis other crops. As a result, their share in the total area under rice in India has also undergone decline. These states are Orissa, West Bengal, Bihar, Tamil Nadu, Kerala, Assam etc. On the whole these traditional rice-growing states accounted for 63.3 per cent of area under rice cultivation in the country in 1970-71, which came down to about 55 per cent in 2001.

During the same period, in non-traditional rice growing states like Punjab and Haryana, strength of area under rice vis-à-vis other crops has witnessed a sharp increase. Therefore, the share of these two states in the total area under rice in the country has increased sharply. These two states taken together accounted for 8.4 per cent of the total area under rice cultivation in the country in 2000-01 as against only 1.7 per cent in 1970-71.

Therefore rice cultivation is often regarded as the by-product of green revolution in Punjab and Haryana plain. At present it is the second major crop after wheat. The last four decades have witnessed a notable spread of area under rice in the plain, because large scale package technology including H.Y.V. seeds, chemical fertilizers and irrigation
facilities were introduced during these period. It may be noted that just prior to the emergence of Punjab and Haryana as separate states in 1966 rice was grown only on a little about 4 per cent of the total cropped area. This figure has gone up to 26 per cent by the year 1999-02.

Over a period of forty years, from 1960-63 to 1999-02, area under rice cultivation has recorded more than nine-fold increase. The annual rate of growth in rice acreage has been of the order of about 21 per cent. During this period the total harvested area of the plain recorded an annual growth rate of only 1.3 per cent, and area devoted to all cereals grew at the rate of 3.5 per cent annually.

Along with area, production of rice has also increased rapidly during this period of forty years. In the year 1960-63, the production of rice was only 10.6 per cent to total production of all cereals. This was because of an otherwise unfavourable climatic condition and lack of sufficient irrigation facilities in the plain. But the post green revolution era has witnessed a marked growth in production of rice in the region. During early 1960s to the early years of the present decade, production of rice has recorded more than 27fold increase, with the annual rate of growth being about 68 per cent. During the same period the production of all cereals recorded an annual growth rate of only 22 per cent. Much of
the gain in production of rice was due to rise in the levels of productivity. By the year 1999-02 rice production amounted to 30 per cent to total production of all cereals. It is important to note that growth rate in the production of rice was at its peak during the 1970s. Thereafter though absolute production has continued to grow, growth rate has declined continuously.

The yield level of rice also has recorded about three-fold increase during the period of last four decades. However, recently yield has recorded a decline during 1990s. From 1960-63 to 1990-93, the per hectare production of rice recorded a growth of 182 per cent. But from 1990-93 to 1999-2000 it has gone down by -0.8 per cent. It seems productivity of the crop has reached its plateau with no scope of further improvement in the same. It is also suggested that a decline in per hectare production of rice can be attributed to increasing attack of insects and pest, disease, stagnation of excess water, and low rice plant population. It may be noted that farmers get the rice saplings transplanted by the migrant labours on contract basis. Labours transplant less number of plants per unit area than the recommended by agricultural universities. So by keeping recommended plant population, rice yield can be increased to some extent.
Rice occupied a very insignificant position in the plain in the pre
green revolution period. It accounted for barely 4.2 per cent of the total
cropped area owing mainly to the climatic condition that is otherwise not
suitable for rice. In addition irrigation facilities were not fully developed.
Rice cultivation was mainly confined in the north and north eastern parts
of the plain.

The intensity of rice cropping declined abruptly towards the south
and south western parts. The extreme southern fringe was conspicuous
with the absence of rice in the farming practices. There indeed existed a
very wide regional variation in the intensity of rice cropping in the
region.

The decade 1960-63 to 1970-73, which also witnessed the onset of
green revolution, is marked with significant spread in area under rice.
Area under the crop recorded a growth of about 83 per cent during the
decade. However, in terms of its share in total cropped area, rice
accounted for only about 7 per cent. The dominance of north and north
eastern parts of the plain continued to exist and the ranking of the districts
remained almost unchanged. Nevertheless, the magnitude of regional
variation in the intensity of rice cultivation underwent a sharp decline.
The decade 1970-73 to 1980-83 was marked with the fastest growth in the area under the crop in the region. Rice came to occupy as much as 14 per cent of the total cropped area. There was a growth of 142 per cent in the area under the crop. This was because of the progress in irrigation facilities and the increased efficiency of the farmers. The magnitude of regional variation in the intensity of rice cultivation further declined during the decade. Although the main concentration continued in the north and eastern parts, the crop witnessed a significant gain in its share in the total cropped area in the south and southwest of the main belt. The most perceptible gain was recorded in the central parts of the region.

By the year 1990-93, rice came to occupy a significant position in the farming practices of the region. The spread of rice cultivation was more prominent in the central and south western part of the plain. These parts experienced a faster growth in area under rice than the north eastern part of the plain during 1980s. On the whole rice occupied about 21 per cent to the total cropped area in the region. However, southern part of the plain particularly the districts of Rewari and Bhiwani continued to report negligible area under rice cultivation. In Mahendargarh rice was not introduced till early 1990s.
The position of rice as a Kharif crop was further strengthened in the region during 1990s. During the year 1999-02 the plain reported about 26 per cent of the total harvested area under rice crop. This could be attributed to further strides made in irrigation. By the year 1999-02, shift in rice cultivation to the south western parts of the plain becomes more evident, through the dominance of north eastern and central parts continues to prevail.

The analysis of district-wise data on area under rice cultivation reveals that there existed two main areas of concentration in the plain, and that it is from these ‘core areas’ that the spread of rice cultivation occurred. While the one ‘core’ of rice concentration was located in the extreme northern part of the region, centered around the district of Gurdaspur, the other was seen in the eastern part. It is interesting to note that initially, it is the ‘core’ in the northern part of the plain that experienced spread, while the one in the eastern part underwent a significant shrink in its spatial extent. However, in the subsequent decades, the latter experienced more rapid expansion. The spread was towards the central part of the plain. Thus, the centre of this ‘core’ shifted in north-west direction. It may also be noted that the spread was much more conspicuous in the Punjab plain than that in its counter part in
Haryana. The 'indices of concentration' for different time points also indicated a general decline in the extent of unevenness in the intensity of rice cropping over the period.

Notwithstanding this general spread, there seems to be a strong preference of the crop in the north and eastern part of the plain. The spread of rice in the southern part over the period of forty years has been quite minimal. This is because of the extremely unsuitable physical factors like topography and average annual rainfall. In addition, underground water in this part is largely saline. Rice is a water intensive crop and requires irrigation more frequently than other kharif crops. Canal irrigation, which is the main source of irrigation in the southern and south western parts, provides water only at fixed interval. As against this, ground water is of better quality in the northern and north-eastern parts, and tube wells, which are capable of providing water at any time it is required, are the main source of irrigation here. Thus, the difference in the nature of two sources of irrigation seems to be an important limiting factor on the extent of spread of rice in the region.

Spread of rice cultivation in the plain has been made possible due to massive strides made in the irrigation sector. Rice cultivation requires irrigation at each and every step. Excessive irrigation has, however, led to
serious ecological consequences. Canal and tube well irrigation has been a blessing where it has helped to increase productivity levels. At the same time it has also created problems related to rise in water table often leading to water logging in some areas and water depletion in other areas. Soil salinity is another problem associated with water-logging has assumed a serious problem in the canal irrigation areas.

In the plain, irrigation facilities has been extended from 57 per cent of net cropped area in 1970-71 to 89 per cent in 2000-01. But not much attention has been paid to the proper water management. The general slope of this plain is towards southwest with local variations due to rivers and dense canal network.

The plain is characterized by significant regional variations in the quality of underground water. In almost 65 per cent part of the plain, the quality of underground water is fresh. The occurrence of fresh groundwater can be seen all along the rivers, central part and in patches in south-western parts of the plain. About 25 per cent area of the study area has ‘marginal’ ground water quality, which occurs in patches in all over the plain but more so in south western parts. Saline ground water patches covers about 10 per cent of the plain, mainly in the central and south
western part of the Haryana plain. In Punjab plain also patches of saline ground water can be seen in the south and south western parts.

In Punjab-Haryana plain rice cultivation that remained very insignificant till the early years of 1960s has assumed significance position. It has added tremendously to food security, but has been linked with serious problems of exploitation natural resources. In the north eastern parts and in patches in central parts of the plain where ground water is fresh, tube wells are the main sources of rice irrigation. Excess extraction of ground water for irrigating rice fields has caused water depletion in north eastern part of the plain. To tackle the problem of falling water table the farmers must initiate steps to harness rainwater and recharge under ground water. For this the latest technology already exists. The need of the hour is to educate the farmers regarding water depletion and provide them other support.

As against this, in southwestern part of the plain ground water is largely saline and unfit for irrigation. Therefore, canals are the main source of irrigation. The irrigated water seeps into the subsoil and underground water has been rising, so the problem of water logging has increased. Therefore on the one hand, due to over exploitation, water table is going down in much of the north eastern parts of the plain,
whereas in central and south western parts, water table is rising due to excess irrigation by canals and poor drainage system. This invariably results in the problem of water logging and salinity forcing lands going out of cultivation every year. All these spell trouble for the economy of a region heavily dependent upon agriculture.

The water table conditions in the plain as anywhere else in the country vary in the pre and the post monsoon period. The expansion of area under rice crop has been significantly associated with the lowering down of water table particularly in the north and eastern parts of the plain. During 1982-92 alone water table declined by about 9 metres in north-eastern and patches in central part of the plain. In extreme south-western part, bordering to Rajasthan, water table has also declined rapidly during the period. As against this, in the central and south-eastern parts water table rose continuously.

The salt-affected soils exist in almost all the districts of the plain in large or small patches around 0.48 million hectares area of the plain was salt affected in 2002. The saline soils can be reclaimed by establishing horizontal sub-surface drainage. In addition Green manuring should be practised. Land should not remain follow. It should always be under crops. Salt tolerant varieties of vegetables namely Palak, Beet root,
Garlic, Knol-Khol, Cabbage, Carrot, Turnip, Onion, Brinjal, Sem, Tomato, Potato etc. should be grown. Gypsum can be used to reclaim the alkaline soils.

Farmers of the plain need an alternate to the existing rice-wheat system particularly in the tube well irrigated areas. Sugar cane cultivation could be the alternate of rice-wheat system. It is important to note that the farmers of the plain have already begun showing interest in sugarcane cultivation, because water requirement of this crop is much lower than rice. Therefore, ground water table can be brought back to the optimal levels. It is also important that sugarcane gives higher profit than 'rice-wheat' system. 'Rice-wheat' system also requires application of high amount of chemical fertilizers, pesticides and irrigation, which is responsible for water depletion, water-logging and soil salinity. So it is necessary to divert some areas under rice and wheat to other crops such as gram, cotton, sugarcane, pulses, oilseeds, soyabean etc. In a broader sense diversification would also mean moving away from crop husbandry to other allied activities.

In water logged and saline areas, only salt resistant crops should be grown. Selection of crops should be done keeping in mind water table depth in the field, as the crops differ in their tolerance to salt and water.
Rice remains an ideal crop to grow when water table is very high. Elephant grass and sugarcane are also quite tolerant the high water table.

A heavy investment will be required for the reclamation of degraded land. It needs to be given serious attention in the coming plans. Steps should also be taken to put an end to the seepage of canal water, which has been responsible of water logging. Therefore irrigation projects have to be modernized to avoid further water logging and increase in soil salinity.

In water logged areas desired irrigation depth can easily be applied, water scarcity—even small discharges 4-6 litres can be handled more efficiently. Sodic water can be used for irrigation with necessary amount of gypsum, thereby we can maintain the soil health as well as sustain the crop yields.

Farmer also should be charged the actual cost of extracting ground water for its judicious use. Sprinkler irrigation, drip irrigation and land levelling may be the better device. Poor quality water can be used in conjunction with canal water for lowering water table. Therefore, these technologies in rice sector need to be adopted, which will not only prevent any further degradation of soil and water resources but also help in revitalizing them for long-term use.
In fresh water areas subsidy on power, diesel oil, rice seeds and credit for tube well should be removed. Government agencies should be strict in granting permission for power connection for tube well and extending loans for rice in over exploited ground water areas. It is time to pay attention to generating better information on use of underground water with active public involvement. Farmer's effective involvement in managing irrigation system is very essential for improving the operational efficiency and financial feasibility of Govt.-irrigation system. Therefore it is necessary to device incentives, which discriminate strongly in favour of farmer's groups and discourage individual service.

For an examination of the determinants and consequences of spread of rice cultivation at micro level, the village of Juan was selected. The village is located in Sonipat district to the north-west of the district headquarter by the same name at a distance of 17 kms. Rice cultivation has a history of 15 to 20 years in the village. Till early 1980s rice occupied a very insignificant position in the village. In Juan village rice cultivation has witnessed a tremendous spread during the last two-three decades. Farmers have begun rice cultivation because of they think that the crop is more remunerative than any other Kharif crop. Remember that high quality basmati rice is grown in the
village which when sold in the market fetches twice money as that of ordinary variety of rice. The farmers in the village are of the opinion that rice cultivation has brought about significant change in their economic conditions. Therefore, not many wish to switch over to other Kharif crops even if rice cultivation often leads to the problem of water depletion, water-logging and salinity/alkalinity. Some 15 to 20 years ago barely one fifth of the farmers devoted a major part of their cultivated land to rice crop. But, by the end of 2004 i.e. the time of the survey, 95 per cent of the farmers were growing rice on a major part of their land. Further, four-tenths of the farmers devoted more than 75 per cent of their land to rice. As a result, production of rice in the village has also witnessed tremendous increase. Increase in output can also be attributed to improvement in the productivity levels. However, at the higher level of productivity, per hectare output has already begun declining in the village. Attack of pests and diseases and deterioration in the overall fertility of soils are some of the main reasons for decline in productivity.

Expanding irrigation has been an important input for the spread of rice cultivation in the village. Tubewells are the main source of irrigation. However in areas underlain by brakish ground water, canal irrigation occupies a significant position. Due to excessive irrigation, water table
has undergone marked decline during the recent past. Farmers are more or less aware of the problem, and therefore, they are gradually using more of canal water for irrigation. In canal irrigated areas, water logging and salinity/alkalinity are coming up as common problems. As remedies, farmers use ‘desi khadh’, plant ‘desi kikar’ and apply gypsum. Sometimes, in the worst affected areas of salinity, the upper most layer of the soil is replaced by fresh fertile soil and irrigation is done by bringing fresh water from other areas by underground pipelines.

Rice is a labour intensive crop. Seasonal migrant labourers in the village fulfil the labour requirement. Farmers also put in family-labour in operations related with rice cropping, the extent of which depends upon the economic status of the household. Rice is a cash crop in the sense that almost the entire produce is sold in the market. While small farmers dispose off their produce in the nearby markets located in Sonipat and Gohana towns, large farmers take their produce to distant places in Delhi and Karnal for sale. Farmers often borrow loans from various sources including co-operative societies and banks for various cultivation related purposes.