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Water Logging and Salinity Trends in Khushab District, Pakistan using Remote Sensing and GIS

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Abstract: Water logging and salinity are the intensively growing problems of Khushab District. The techniques of Geographical Information System (GIS) and Remote Sensing (RS) were colossally useful to map and represent the areas of water logging and salt-affected soils. To accomplish this research different data sets were used from diverse sources including, soil samples, canal data, water table depth, meteorological data and satellite images. An index-based methodology using remote sensing data in combination with GIS was also used in this study. The ratios of image bands with defined combinations of different spectral indicators were used to idenify salinity, water logging and vegetation. The indices were calculated from satellite images on temporal basis over a period of twenty years with five years interval to identify the trend change in different parameters. The satellite image based indices were calculated to find out the correct patterns of the soil salinity using Normalized Difference Salinity index (NDSI). Two other indices such as NDWI (Normalized Difference Water Index) and NDVI (Normalized Difference Vegetation Index) were also projected to recognize the spatial and temporal trend in vegetation, salinity and water logged areas respectively. There was increasing trend in water logging and salinity while the vegetation showed declining trend on the basis of sequential scale of 20 years. Thematic maps of meteorological data pertaining to rainfall and temperature were also developed using time series data to delineate the potential effective areas of water logging and salinity. The water table depth map was developed to establish the ratio of water table depth with respect to water logging areas. Finally, weighted overlay analysis was applied on the related data sets according to their relative influence to generate the overall spatial distribution of water logged and saline areas. These maps and analysis techniques can also be used for the extended study of any area having same problem using specific parameters.

Key words: Water logging · Salinity · Index · Spatial · Remote Sensing · Satellite image · Image band

INTRODUCTION

Water logging is the condition of soil when water table is too high to replace oxygen with water; the soil becomes saturated with water. Salinity is the condition of soil when it contains too high salts concentration to support the proper germination and plant growth. The main cause of salinity in Pakistan is low rainfall which causes the extensive irrigation practices. The irrigation water is not enough to leach down the salts away from the root zone.

The application of brackish water of tube wells and weathering of soil profiles also cause salinity.

The escalation of the water table depth to the surface level is called "water logging" and the appearance of salty patches is called "salinity" [1]. The magnitude of the salinity problem has been increasing with the passage of time where, agricultural area has been seriously damaged by this problem. It was analyzed that seepage losses, water logging and soil salinity may be addressed more efficiently by improving water management than by modifying physical structures [1].

The perennial canals were introduced for irrigation system, surplus water seeps to the subsurface throughout the year.

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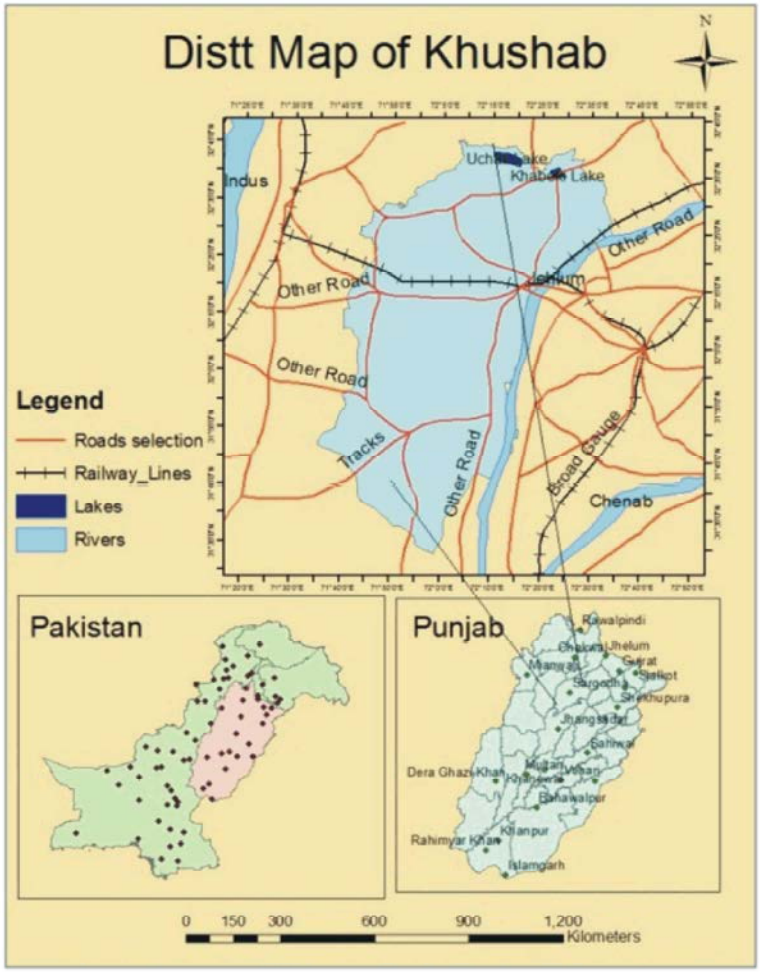

Fig. 1: Study Area Map of District Khushab

Due to seepage of water from unlined canals and irrigated lands, enormous water supply is increased and then lost by evaporation of water. Water ascends up in the subsurface and the water table rises. As long as the depth of water table remains five meters or more below this surface level then there is no problem. But when it rises up to five meters or move from the surface, the water starts to move to the surface through the capillary action which causes water logging and salinity [3].

MATERIALS AND METHODS

This research work was conducted to delineate the water logging and salinity, by using several meteorological, agricultural and other remotely sensed parameters of temporal datasets. Two types of data, meteorological data and satellite data were obtained to achieve the objectives of this research in this study. The satellite data used during three time periods of different years 1992, 2001 and 2010. Data obtained for this research confined with the interval of ten years. The use of satellite data of different months and years of significant variation of salinity and vegetation cover was also acquired.

Data Preparation: The available data were in different formats and in different types including satellite images. To build interoperability among all datasets and to perform GIS analysis, the data were prepared in software affable formats. Most of the meteorological and soil salinity data were in manual traditional paper file system, except a few years data of two places were in electronic file system. So, all the data was organized accordingly. The database for meteorological data (rainfall, temperature (min, max), soil salinity and water table data were generated in MS Excel.

Temporal and Spatial Trend Changes of Rainfall and Temperature: Temperature and rainfall data were obtained from meteorological and agriculture department. This data was in raw form. After tabulation of the raw form data, interpolation method was applied to constructs maps. These maps expressed the trend change on the basis of temporal and spatial trend.

Analysis on Images: Image processing was necessary to analyse NDWI (Normalized Difference Water Index), NDVI (Normalized Difference Vegetation Index) and NDSI (Normalized Difference Salinity Index). Normalized Difference Vegetation Index (NDVI) was used to detect vegetation brightness in the study area. The changes for rainfall, NDVI and crop yield were calculated to find out the trend change for different years in water logging and salinity. The correlation and regression analysis among different parameters has been performed to verify the extant and dependency of vegetation on rainfall and salinity conditions.

Indices of Remote Sensing: Indices were generally calculated to associate the spectral bands. It is powerful tool of categorizing features of interest. The indices were calculated for salinity, water logging and for change in vegetation cover. But there was deficiency of evidence about water logging and salt affected lands. The spectral band combinations were used to detect water logging and salinity in the study areas. These bands contain spectral reflectance pattern to detect salt pattern present in the soil layers accountable for salinity. This term, the salinity was used for saline soils which were prominent in Khushab district. Water logging and salinity were two major problems in study area [4].

To detect water logging and salinity, followings main indices were calculated;

NDVI (Normalized Difference Vegetation Index) [5].

$$NDVI = (\square IR - \square R) / (\square IR - \square R) \quad (1)$$

whereas
? IR = Near Infrared band reflectance (Band 4)
? R = Red band in reflectance (Band 3)
? NDSI (Normalized Difference Salinity Index) [4].

$$NDSI = (band\ 3 - band\ 4) / (band\ 3 + band\ 4) \quad (2)$$

Brightness Index (?Blue) = □ RED+ □ IR

□ NDWI (Normalized Difference Water Index) [6]

$$NDWI = (Green - NIR) / (Green + NIR) \quad (3)$$

Salinity Status of Soil Samples in Khushab District: Different samples were taken from Agriculture Department of Khushab to know the condition and status of soil salinity. From these samples, it have been identified that how much soil in study area was saline, saline sodic and sodic soil.

Weighted Overlay Linear Combination: Water logged and saline areas were calculated as a weighted linear combination for the participation of factors. Due to this analysis each factor has great influence on water logging and salinity has been analyzed and implemented in the model [7]. At temporal scale meteorological data of different years 1992, 2001 and 2010 were evaluated by using weighted overlay linear combination. Following weighted appearance is under:

$$Wt = \square WiDi \ldots WnDn \quad (4)$$

where,
Wt = The total weight
Wi = Weight value in each parameter
Di = Score value in each parameter

RESULTS AND DISCUSSION

According to the aims of study, different combinations of methods, analyses as well as statistical relationship were applied using various indices, equations and approaches

Spatial Trend Change in Water Table Depth of Khushab: Water table depth showed the trends over multiple years in different areas of Khushab districts. Figure 2 showed change in water table depth with respect to time. According to Figure 2 the range of water table depth was high in north western side of Khushab district and southern areas of the study area. In Noshera water table depth was high. The reason is that the saturation level became high because of low depth in water table and these areas showed water logging and salinity. The intensity of water logging is not extreme in the low water table depth. In central part the study area showed low water logging because of canal network. Near the canals, especially link canal saturation level was high due to abundant water.

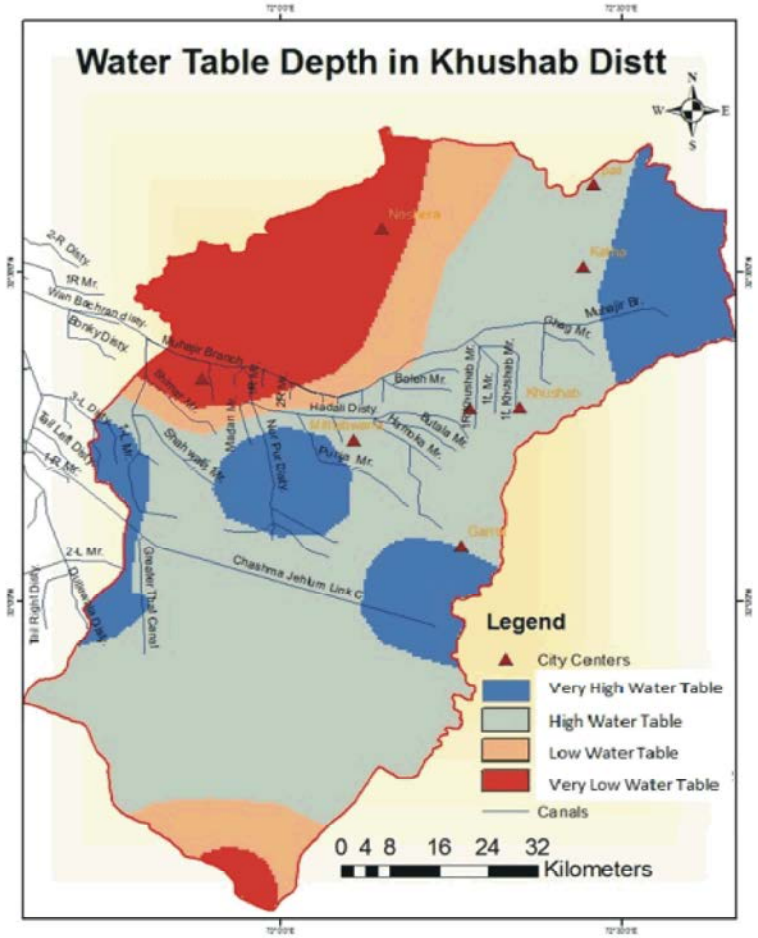

Fig. 2: Water Table Depth in Khushab District

The Spatial Pattern of NDVI in Khushab District: The spatial pattern of NDVI was calculated to validate the deviation of vegetation during years of 1992, 2001 and 2010 from NDVI values. The maps of NDVI showed the spatial pattern and percentage (%) change in vegetation which was shown on the graphs in (Figure 4). Northern and eastern areas of Khushab showed dense vegetation while scattered vegetation was also presented in south and west of the study area. With the passage of time vegetation has been decreased.

There was negative NDVI from the years of 1992, 2001 and 2010 (Figure 3).

There was more water logging in the west of river Jhelum and south eastern side of Khushab. Near lakes (Uhcali and Khabaiki) and link canals of the study area, the land was much affected by seepage of water. Figure 4.6 showed that in 1992, there was 7% water logged area, 47% area of vegetation and 46% area of bare land.

After ten years interval, the agricultural area was decreased to about 1800 km^2 and water logged area increased upto1400 km^2. The bare land cover was of 3600 km^2 during the year of 2010.

Spatial Pattern Change in NDSI of Khushab: In the saline areas salinity showed maximum reflection in thermal IR band and minimum reflection in near infrared band of the image [1]. NDSI detected the salt affected soil and cropped areas [8]. Figure 5 shows that salinity trend increased with the passage of time. In 1992, there was high salinity in Katha, Pail, Noshera and Johrabad and less in Mithatiwana and Garrot. Katha, Pail, Noshera and Johrabad were northern areas therefore salinity was maximum because of Salt Range of north. There was very low saline soil in Luku, Roda and RangpurBhagour in 1992 in the south areas of Khushab. After the overlay analysis of different years of 1991, 2001 and 2010, it is clear that trend in saline areas of Khushab districts was increasing with the passage of time. The main reason of extending salinity was Salt Range in northern areas of Khushab.

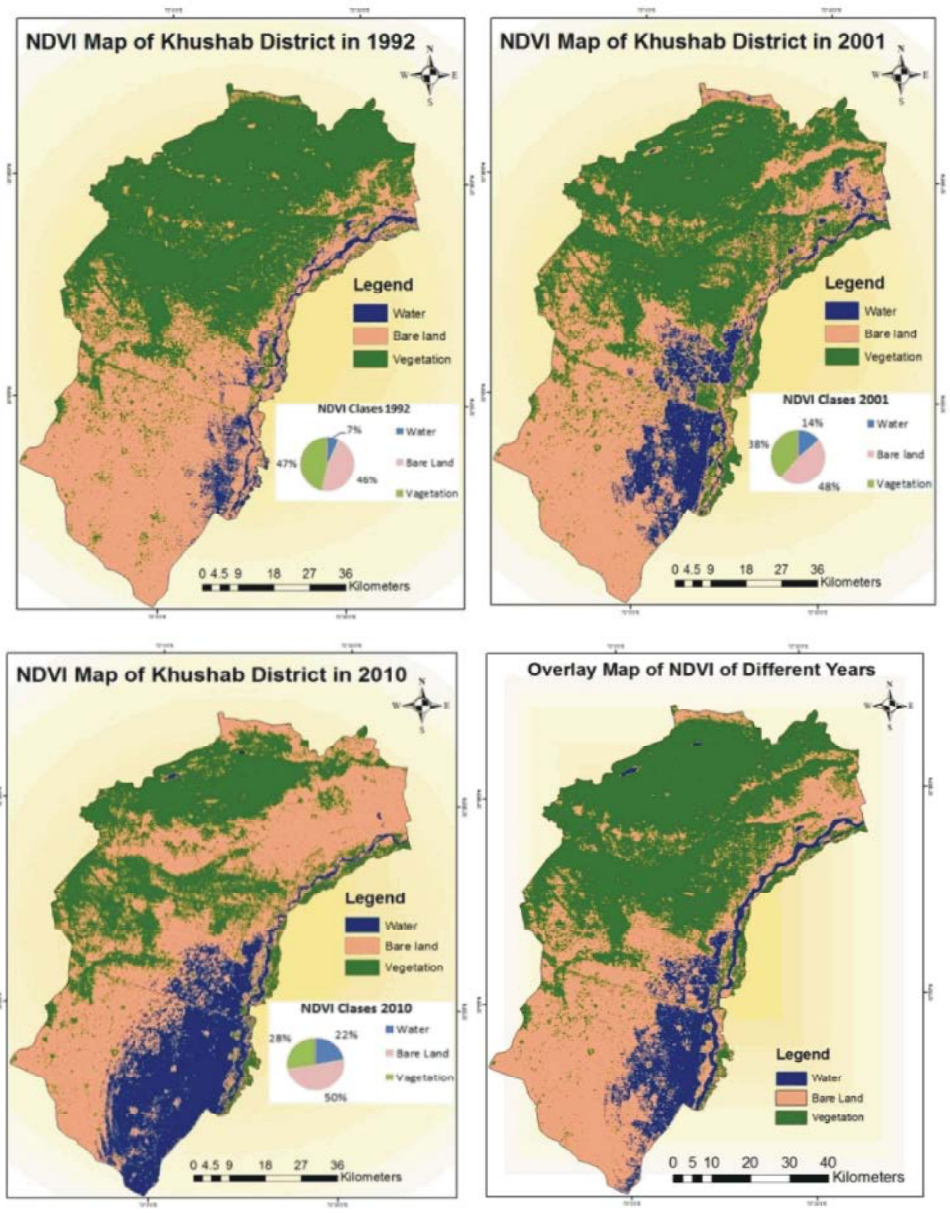

Fig. 3: NDVI Maps in Different Years of Khushab

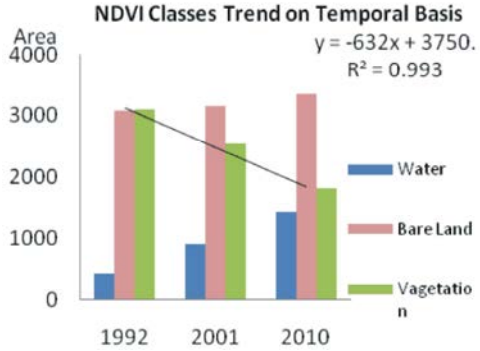

Fig. 4: The Trend Change of NDVI Classes on Temporal Basis

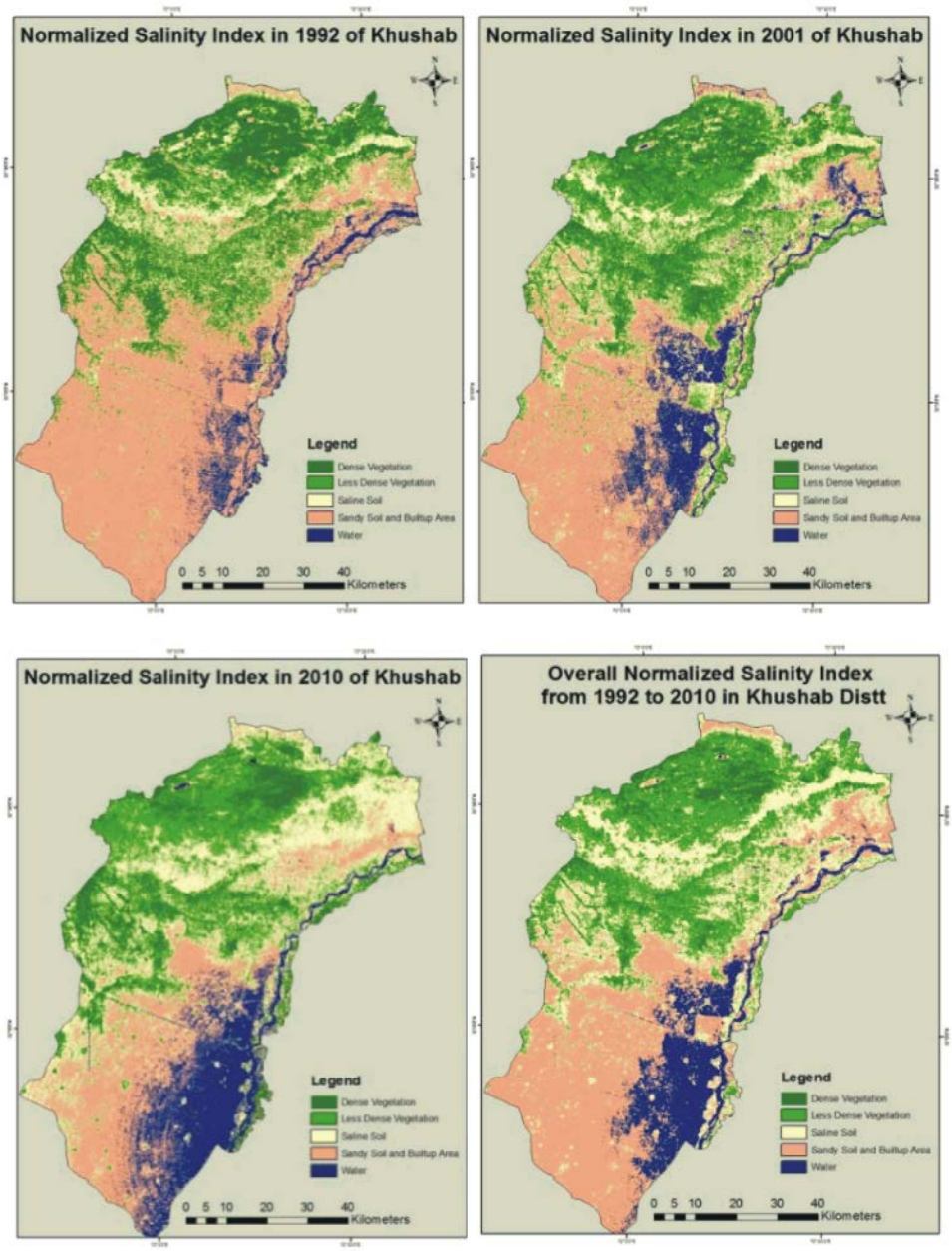

Fig. 5: NDSI Maps of Different Years in Khushab

Katha, Pail and Quaidabad showed extreme salinity. There was maximum salinity in Johrabad, Mithatiwana and minimum in Luku, RangpurBhagour and Roda. The minimum saline areas were in south western parts of Khushab. There was maximum build up areas and scattered vegetation. According to Figure 7 overlay analysis measured water bodies in east and south eastern side of Khushab districts. Lake Khabaiki and Uchali also in northern areas of Khushab and there was maximum salinity and scattered vegetation near these lakes.

Weighted Overlay of Water Logging in Khushab District: Weighted overlay analysis was applied on NDVI Index, Buffer of canal command area, rainfall map and water table depth map. According to this analysis different ranks and weights were given. NDWI has influenced 70%, rainfall 5% and water table depth 15 % and buffer along the canal command area has influenced 10% (Figure 6). In rainfall map, weights were allocated high rainfall to low and divided into two classes. In water table depth four classes were given and have weights low

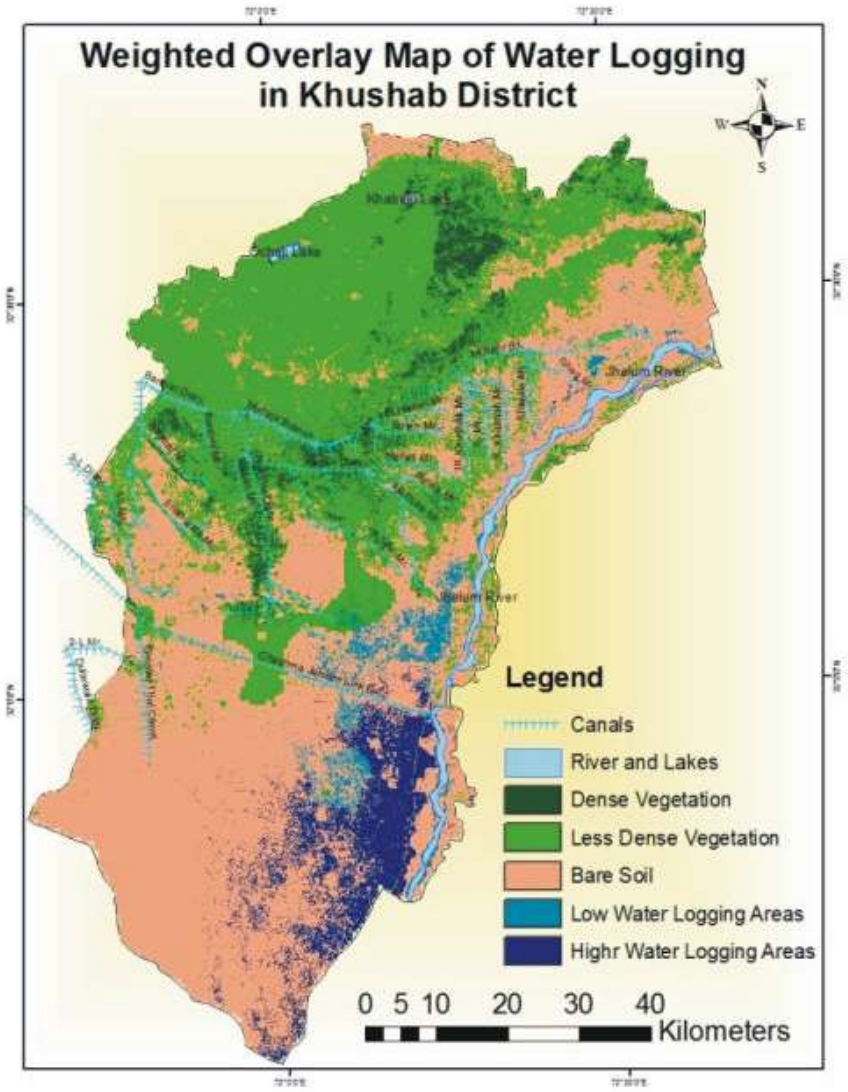

Fig. 6: Weighted Overlay Map of Water Logging

water table depth to high. Weights were assigned minor to major in buffer of canal command area and have two classes.

The weighted overlay analysis for delineation of salinity was performed by using the NDSI, NDVI, temperature, rainfall and water table depth maps. Figure showed the weighted overlay analysis of salinity in Khushab district. In the east of the study area, near river Jhelum, there are saline areas due to saline water.

Least saline areas were in south of Khushab and some saline areas in northern part. The central part exhibited maximum saline areas because of salt range. There were Uchali and Khabaki Lakes in study area. Near these lakes the areas showed water logging and salinity because of water saturation. In south of Khushab, near the chashma link canals, there were maximum water logging and salinity. Salinity was due to saline water of Khushab. Due to presence of salt range in the northern side, salinity increased with the passage of time. Water became saline due to salt range. This saline water entered in the field and water evaporates, the area became saline.

Salinity Status of Soil Samples in Khushab District: According to Table 1, the most of areas of Khushab were non-saline. The saline areas were less than non-saline areas. The mostly northern side of study area was saline because of salt range. Soanvally, Mohar area and Hadali were high saline areas. Some areas of Khushab were sodic and saline sodic.

Table 1: Soil Samples of Khushab District

Tehsil Name	Non-saline	Non-saline %	Saline	Saline %	Saline sodic	Saline sodic %	Sodic	Sodic %
Soon Vally	1080	40.2	150	14.5	50	9.5	10	5.9
Mohar Area	200	7.4	400	38.8	150	28.7	60	35.5
MithaTiwana	270	10	100	9.7	100	19.1	20	11.8
Hadali	250	9.7	150	14.5	65	12.4	20	11.8
Quidabad	130	4.8	30	2.9	20	3.8	12	7.1
Mohar Area	60	2.2	50	4.8	40	7.6	11	6.5
ChahWala	90	3.3	20	1.9	10	1.9	6	3.5
Rangpor/Adhikot	200	7.4	100	9.7	70	13.4	24	14.2
NoorpurThal	400	14.9	30	2.9	16	3.07	6	3.5
Total	2680	0	1030		521	0	169	0

Source: Agriculture Department of Khushab (Year 2010)

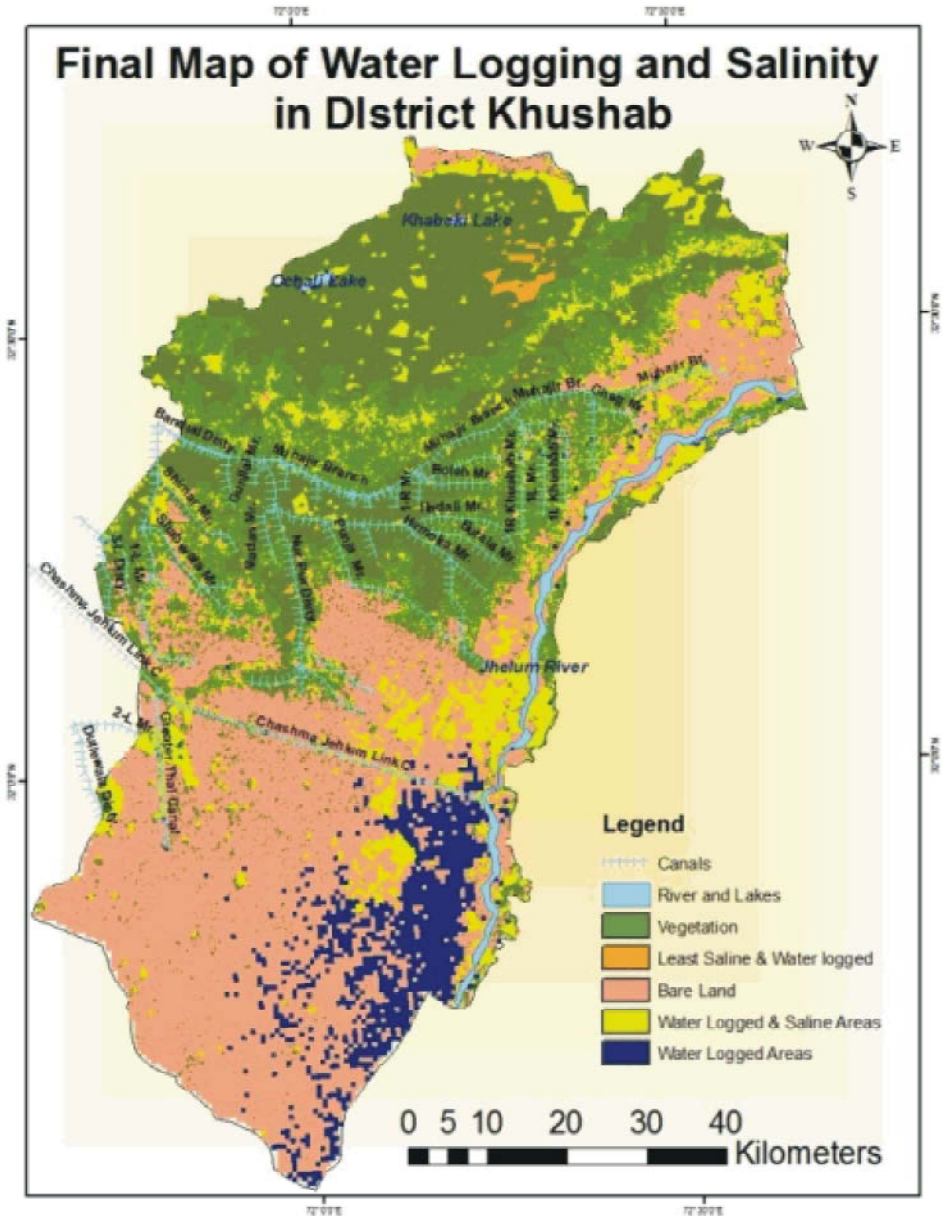

Fig. 7: Final map of Water Logging and Salinity in Khushab District

CONCLUSION

The NDVI values were descending with respect to time over an interval of ten years. Spatial pattern of NDVI showed that vegetation area decreased and water logged area increased after time interval of twenty years. Weighted overlay of salinity showed that there was maximum salinity in north and central portion of Khushab due to salt range and saline water. The maximum water logged area was in south and south eastern side of Khushab because of water discharge of perennial canals and link canals. NDVI classes on temporal basis by Regression analysis showed that water logged area increased and vegetation decreased during interval of twenty years of time. Water logged area is becoming double with respect to time.

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