Land Degradation in Uttar Pradesh: Causes, Extent and Intensity

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Abstract: *This paper focuses to assess the extent and intensity of land degradation due to various forms in Uttar Pradesh. Various forms of land degradation are assessed by taking the latest data from various secondary sources of central and state government sources. The intensity or severity of land degradation at districts level are measured by constructing indices through Ranking method, Index method and Principal Component Analysis (PCA) at the district and regional level in the state. However, the measurement of overall land degradation is based on the construction of index by using six different indicators. The proportion of wasteland to reported area, degraded forest to the reported area, annual rainfall data, percentage use of ground water and disproportionate use of fertilisers etc. are used for constructing the index. Based on the technique, Mirzapur in Eastern region stands on the first followed by Laxmipur in Central and Lalitpur in Bundelkhand region as second and third severe land degraded districts in the state.*

I Introduction

Land degradation occurs due to natural hazards, some direct and underlying causes, which deteriorate the fertility of the soil (FAO, 1994). Land shortage and poverty taken together lead to non-sustainable land management practices vis-à-vis soil degradation. On the other hand, defective agricultural practices would lead to deterioration of land quality (Reddy, 2003). Land degradation takes place largely in the form of soil erosion due to water. Water related erosion takes place due to direct and indirect causes. Direct causes are floods and surface run off, while indirect causes are due to excess or inappropriate use of water resulting in waterlogging and salinity. The impact of land degradation in the value addition of GDP or productivity or agricultural production has been described variously. The costs of land degradation were estimated as 4.5 percent of the GDP in 1992 in India (TERI, 1998). However, these kind of studies are unable to identify the problems associated at the regional level or due to specific kind of land degradation. Various studies identified the impacts of land degradation on the socio-economic condition of people in the irrigated command areas. The damage is often caused by the combination of irrigation induced salinity and waterlogging in different proportion. The canal irrigation network in the command areas due to the problems of soil salinity and waterlogging had generated a chunk on the fertility of the soil and made these areas out of cultivation (Jhosi and Agnihotri, 1984; Chopra, 1989). The problem of waterlogging and salinity reduces intensity and productivity of various crops, viz., rice, wheat, sugarcane etc. in the canal command areas (Government of India, 1979-80; Jhosi and Agnihotri, 1984; Abrol, 1984; Joshi, 1987; Yudelman, 1989; Chopra, 1989; Joshi, et al, 1992; Dinakar, 1993; Datta, et al, 2000; Reddy, 2003). Due to continuous decline of productivity of various crops, the investment made on resources use for cultivation has been declined (Jhosi and Agnihotri, 1984; Repetto, 1986; Joshi, 1987; Datta, et al, 2000). This further caused the decline in profitability and income of the farming class depending on these affected lands (Joshi, et al, 1992; Datta, et al, 2000). It affects the global climate through alterations in water and energy balance and disrupts in the cycles of carbon, nitrogen and other elements and different water born diseases become prominent in these areas (Joshi, et al, 1992; Dinakar, 1993; Datta, et al, 2000). The eventual impact became severe by declining of the cultivated land in the canal command areas (Joshi, 1987; Chopra, 1989; Datta, et al, 2000). It leads to economic, social instability due to intensive dependent on degraded land (Dinakar, 1993). Hence, the investment made on the development of canal irrigation in these areas became uneconomic to the society.

There has been tremendous pressure on land due to increase of population and livestock in various parts of the

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country (Iyengar, 2003; Reddy, 2003). At all India level, the population density between 1951 to 2001 has increased from 117 persons per sq km to 324. Along with the human population, the livestock population increased by 60.81 percent during 1951 to 1992. The unprecedented rise in human and livestock population has resulted in changes in land use and intensity of land use. However, the problem associated at the national level is not different from that of the state level. In Uttar Pradesh, total population has increased from 883. 41 lakhs in 1971 to 1661.75 lakhs in 2001. However, the density of population has increased from 473 persons per sq km in 1991 to 689 persons per sq. km in 2001. The density of population is also larger than that of national level in 2001. Moreover, total livestock population has increased from 494.04 lakhs in 1961 to 701.52 lakhs in 1993. The consequent result of the combined pressure of population and livestock has declined the land man ration from 1.16 hectares in 1971 to 0.86 hectares in 1996-97. Similarly, per capita net sown area has declined from 0.20 hectares in 1971 to 0.10 hectares in 2001in the state. No doubt, the productivity of foodgrains and non-foodgrains has increased to meet the requirement of food for the increased population. However, the increase of input intensification such as chemical fertilizer and pesticides, heavy use canal and groundwater and modern agro-mechanics has resulted both reversible and irreversible environmental damages to the areas under crops (Iyengar, 2003).

Objectives

In view of above background of causes and impacts of land degradation, the study would like to focus on the following issues in Uttar Pradesh. Firstly, to find the extent of various forms of land degradation explored by different organizations. Subsequently, the causes, consequences of each sub-category of land degradation are discussed under this section. Secondly, the overall land degradation or disparities of land degradation at the districts level are also estimated. The overall land degradation at districts level is estimated by constructing different indices by applying different techniques. Hence, thorough evaluation is essential for the above aspects by taking latest data in various regions as well as districts of Uttar Pradesh in order to provide right policy measures to enhance agricultural growth vis-à-vis economic development in the coming years for food security in a growing populated state.

Methodological Issues

Secondary sources data relating to sub-categories of land degradations such waterlogging, salinity, ravine lands, degraded forest land, fertilizer consumption, groundwater level data etc. are collected from various volumes of Statistical Dairies of Uttar Pradesh, Centre for Monitoring Indian Economy (CMIE), Fertilizer Statistics, Other State and Central Government reports. Various forms of land degradation at districts level is collected from National Remote Sensing Agency (NRSA), Government of India.

The study period is restricted 1970-71 to 2001-02 for aggregate level, such as fertilizer consumption, degraded forest land and irrigation by sources. In some cases, the study period is different depending on the availability of data. However, the groundwater recharge and its utilization at state and regional level are confined during 1987-2000 for four different time intervals. Moreover, degraded land and degraded forest areas at district level are collected from NRSA, whereas data on rainfall, groundwater utilization and fertilizer ratios are collected from state government sources. The latest data available from NRSA sources is on 2000-01 for 49 districts. Hence in order to keep balance for all other indicators in 49 districts, we have collected data on other indicators for the same year. For constructing indices for land degradation, we have taken 49 districts.

The judgment of overall land degradation across districts or regional level needs to combine different indicators into a single or composite indicator prominent at the district or the regional level. This raises issues regarding the weights assigned to different indicators and the technique used for their aggregation. The most commonly used methods for preparing a composite index are the ranking method, indexing method, principal component analysis (Singh, 2000).

The ranking method is the simplest and most commonly used method for preparing composite index. This method consists of assigning ranks for each indicator separately and simply totaling the ranks for each unit/ region to arrive at the aggregate rank. In this method all the indicators are assigned equal weights, which may not e always appropriate. This method also fails to take into account the extent of variations in the magnitude of difference between units.

The indexing method removes this limitation. Under this method, the value of an indicator for a region or district is expressed as a ratio or percent of the average value of all the units studied, which is often expressed as 100. The values are then added together to arrive at the total score on the basis of which the units are arranged in an hierarchical order. This method also assigns equal weights to all indicators and is also sensitive to extreme values of the indicators.

The principal component analysis is statistically more sophisticated method than the ranking or the index method. Under this method, weights are assigned to each variable on the basis of the correlation matrix. This method redefines a set of original variables into a new set of orthogonal variables called principal components. The component loading, which represents the correlation between the original variables and the derived components are used to calculate components scores. Normally the first principal component alone is used to calculate the scores but sometimes weighted average of more than one component may be used.

This article is divided into four sections. Section I deals with introduction, objectives and methodology of this study. While, Section II highlights the extent of various form land degradation at different regions of the state during 1970-71 to 20001-02. Section III describes the overall land degradation or difference in land degradation among major districts during 2000-01. Section IV deals with summary and conclusions of the study.

II Extent of Land Degradation in Uttar Pradesh

Various organizations are entrusted to collect data on land degradation starting from the village level to regional, state and national level. However, land degradation statistics are complied at the village level by the Patwari or Talati, which are further processed at district, state and national level. These statistics are published in the ministry of agriculture in different state governments as well central government (Iyangar, 2003). In addition, the international organizations, viz., UNDP, FAO and UNEP also estimate the data on land degradation.[2] The government estimate cover five broad categories of degradation namely, water erosion, wind erosion, waterlogging, salinity and nutrient depletion. Moreover, National Remote Sensing Agency is also collecting data on land degradation by using remote sensing technique at the districts level in the country. It provides more detailed information including mining and industry related degradation. The methodology and techniques used for collection of these data are different by these organizations. Hence, there has been a lot of difference in the classifications of sub-categories of land degradation and the extent in the sub-categories as well as in the aggregate level differs by various organizations. But, the seriousness of the problem is well agreed by all of the organizations.

The problems associated with land degradation at the National level are no way different from the state level. In Uttar Pradesh, the state planning commission estimated nearly 74.48 lakh hectares of land, which is 30.77 percent of the reporting areas are degraded land (Table 2). On the other hand, NRSA estimated nearly 38.84 lakh hectares, which is 13.19 percent of the geographical area of the state, are degraded. The trend of data on land degradation by remote sensing is lower than that of the state government estimation is explained variously. Remote sensing techniques (RSTs) have poor capabilities in respect of ascertaining sub-surface degradation and nutrient losses. So far as sub-surface waterlogging is concerned, remote sensing technique is just not capable of any estimation (Dhar, 2004). Hence, the quantitative estimates in respect of rill and wind erosion can not be reliable. In such cases, it would be prudent to believe the state government's data on land degradation, which are akin to ground realities. Secondly, NRSA provides information on gullied/ravine lands and land with or without scrub, which represents land under water and wind erosion. But the magnitude is marginal compared to that of water and wind erosion given by state record (Reddy, 2003).

[2] The classification of land use data has been developed historically. Prior to the introduction of agricultural planning in 1950, the land use data were in five categories. However, during the planning period (after 1950) these were developed and the detailed classification were made into nine categories (for details see, Iyangar, S., 2003)

Table 2: Land Degradation in Uttar Pradesh (in Lakh hectares)

Types of degradation/Year	NRSA (2000-01)	GOUP (2002)
Soil Erosion	-------	36.82
Salt Affected area	5.81	7.63
Waterlogged Area	4.98	7.30
Marshy/Swampy Area	0	-------
Gullied /Ravines Area	2.81	9.23
Land With or Without Scrubs	5.5	------
Sandy Area	0.47	----
Riverine land	0	13.5
Barren/Stony/Sheet Rock Area	1.18	------
Shifting Cult	0	-----
Grass/Grazing Lands	0.45	------
Degraded Plantation Crops	0.05	------
Degraded Notified Forest land	3.4	-----
Salt/Pans/Snow Covered	13.17	------
Steep sloping area	0.99	------
Mining Area	0.03	---
Total Wasteland Area	38.84	74.48
Total Geographical / Reporting area	294.41	242.02
Percent of the Reporting Area	13.19	30.77

Source: NRSA, 2000-01 and Government of Uttar Pradesh, 2002-03

Note: Total geographical area differs from NRSA estimation to GOUP estimation; NRSA has estimated the land degradation before the division of Uttaranchal, whereas GOUP estimation is based on after the division.

The problem of land degradation is more severe at the regional and district level. Some districts such as in Lalitpur and Bahraich has 25 percent and 23 percent of the reporting area are degraded land respectively. Similarly, nearly 10 to 20 percent of the reporting areas are degraded land in another seventeen districts (Dhar, 2004). According to NRSA, Western and Central regions are mostly affected regions in the state. However, NRSA estimates nearly 12 percent and 13 percent of the reporting areas are degraded at Central and Western region. The estimation of land degradation by the Groundwater Department, Government of Uttar Pradesh differs from the estimation of the NRSA. The sub-classification data on land degradation has not been estimated by the Groundwater department. However, the data on waterlogging broadly represents different forms of degradation. In the state, most of the lands are affected by salinity/alkalinity due to persistence problem of waterlogging and marshy/swampy areas. Based on this estimation, Eastern and Central regions have 54.81 percent and 36.53 percent are degraded land followed by Western region having 27.20 percent are degraded land. The comparison of various forms of degraded land at district or regional level between NRSA and state government data is not fully appropriate as there is no availability of data at most of the districts given by the state government.

1. Waterlogging

Waterlogging not only mean that the rise of water table above the surface areas but also it covers in the sub-surface areas. However, it is more problematic in the sub-surface areas. The definition of waterlogging differs among the various organization depending on the area and soil conditions. However, Groundwater Department, Government of UP has defined waterlogging in the state based on the soil conditions and water level, which is more relevant for measuring the extent of waterlogging in the state. There are four categories of waterlogging area in the state. Firstly, wet lands include marshy land and pond areas, where water level may be above the ground surface or perched waterlogging conditions prevails. Secondly, critical waterlogged areas such areas in clay loam soils within 2.0 meters of groundwater level in post-monsoon month and capillary rise of groundwater reaches the ground surface. Thirdly, semi critical areas fall between 2.0 to 3.0 mbgl level and groundwater capillary rise reaches the root zones of cereals crops in clay loam to sandy loam soils. Fourthly, potential for waterlogging covers between 3.0 to 5.0 mbgl, where excessive surface water irrigation and poor groundwater pumpage in such areas may create waterlogging problems (Government of UP, 2003). It is estimated that 45.84 lakh hectares of land coming under 0 to 2 meters below the groundwater, 38.09 lakh hectares are in the 2 to 3 meters range in the post monsoon of 1996. In other words, 83.93 lakh hectares, which is nearly 42 percent of the reported land of the state is waterlogged (Table 3). The level of waterlogging has declined marginally to 79.63 lakh hectares, which is nearly 40 percent of the reporting area during the post-monsoon of 2000 in the state. Waterlogging becomes a widespread problem especially in Eastern and Central region of the state not only due to recurrent floods but also rise of the water table above and very close to surface areas due to absence of well drainage system in the irrigated canal areas. It is estimated that just a little under one third of land area in the state is affected by surface and sub-surface waterlogging (Dhar, 2004).

Table 3: Region wise Waterlogged Area in Uttar Pradesh (in lakhs hectares)

Region	Reported area	Waterlogged Area (0-2.0 mbgl)		Waterlogged Area (2.0-3.0 mbgl)		Total	
		1996	2000	1996	2000	1996	2000
Eastern Plains	45.28	11.35	7.26	8.90	9.28	20.25 (44.72)	16.54 ((36.53)
Central plains	75.02	23.59	15.70	17.31	25.42	40.90 (54.52)	41.12 (54.81)
Western plains	80.77	10.90	9.81	11.88	12.16	22.78 (28.20)	21.97 (27.20)
UP Plains	201.07	45.84 (21.84)	32.77 (16.30)	38.09 (18.90)	46.86 (23.31)	83.93 (41.74)	79.63 (39.60)

Source: Government of Uttar Pradesh, 2004, p.14.5

The key requirement is to reduce the water table in the waterlogging areas. That would possible by reducing seepage of recharge and use of shallow tube wells for irrigation. However, reliable data on sub-surface and waterlogging and appropriate water management strategies are needed. The appropriate water management strategies such as conjunctive use of water (reducing canal irrigation in such areas on the one hand and increasing shallow acquifer groundwater pumping on the other for such areas), proper drainage, appropriate crop rotations, and even use of water absorbing hydropaths (tree species that absorb water, i.e., eucalyptus). Various strategies are suggested for better implementation of conjunctive use of irrigation in the waterlogged areas. Firstly, it is recommended to go for a conjunctive use of surface and use adequate quantity of groundwater from the tubewell irrigation, so that the pre-monsoon groundwater level should be around 10 meter below the land surface in such places where canal irrigation is in operation. Secondly, analysis of data from rainfall, canal water usage, ground water use and the groundwater level in each canal command areas has to be done to decide the exact and most suitable conjunctive use of surface and groundwater to attain the maximum crop production. It is desirable to equip the officers of the irrigation department with computers and employ suitable staff to operate them and sue their analytical results. Thirdly, it is necessary that pizometers should be installed in all villages to watch the rise and fall of water table to monitor the use of canal and groundwater. Fourthly, in the areas where the water table has declined below 20 meters of land surface, it is desirable that the canal irrigation might be introduced and conjunctive use of surface and groundwater should be planned in such a way that the ground water table is not allowed to rise beyond 10 meter below land surface. Fifthly, the farmers who use the groundwater in canal irrigated areas, where canals are not closed should be given incentives. Sixthly, each cultivator should be encouraged to have one piezometer installed in his filed. They should be advised to observe the water table regularly and to maintain the water table preferably below 4 meter in sandy soil and below 6 meter for silty and clay soils from land surface in rabi season.

2. Salinisation

Saline soil 'which contains excess neutral soluble salts, chiefly chlorides and sulphate of sodium, magnesium and calcium in the quantities is sufficient to affect plant growth adversely. The salt affected soils are distinguished on the basis of chemical composition by three categories. Firstly, saline soils, which are characterized by chlorine and sulphate. Secondly, alkaline soils, which are preponderance of carbonate and bio-carbonate. Thirdly, saline-alkaline soils have both the contents, which are difficult to reclaim.

The origin of salinity directly or indirectly comes from waterlogging problems. The intensity of salinity also depends on the soil type, hydrogeology, climatic condition, and irrigation practices (Rai, 2003). Hence, the estimation of only saline soil is very difficult as salinity developed due to waterlogging in the flood affected and irrigated areas as well as non-irrigated areas due to the existence of salt content in the soil. Therefore, salinity/alkalinity occurs in the waterlogged areas as well as other fallow and wastelands. The major wasteland/ fallow lands can be mainly grouped under four categories such as usar and uncultivable wastelands, culturable wastelands, current fallows and other fallows. In general sense, the current fallows and other fallows are not grouped in the category of sodic land but such areas are not in cultivation. So, it can be counted as unproductive lands and some of these areas are classified as wasteland. The experience indicated that most of these wastelands are closely related with waterlogging conditions (Rai, 2003). In most of these cases, sodic land is the consequence effect of waterlogging and wide areas of fallow lands fall in waterlogged zones. The usar soils of waterlogged areas can be categorized in three sub-groups, such as 'A' type usar with moderate pH 8.0-8.5 (double cropped but poor crop yield), 'B' type usar, with moderate to high pH 8.5-9.5 (mono-cropped and poor yield), 'C' type barren usar land with pH>9.5.

Table 4: Extent of Wasteland/ Fallow Lands (in lakh hectares)

Types of waste land/fallow land	1950-51	1960-61	1970-71	1978-79	1990-91	1996-97
Usar land	14.98	11.40	9.96	11.46	10.35	9.78
Cultivable waste	23.11	16.40	13.45	13.38	10.34	9.45
Current Fallows	10.46	1.46	8.70	9.32	10.84	10.67
Other Fallows	2.91	12.60	5.46	6.07	8.84	8.33
Total	41.36	41.86	37.57	40.23	40.37	38.23

Source: Board of Revenue, Government of Uttar Pradesh (1997-98).

Uttar Pradesh Government has been undertaking serious measures for reclaiming degraded land even before the plan era. However, reclamation of degraded land has a long history in the state. In 1884, 1200 hectares of ravine lands were forested by the then collector of Etawah (Dhar, 2004). In 1870, the Reh committee suggested deepening of canals for reducing saline efflorescence area due to over-irrigation in the districts of western Uttar Pradesh. The use of gypsum arrived later towards the end of 19^{th} century. In the post independence period, saline reclamation started in 1949 in the districts of Central and Western region of the state. In the last decade, many important schemes are being undertaken for the reclamation of saline land in the state. Most importantly, Uttar Pradesh Bhumi Sudhar Nigam (UPBSN) started reclaiming saline land with the support from World Bank in 1993. Moreover, the second phase of the same project was extended in 1999 to reclaim barren alkaline and other usar land in the severe affected districts of the state However, it is estimated that out of 12 lakh hectares of Usar land (Saline, Alkaline and saline-alkaline), only 1.6 lakh hectares of land are reclaimed (Government of Uttar Pradesh, 2004). The task is very much significant in the future years to reclaim the degraded land in the state. We can not forget the importance of food security in a growing populated state, where pressure on land is increasing.

Various methods are useful to control the salinity problems in the irrigated land. Firstly, the proper use gypsum in terms of quantity and periods are very essential to eradicate the salinity problems in the soil. Secondly, the consumption of chemical fertilizers can be reduced by using organic fertilizers. Biological control technique for pest and disease control etc. can be made easily available at a subsidized rate. Proper agricultural extension services to advise and educate the farmers on the application of fertilizers and pesticides. Thirdly, in order to reduce soil degradation, it is required that fertilizer of right type is applied in optimum quantity at the right time. For example, in the beginning of plant growth, requirement is low and therefore, level of application should be low.

3. Deforestation

There are various activities, which cause for the deforestation in the state. The direct causes of deforestation are land clearance for agriculture (including shifting cultivation), urbanization, construction of roads, bridges, irrigation dams and canals, different forms of encroachments, overgrazing, excessive fuelwood collection and logging etc. (Dutta et al., 2005). Forest lands are important source of grazing and fodder in the absence of adequate land and a viable policy of the fodder development.

The recorded forest area of the state is 51.66 lakh hectares, which constitutes 17.55 percent of its geographic area in 1997. By legal status, reserved forest, protected forest and unclassed forest constitute 70.51, 2.90 and 26.59 percent of the total forest respectively. Total forest area has increased from 10 percent in 1950 to nearly 18 percent in 1997 and declined to 7 percent in 2000 in Uttar Pradesh (Table 5). The decline of the forest area below 10 percent in 2000 is the bifurcation of Uttaranchal from the state. However, over the last 50 years the forest area covered in the state has been lower than that of the average of India. There has been 14 .26 lakh hectares of forest area, which constitutes nearly 5 percent of the geographical area degraded in the state. However, NRSA estimates that 2.24 lakh hectares of degraded forest land constitute nearly 2.5 percent of the total geographical area. Mirzapur covers nearly 52 thousand hectares of degraded forest and it is highest in the state.

Table 5: Area under Forest in Uttar Pradesh (in lakh hectares)

Year	Total Geographical Area	Area under Forest Dept.			Others	Total	Area under open Degraded forest	Forest as percent of TGA	Degraded forest as percent of TGA	Forest as percent of TGA in India
		Reserved	Protected	Total						
1950	294.41	NA	NA	24.72	5.52	30.25	NA	10.27	NA	22.34
1960	294.41	NA	NA	35.17	6.13	41.30	NA	14.03	NA	20.98
1970	294.41	NA	NA	40.98	8.56	49.53	NA	16.82	NA	22.75
1980	294.41	NA	NA	40.68	10.61	51.30	NA	17.42	NA	22.41
1990	294.41	NA	NA	41.04	10.58	51.62	NA	17.53	NA	22.38
1995	294.41	36.15	1.06	37.21	14.29	51.50	14.26	17.49	4.84	23.36
1997	294.41	36.42	1.50	37.92	13.74	51.66	14.26	17.55	4.84	23.28
2000	240.93	12.59	1.38	13.97	3.03	17.00	14.26	7.06	5.92	19.39

Source: Government of India 1997, 99, 2001 and Various Volumes of Statistical Abstract of Uttar Pradesh

4. Soil fertility decline

It is more precisely described as deterioration in physical, chemical and biological properties of the soils. It occurs through a combination of lowering of soil organic matter and loss of nutrients. The main processes involved are the following. 1. Lowering of soil organic matter with associated decline in soil biological activity. 2. Degradation of soil physical properties (structure, aeration, water holding capacity) as brought about by reduced organic matter. 3. Adverse changes in soil nutrient resources, including reduction in availability of the major nutrients, i.e., nitrogen, phosphorous, potassium. 4. Buildup of toxicities, primarily acidification through incorrect fertilizer use.

Over the last 35 years, there has been a large increase in fertilizer consumption in India associated with the introduction of high yielding crop varieties. This has become major reason for increase of crop productivity. However, an inter related set of soil fertility problems has been reported, directly or indirectly associated with fertilizer consumption (Bowonder, 1981). **Imbalances in Fertilizer application**: Fertilizer use in the region is dominated by nitrogen; N: P and N: K ratios are higher than in the other parts of the world. The N: P: K ratio for India is 1:0.33:0.17 compared with 1:0.52:0.40 for the world (FAO, 1994). When fertilisers are first applied to a soil, high response is frequently obtained from nitrogen. The improved crop growth depletes the soil of other nutrients (FAO, 1994). The same trend has been observed in Uttar Pradesh during 19970-71 to 2001-02 in different regions. However, the ratio of N and P with respect to K has been increasing over the study period in all the regions as well as the State level (Table 6). Moreover, the NPK ratio is observed unbelievable in Bundelkhand region due to the application of negligible amount potassium in the soil.

The impact of excess and disproportionate consumption of fertilisers has been explained variously. The crops and plants cannot take all the fertilizers applied and significant portion is lost in the soils. It means, application of more than the required quantity of fertilizers remains in the field, ultimately leads to polluting the soils. The excess or inappropriate consumption of various fertilizers than the recommended quantity or ratio leads to polluting the soil, which ultimately causes for the decline of productivity of various crops. The excess amount of nitrogen applied in the soils automatically converts into nitrate. As nitrate is not observed by most soils, it remains in solution. If it is not taken up by plant roots, it is either washed into the drainage water or biologically reduced to dinitrogen gas. Nitrate that is washed out of the soil represents an economic loss to the farmers and possible health hazard if it reaches drainage water (Wild, 2003). Dev, et al. (1995) found that one of the effects of excessive fertilizer use is the contamination of ground water. Rao (1994) found that the major source of environmental degradation in rural areas is the misapplication of yield increasing inputs like water, chemical fertilizers, and pesticides causing waterlogging, salinity and pollution of drinking water and loss of fish etc. However, chemicalization of agriculture may pose a greater threat to the rural economy at much higher levels of application of chemical fertilizers and pesticides. High doses of fertiliser lead to salinity in the soil (Singh, 1997).

Table 6: Region wise Fertilizer Consumption in Uttar Pradesh (000' tones)

	Year	**Total Fertilizer**	**Nitrogen**	**Phosphatic**	**Potassic**	**Ratios**
Uttar Pradesh	1970-71	410.54	291.43	74.51	44.61	7:2:1
	1980-81	1150.59	860.64	209.34	80.61	11:3:1
	1990-91	2240.91	1690.66	453.98	96.26	18:5:1
	2000-01	2961.82	2206.5	662.09	93.24	24:7:1
	2001-02	3352.13	2503.54	749.76	98.83	25:8:1
Central	1970-71	27.51	20.32	4.47	2.73	7:2:1
	1980-81	97.15	75.21	15.47	6.47	12:2:1
	1990-91	207.06	156.72	41.79	8.54	18:5:1
	2000-01	304.24	216.51	80.84	6.9	32:12:1
	2001-02	388.48	282.03	99.7	6.76	42:15:1
Eastern	1970-71	151.71	104.18	28.31	19.22	5:1.50:1
	1980-81	399.91	295.55	71.89	32.45	9:2:1
	1990-91	696.46	496.27	163.69	36.51	14:4.50:1
	2000-01	913.54	684.52	196.51	32.53	21:6:1
	2001-02	1024.96	784.65	211.8	28.53	27.5:7:1
Bundelkhand	1970-71	7.45	4.83	1.89	0.75	6.5:2.5:1
	1980-81	27.76	17.56	9.13	1.06	17:9:1
	1990-91	58.99	36.88	21.61	0.52	71:42:1
	2000-01	79.11	45.3	33.63	0.21	215:160:1
	2001-02	92.51	56.09	36.31	0.13	431:280:1
Western	1970-71	195.2	141.61	35.05	18.58	8:2:1
	1980-81	546.57	416.51	96.07	34.01	12:3:1
	1990-91	1020.24	762.74	220.78	36.7	21:6:1
	2000-01	1367.89	1051.34	270.91	45.61	23:6:1
	2001-02	1544.32	1156.92	329.53	57.83	20:6:1

Source: Various Volumes of CMIE.

The study by APPCB (2000, p.17) revealed that "the per hectare yield of paddy, maize & cotton has increased more in between 1972 and 1982 but much less between 1982 and 1992. Similarly, the per hectare yield of groundnut and sugarcane has declined between 1982 and 1992. According to departmental statistics, chemical fertilizers seem to have peaked in productivity per hectare between 1978 and 1986. Thereafter, there has been a steady decline in productivity." Moreover, the same study also found that the constant, unbalanced use of chemical fertilizers has left the soils in a totally bad shape. However, there is not much scope for attaining growth through increasing fertilizer use except in selected pockets of the state with the existing technology and irrigation level (Subrahmanyam, et al., 2003).

5. Groundwater Depletion

Groundwater plays a vital role for the integrated sustainable development of an area. On the one hand, it's judicious and balance use can optimize and sustain agricultural growth, on the other hand, excessive or under utilization of groundwater may cause adverse impacts. In the areas of excessive groundwater pumpage causes lowering of water level, which further causes failure of the water structures, land subsidence and eventually make the water polluted. In the areas of excess recharge of groundwater over poor pumpage may cause flooding, surface and subsurface waterlogging, which further causes water pollution and health hazard (Rai, 2004). In the state, the groundwater level has been declining due to heavy use of private and public hand pump sets and tubewells for domestic, agricultural, industrial and other uses in both urban and rural areas. However, it has been observed that the groundwater level has been declining up to strata-II (80-90 feet) in many urban areas of the state and it has crossed the strata-I (40-50 feet) in rural areas. Unless, there have been enough mitigating efforts, the problem of groundwater depletion is not far away to cross strata–III. The depletion of groundwater further enhances the economic and environmental problems to the society. The cost of pumping per hour through groundwater by electric/ diesel pump sets increases further as groundwater level go down, which eventually increase the cost of agriculture. The depletion of groundwater causes a serious threat on environment, as it affects in different ways. Firstly, declining of water table has major implications for the base flow of the stream. If affects the down stream users' as they loose access to water at critical times and pollution both surface and groundwater is likely to increase. It affects many shallow small streams as they became dry after rainy season and even big rivers are become dry. This ultimately affects the availability of drinking water. Secondly, as the water content declines in the soil, soil becomes more and more dusty and ultimately become prone to wind erosion. Thirdly, as the water content declines, it affects the trees, grass and other animal for useful needs. Fourthly, over extraction of groundwater affects the water quality directly. Sometimes, pollution poses a serious threat to all groundwater aquifers in the state. With the expansion of irrigated area and increased use of fertilisers and pesticides groundwater gets polluted ultimately causes health hazard.

The level of groundwater can be examined by three sets of data, such as volumetric data on groundwater, irrigated area statistics, data on water table to analyse the major aspect of groundwater depletion or the decline of water table (Dhawan, 1995). In a volumetric approach, the statistics of groundwater recharge and groundwater utilization are compared with each other. Groundwater depletion is signified by groundwater use for irrigation purpose exceeding groundwater recharge in a long run. The essential of the area approach are similar to those of the volumetric approach, the difference being use of utilization of groundwater irrigation potential instead of groundwater recharge and resource to be created groundwater potential in lieu of groundwater draft. As the information on water table is concerned, depth of water table is measured in selected observation of wells. The Central Groundwater Board and State Groundwater Department measures the water table on regular basis through selected depth of wells. The case of over exploitation arises, when the pre-monsoon and post-monsoon depth to water table in a well increases permanently.

The region wise comparison of groundwater recharge and its level of exploitation over a period for irrigation as well as other uses are depicted (Table 7). There is widespread disparity in the use of groundwater exploitation over regions/ districts as well as major river basins in the state. The level exploitation of groundwater in the western region is always highest followed by central and eastern region. Some of the districts namely Buduan and Bagpat exploit nearly 90 percent and 82 percent of the total available groundwater in western region respectively. Similarly, Laxmipur kheri and Sitapur utilize 81 and 73 percent whereas Barabanki utilizes only 24 percent of the total available groundwater in the central region respectively. The districts such as Gonda and Ambedkar Nagar utilizes 68 and 63 percent, on the other hand Kushinagar utilizes only 25 percent of the total available groundwater respectively in the eastern region. However, the level of exploitation is being lowest in Bundelkhand region. Lalitpur district utilize highest up to 54 percent and Jalaun utilizes only 19 percent of the available groundwater respectively. The level groundwater exploitation is highest in the western region as it is scanty rainfall area and having less canal irrigated area. Moreover, the groundwater recharge and its level of exploitation during 1987-2000 in all the regions as well as the state level have shown a increasing trend. However, the volumetric data on groundwater recharge and its level of exploitation over a period of time in the state, does not show the actual level of groundwater depletion and its intensity of threatening to the animal beings.

Table 7: Region wise level of groundwater recharge and use during 1987-2000 (in '000 ham)

Year	Region	Central	Eastern	Bundelkhand	Western	UP
1987	Net Groundwater earmarked for irrigation (`000ham)	1428.96	2362.39	548.57	2674.61	7014.53
	Groundwater used for Irrigation (000ham)	293.26	697.27	94.68	1018.80	2104.01
	Percent groundwater used for irrigation	20.52	29.52	17.26	38.09	30.00
1990	Net Groundwater earmarked for irrigation (000ham)	1423.96	2456.12	498.11	2516.72	6894.91
	Groundwater used for Irrigation (000ham)	482.90	882.60	100.70	1144.41	2610.61
	Percent groundwater used for irrigation	33.91	35.93	20.22	45.47	37.86
1995	Net Groundwater earmarked for irrigation (`000ham)	1422.79	2496.88	502.22	2258.14	6680.03
	Groundwater used for Irrigation (000ham)	561.08	905.09	95.07	1038.46	2599.70
	Percent groundwater used for irrigation	39.44	36.25	18.93	45.99	38.92
2000	Net Groundwater earmarked for irrigation (000ham)	1892.89	2698.54	664.33	2774.97	8030.74
	Groundwater used for Irrigation (000ham)	1053.44	1324.24	174.04	1843.35	4395.08
	Percent groundwater used for irrigation	55.65	49.07	26.20	66.43	54.73

Source: Groundwater Department, Government of Uttar Pradesh

It has been observed that out of 819 blocks in the state, declining trend of groundwater is being observed in 559 blocks. Nearly 19 blocks are identified, where the water level declined more than 15 meters. In the latest assessment, 22 blocks are under critical category and 53 blocks are in semi critical category (Jurel, 2003). However, this is not the end of the story. The reliability of shallow tube wells as sources of drinking water has been reducing due to groundwater extraction from agriculture and fluctuations in water table. In fact due to declining of water level, most of the drinking wells have dried up in the plains of Uttar Pradesh affecting the availability of drinking water in rural areas. It is projected that over 40 lakh hectares of agricultural land affect badly in 260 blocks of the state. These areas have been already declared problem zone in western and eastern regions of the state (The Times of India, 2004).

7. Secondary Salinisation

Sodic lands are being reclaimed by the UP Sodic Land Reclamation Projects in the districts of Unnao, Rae Bareilly, Sultanpur, Hardoi, Barabanki by using gypsum in the soils. However, curative method is not enough for land reclamation in a sustained basis. Due to rise in the water table in those areas, the reclaimed sodic soils are reversed to alkalinity again (Dhar, 2004).

II Overall Land Degradation at the Districts Level in the State

The present study explores the possibility to construct a representation for land degradation in totality and to identify the major issues related to land development by the state government and other agencies. Land degradation occurs through different other indicators. It is not only reflects the wasteland but also some invisible indicators like groundwater depletion and disproportionate use of fertilizer consumption. The purpose is to combine all the possible indicators into one composite index and to identify more severe and less severe districts in the state.

All the three methods such as simple ranking, indexing and principal component analysis have been used to combine different indicators to prepare a composite index for land degradation. The ranks of districts in the overall composite index according to all the three methods used are then compared and classify into three categories, i.e., severely affected, moderately affected and less affected districts.

The measurement of overall land degradation at the districts or regional level has been estimated by using major six indicators and tested by all the three techniques. In this regard, two types of indices are constructed for measuring the overall land degradation at the district level in the state. The first index is constructed by taking data on percentage of degraded land to the reported area, percentage of degraded forest and annual rainfall. These indicators are more visible and the impacts are felt immediately. Hence, clubbed into one category. The second indicator is constructed by adding percentage of groundwater utilization to total recharge and the ratio of fertilizer consumption (NPK). However, the first category of indicators is tested by applying both ranking and indexing method and the second category of indicators are applied through all the techniques.

The selection of indicators for constructing a composite index is a complex phenomenon and sometimes become controversial. However, considering the theoretical background of many indicators, we have selected only six indicators for representing total land degradation in the state. The most important indicator for representing the land degradation is various type of wasteland. Total wasteland consists of the 13 fold classification of the NRSA. The 13 fold classification is mentioned earlier. The second indicator for land degradation is total degraded forest. However, it is absent in some of the districts and also severe in other districts. Annual rainfall is considered as an indicator for overall land degradation because of its variability within regions, within months in a year and years. Less rainfall area is more prone to drought and high rainfall area lead to floods. Sometime heavy rainfall in a month or two cause floods and other part of the year remain dry. Some regions consistently face drought because of low and inconsistent rainfall, whereas other regions of the state face heavy floods. Hence considering its background, we have taken the inverse of the tri-annum average of rainfall data for constructing the indices. Because, low rainfall will have high value and high rainfall will have low value. In other words, high value reflects more damages to land and other wise. Another important indicator, i.e., the percentage of groundwater utilization out of net groundwater availability for only irrigation has been considered for the composite index. The last but not the least indicator, i.e., the consumption of N, P and K out of total fertilizer is also considered for constructing an index of overall land degradation. No doubt, fertilizer along with irrigation (or alone in non-irrigated area) plays an important role for raising the productivity of various foodgrain and non-foodgrain crops. However, the exact proportional use of N, P and K based on soil and climatic condition would able to maintain the required nutrients in the soil and enhance the productivity on a sustained basis. On the other hand, disproportionate use of the N, P and K may cause the loss of some nutrients in soil, hence no further scope for raising the productivity. The proportionate use of N.P.K is 4:2:1 as recommended in all India level. However, it may be varied in the state level as the soil, climatic and cropping pattern changes. But, it is highly different, i.e. 25: 7:1 in the state in 2000-01. It means, nearly 57 percent nitrogen, 29 percent phosphorous and 14 percent potassium of the total fertilizer consumption should be applied. However, nearly 73 percent nitrogen, 24 percent phosphorous and 3 percent potassium is applied in the soil. So, Nitrogen variety is applied higher than the required amount, whereas both phosphorous and potassium variety is applied less than required amount. It has two types of implications for the soil requirement. On the one hand, there is nutrient loss supplied by P and K variety and on the other hand there is surplus or wastage of nutrients supplied by the N. Hence, we have taken all the three varieties of fertilizer for the construction of the composite index. However, in order to avoid the unusual effect on a particular year, we have taken the tri-annum averages of rainfall and fertilizer consumption data. Some times statistics never goes together with the reality. Including all the seven indicators, the results are felt statistically insignificant. Hence, the percent of K to the total fertilizer consumption has been dropped. Exploitation of minerals is considered as one of the important indicators, but the availability is spreaded only in few districts. Hence, it is excluded form the list.

Analysis of the results of PCI

It is combination of multiple variables in the form of one derived variable, which captures to a maximum extent to portray all the original variables (Tacq, 1997). It is used to identify a relatively small number of factors that can be used to represent relationship among sets of many interrelated variables. Thus factor analysis can help in explaining complex phenomenon in terms of a small number of factors. The factors are inferred from the observed variables and can be estimated as linear combination of them. The functional form of factor analysis is as follows.

$$Z_i = U_{11} X_1 + U_{12} X_2 + U_{13} X_3 + U_{14} X_4 + U_{15} X_5 + U_{16} X_6$$

Where, U_{ij} is the matrix of factor score co-efficient. X_1 is the percent of wasteland to total geographical area, X_2 is the percent of degraded forest land, X_3 is the inverse of tri-annum average rainfall, X_4 is the percent of ground water utilization to total net recharge for irrigation, X_5 is the percent of N to the total fertilizer consumption, X_6 is the percent of phosphorous to the total fertilizer consumption.

The correlation co-efficient in matrix indicate the association between pairs of variable in the data matrix. It shows that higher the co-relation co-efficient means stronger the relations between the pairs and vice-versa. However, some of the variables such as X_1, X_2 and X_5, X_6 are highly correlated , i.e., 0.74 and -0.98 respectively (Table 8). Some of the other variables are moderately co-related.

Table 8: Correlation Matrix of Indicators of Land Degradation

	X_1	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**
X_1	1.00	0.74	-0.08	-0.15	-0.35	0.36
X_2	0.74	1.00	-0.28	0.00	-0.16	0.12
X_3	-0.08	-0.28	1.00	0.18	-0.01	0.05
X_4	-0.15	0.00	0.18	1.00	0.39	-0.41
X_5	-0.35	-0.16	-0.01	0.39	1.00	-0.98
X_6	0.36	0.12	0.05	-0.41	-0.98	1.00

Source: Estimated

The analysis of Eigen value shows the degree of success in condensing the data. There are 6 PCs are estimated, as, there are 6 variables in our analysis. The first PC captures nearly 43 percent of the total variance, where as the first three PCs together accounts for as much as 86 percent of the total variance (which is measured by the Eigen values).

Table 9: Eigen Values of Various Factors

Factor	Eigen value	% of Variance	Cumulative %
1	2.58	42.93	42.93
2	1.53	25.55	68.48
3	1.06	17.59	86.07
4	0.61	10.20	96.28
5	0.21	3.44	99.72
6	0.02	0.28	100.00

Source: Estimated

The component matrix explains the relationship between components and variables. The first three PCs explain better for all the variables in our analysis. However, PC_1 explains X_1, X_5 and X_6, PC_2 explains X_2 and PC_3 explains X_3 and X_4 at a better rate (Table 10). The square of correlation coefficients can be interpreted as a proportion of explained variance. The loading of X_1 on PC_1 is 0.69. The square of $(0.69)^2 = .4761$, that means nearly 48 percent of the variance X_1 is explained by the PC_1. Similarly, nearly 78 percent of the variance $X_{5,}$ X_6 is explained by the PC_1. On the other hand, nearly 62 percent of the variance X_2 is explained by PC_2. However, both X_3 and X_4 explain 64 and 32 percent of their variance respectively to PC_3. Beyond that none of the PC explains at a higher variance to any of the variables.

Table 10. Analysis of Component Loading

	Component					
Variables	1	2	3	4	5	6
X_1	0.69	0.55	0.28	0.21	0.31	-0.01
X_2	0.51	0.79	0.13	0.04	-0.31	0.01
X_3	-0.15	-0.45	0.80	0.37	-0.09	0.00
X_4	-0.53	0.30	0.56	-0.57	0.05	0.00
X_5	-0.88	0.38	-0.07	0.26	0.05	0.09
X_6	0.88	-0.41	0.10	-0.21	0.01	0.09

Source: Estimated

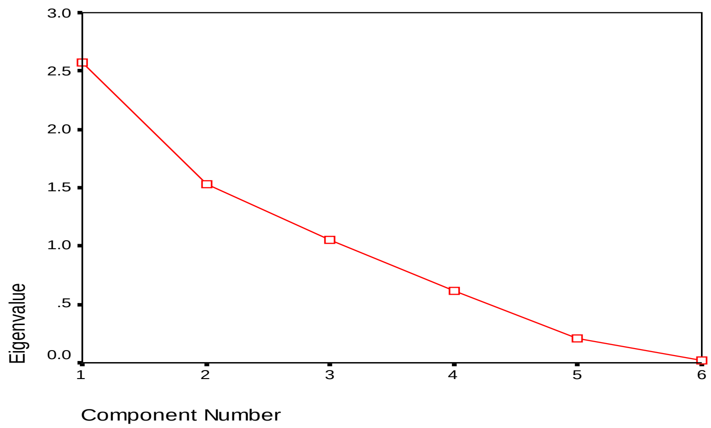
The selection of components for final composite index is based on certain criteria.

Kaiser (1959) says retain only the components of which the Eigen value is greater than 1. Considering this criterion, we can retain the first three PCs in our case study. However, this criterion has also some limitations. Some times some variables explain at higher variance to the PC having less than 1 Eigen value. Of course this is not applicable to our case. In another case, Singh (2000) explains that the final composite index can be constructed by two ways. One PC can be taken if it explains nearly 70 percent of the total variance. In cases where first PC accounted less 70 percent of the variation, a weighted composite index was used by aggregating the factor scores of the first and second (in some cases the third) PCs using the percent of variation explained as the weights. In the second stage, the composite index can be constructed by taking all the PCs. However, considering this guidelines, we can take the first three PC for our analysis, where all the six variables are explained at higher rates. Moreover, Bartlett (1950) illustrates an inferential approach of PCA as a technique of dimension reduction. According to Bartlett estimation, the dimension reduction is possible if the estimated chi-square value is sufficient enough to reject the null hypothesis at one percent level of significance.[3] However, considering the Bartlett approach, the chi-square value is 213. 54 at df=15. Hence, the level of significance is at one percent. It confirms the dimension reduction of the PCA.

Considering the percent of variance explained by all the variables to different PCs on the one hand and the guidelines suggested by the above researchers, we have considered retaining the first three PCs by constructing another composite PC for the final analysis. This can be confirmed by looking the shape of the Figure I. It shows that the Eigen values are declining at a higher rate after the third PCs. Hence, it will more meaningful to consider the scores of the first three PCs.

Figure 1: Scree Plot of Eigen values of all the Components

[3] For details see Tacq (1998).



As we have already explained that the first PC explains nearly 44 percent of the total variance in the study. The equation of the first PC stand as:

$Z_i = 0.27 X_1 + 0.20 X_2 -0.06 X_3 – 0.20 X_4 – 0.35 X_5 + 0.34 X_6$

The co-efficient of all the variables are nothing but the component score coefficients of the first PC (Table 12). Similarly, the equation for second and third PC can be constructed by using the score co-efficient of PC_2 and PC_3 respectively.

Table 12: Analysis of Component Score Co-efficient

Variables	Component					
	1	2	3	4	5	6
X_1	0.27	0.36	0.27	0.34	1.50	-0.54
X_2	0.20	0.52	0.13	0.07	-1.50	0.55
X_3	-0.06	-0.29	0.75	0.60	-0.45	-0.18
X_4	-0.20	0.19	0.53	-0.93	0.27	0.15
X_5	-0.34	0.25	-0.07	0.42	0.25	5.34
X_6	0.34	-0.27	0.09	-0.34	0.03	5.52

Source: Estimated

As the first three components taken together explains 86 percent of the total variance, it is worth to develop one combined component scores (CCS) based on the first three components score. In the process of combination of scores, weights were allotted to each set of component scores in proportion to the variance explained by it. The component scores for the first three components were calculated ignoring the negative sign of loadings. However, based on the results of the three methods, the districts are ranked and produced in the annexure 1. Moreover, all the districts are divided in to severe, moderate, less severe and unclassified based on all the three methods. It is observed that most of the districts are coming under unclassified category because of the difference in the methods of estimation by the techniques (Table 13). The first two methods produce similar results as it gives equal weights to all the indicators, whereas PCA gives weight based on the absolute value. For example, the area under wasteland and degraded forest are given equal weight under the first two methods, but there is significant difference in absolute values. This difference is captured by the PCA and gives weight based on the absolute values. Hence, based on the superiority in PCA, we have ranked separately all the districts under three categories in regional basis.

Table 13: Classifications of the Districts based on all the Methods

Classification/ Regions	Central	Eastern	Bundelkhand	Western
Severe	Raebareli	NA	NA	Etah, Agra, Bijnor, Moradabad
Moderate	NA	Ghazipur, Gorakhpur, Jaunpur	NA	Aligarh, Ghaziabad
Less Severe	Sitapur, Lucknow, Fatehpur	Azamgarh, Deoria	Na	Shahjahanpur
Unclassified	Kanpur, Lakhmipur, Hardoi, Barabanki, Unnao	Ballia, Mirzapur, Pratapgarh, Allahabad, Bahraich, Varanasi, Faizabad, Gonda, Sultanpur, Maunathbhanjan	Jhansi, Janaun, Hamirpur, Banda, Lalitpur	Mathura, Muzaffarnagar, Saharanpur, Bulandshahar, Mainpur, Meerut, Rampur, Bareilly, Etawah, Pilibhit

Source: Estimated

According to the PCA technique, Mirzapur in Eastern region stands on the first followed by Laxmipur in Central and Lalitpur in Bundelkhand region as second and third severe land degraded districts in the state. However, all the districts in Bundlekhand region are coming in the severe category, where five districts are from western, three each from central and eastern regions are coming under severe category of land degradation (Table 14). Moreover, Etawah from western and Unnao from central regions are least affected by land degradation in the state.

Table 14: Classifications of the Districts based on PCA Technique

Classification/ Regions	Central	Eastern	Bundelkhand	Western
Severe	Lakhmipur, Hardoi, Raebareli	Mirzapur, Mirzapur Maunathbhanjan	Jhansi, Janaun, Hamirpur, Banda, Lalitpur	Etah, Agra, Bijnor, Moradabad, Badaun
Moderate	Kanpur, Barabanki	Basti, Ghazipur, Varanasi Gorakhpur, Jaunpur		Pilibhit, Mathura, Muzaffarnagar, Saharanpur, Aligarh, Agra, Bulandshahar
Less Severe	Sitapur, Fatehpur, Unnao, Lucknow	Pratapgarh, Faizabad, Ballia, Sultanpur, Azamgarh, Deoria, Allahabad		Meerut, Bareilly, Etawah, Rampur, Farrukhabad, Shahjahanpur, Mainpur.

Source: Estimated

Conclusions

Land degradation becomes the important element of environmental degradation causes a serious treat for the economic development in the state. However, deforestation, salinity, waterlogging, decline of water table, improper use of fertilizer in both irrigated and non-irrigated area, are serious causes of land degradation in the state. The state planning commission estimated nearly 74.48 lakh hectares of land, which is 30.77 percent of the reporting areas are degraded land in the state. On the other hand, NRSA estimated nearly 38.84 lakh hectares, which is 13.19 percent of the geographical area of the state, are degraded. Not only have the different patterns of development in the state led to the degradation of natural resources but also the under lying causes like population growth, poverty, decline of land man ratio and the unsustainable activities adopted by them have become crucial for the degradation of the valuable natural resources in the state.

The over all severity of land degradation at the district level is measured by applying ranking, indexing and principal component analysis. However, the measurement of overall land degradation is based on the construction of index by using six different indicators. The proportion of wasteland to reported area, degraded forest to the reported area, annual rainfall data, percentage use of ground water and disproportionate use of fertilisers etc. are used for constructing the index. Based on the technique, Mirzapur in Eastern region stands on the first followed by Laxmipur in Central and Lalitpur in Bundelkhand region as second and third severe land degraded districts in the state. Moreover, Etawah from western and Unnao from central regions are least affected by land degradation in the state.

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Annexure: Table 1: Hierarchical Positions of districts based on all the Three Methods

		Ranking Method		**Index Method**		**PCA Method**
Sl No.	Districts	Ranking 1	Ranking 2	Ranking 1	Ranking 2	Ranking 1
1	KANPUR ®	4	11	4	9	26
2	LAKHIMPUR	6	6	23	16	2
3	SITAPUR	41	34	40	33	44
4	HARDOI	3	24	2	23	11
5	UNNAO	11	21	11	22	48
6	LUCKNOW	26	37	20	37	42
7	RAEBARELI	5	13	10	14	15
8	FATEHPUR	33	41	33	41	43
9	BARABANKI	28	42	30	44	19
10	PRATAPGARH	42	33	29	21	37
11	ALLAHABAD	18	19	11	14	40
12	BAHRAICH	7	29	5	27	14
13	FAIZABAD	42	38	43	40	47
14	GONDA	14	2	7	2	24
15	SULTANPUR	31	27	32	29	45
16	AZAMGARH	49	45	49	46	36
17	BALLIA	18	12	25	13	41
18	BASTI	44	22	40	19	21
19	DEORIA	46	35	46	34	38
20	GHAZIPUR	47	26	47	25	22
21	GORAKHPUR	27	27	36	35	29
22	JAUNPUR	45	25	44	26	23
23	MIRAZPUR	9	43	9	42	1
24	VARANASI	32	44	30	43	28
25	MAUNATHBHANJAN	33	46	47	49	12
26	BANDA	30	48	13	44	7
27	JALAUN	28	47	25	47	10
28	JHANSI	7	38	6	39	5
29	LALITPUR	10	40	7	38	3
30	HAMIRPUR	36	49	21	48	4
31	BADAUN	15	1	15	1	9
32	BAREILLY	40	17	42	18	33
33	ETAH	13	13	16	12	13
34	FARRUKHABAD	38	31	37	31	46
35	MAINPURI	16	23	27	31	34
36	PILIBHIT	21	9	18	6	30
37	SHAHJAHANPUR	39	31	37	30	39
38	AGRA	1	7	1	5	16
39	ALIGARH	18	29	17	27	18
40	BIJNOR	23	3	21	3	6
41	BULANDSHAHAR	12	8	13	7	27
42	ETAWAH	2	10	3	10	49
43	GHAZIABAD	33	20	39	24	31
44	MATHURA	22	35	23	35	17
45	MEERUT	23	16	27	17	32
46	MORADABAD	48	15	44	11	8
47	MUZAFFARNAGAR	25	5	18	4	25
48	RAMPUR	37	18	35	20	35
49	SAHARANPUR	17	3	33	8	20

Source: Estimated