ASSESSMENT OF SALINITY CONTROL AND RECLAMATION PROJECT (SCARP) IMPACT ON CHOLISTAN DESERT USING GEOINFORMATICS

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ABSTRACT: *Agriculture is the backbone of Pakistan. In 1997 a project a salinity control and reclamation project (SCARP) was launched in Cholistan and Bahawalpur division to increasing agricultural production. The objectives of this research are (1) to utilize remote sensing and GIS technologies to assess the spatio-temporal trend of vegetation cover in Cholistan after the implementation of SCARP project and (2) to examine the relationship between vegetation cover with other land cover in study area. Multi-temporal Landsat satellite imagery for years 1991, 2000 and 2013 was used with three different image processing techniques including Maximum likelihood Classifier, ISODATA classifier and Normalized difference vegetation index. . The results show that vegetation has been increased by 24.34% in Cholistan and Bahawalpur region from 1991 to 2013. Whereas the barren land including the desert area has been decreased almost 22.96% in the same time period.Strong negative correlation with the value of –0.99 was observedbetween these two landcover classes.There can be no doubt that the SCARP-projects have provided some relief to the affected lands, which can be witnessed in the Cholistan desert and Bahawalpur district.The Geoinformatics provide a rapid, effective, spatially comprehensive and multi-scalar technique for mapping land cover particularly the vegetation in arid regions which is otherwise not possible to attempt through conventional mapping.*

INTRODUCTION

In the southern Punjab the Cholistan desert consist of an area about 26,000 sq. km. In hot deserted areas the expansion and growth of vegetation is mainly influenced by availability and quality of water [1]. From the agriculture perspective Cholistan is highly mesmerizing keeping a great capacity as a range-land provided it is managed, derive benefit and utilized fully [2,3]. Cholistan desert is distributed into two geomorphic regions on the basis of its landscape. Lesser Cholistan expand on an area of approximately 7,770 km^2 in the northern part that is adjacent with the canal-irrigated regions whereas in southern part the Greater Cholistan covers an area about 18,130 km^2.

Soil salinity may be deprivingPakistan of about 25% of its capacity of producing major crops [4]. In an arid sub-tropical areas with extreme hot temperature, high evaporation and low precipitation as well as sandy soil, plain geography and worst natural drainage, these are factors that lead to water logging and salinity because of inadequate drainage system for irrigation. By the 1960 series of Salinity Control and Reclamation Projects were initiated to minimize the water logging and soil salinity. SCARP-VI project was implemented in the districts of Rahim Yar Khan and Bahawalpur of Punjab province of Pakistan, which was suffering from waterlogging and salinity since early1960s [5]. The aim of the project to increase agricultural production by reducing soil salinity, waterlogging and providing irrigation water. The total area under this project is approximately 1.46 million acres (Mac) from this about 1.267 Mac are controlled by Punjnad and Abbasia Canals.

In 1989 SCARP-VI [6] started to install 514 deep drainage tube wells to avoid waterlogging. The operation of 514 tube wells of. Embankments have placed at saddle and in between the ridges to make ponds banks. The stream networks have been done by cutting the dunes to connect the neighboring ponds, which have adapted them in to adjoining series of ponds. Discharge of salinity within the range of 18000 to 25000 ppm has been run into these evaporation ponds for removal with the process of leaching and evaporation.

The vegetation of Cholistan desert includes xerophytic species, adapted to extreme climatic conditions, variability of moisture and extensive diversity of edaphic conditions. Vegetation cover vary area to area in Cholistan, depending upon the soil topography and chemical composition. So, it is important to map the vegetation cover to observe the growth pattern and conclusively do the effective measures to increase the vegetation where possible by utilizing the resources efficiently.

Traditional method of vegetation mapping comprises of field survey by creating the quadrants over an area under observation. In every single quadrant the species can be surveyed by the number of individuals, existence/nonexistence or the percentage of species in each quadrant.

With the advancement of remote sensing techniques, it has become a common practice to monitor the vegetation and its species using different approaches[7-9]. There are various types of remote sensing products and techniques that can be used to map the vegetation and its species using classification of remotely sensed data and normalized difference vegetation index (NDVI), or other vegetation indices [10].

The objectives of this research are (1) to utilize remote sensing and GIS technologies to assess the spatio-temporal trend of vegetation cover in Cholistan after the implementation of SCARP project and (2) to examine the relationship between vegetation cover with other land cover in Bahawalpur Division.

MATERIALS AND METHODS

Study Area

The research study was carried out in the Cholistan desert that is situated in South-West of Punjab, Pakistan (figure 1). Cholistan desert is an extension of Great Indian Desert and lies between latitudes 27º 42' and 29º 45' North and longitudes 69º 52' and 75º 24' East [11]. Over-all land extent of Cholistan desert is about 2.6 MH [12], and has a span of about 480 km and size vary from 32 to 192 km [13]. Depending upon the core material, landscape, soil and vegetation, the entire desert can be divided into two geomorphic regionsLesser Cholistan (Northern area) and Greater Cholistan (southern area) [14].

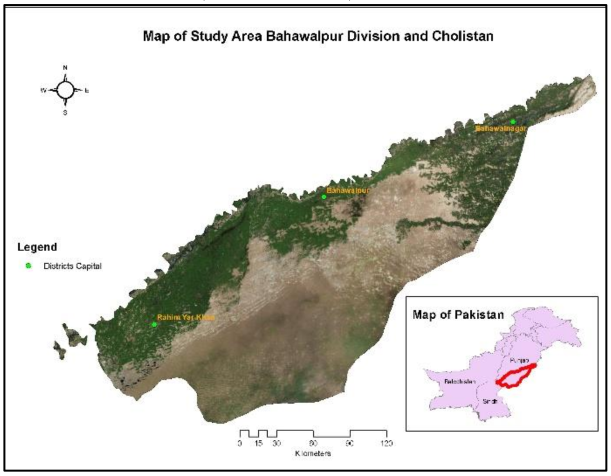

Figure 1: Location map of study area, Cholistan and Bahawalpur division.

Satellite Data

For this research, a multi-source remotely sensed dataset (table 1) is used for land cover and vegetation assessment of Cholistan from 1991 to 2013.

Landsat 5 Thematic Mapper (TM) acquired for 1991. The image consists of seven spectral bands (from Band 1 to Band 5 and Band 7) with a spatial resolution of 30 meters and for thermal Band 6 it is 120 meters.

Landsat 7 Enhanced Thematic Mapper Plus (ETM+) acquired for 2000. The image consists of eight spectral bands (from Band 1 to Band 5 and Band 7) with a spatial resolution of 30 meters and for thermal Band 6 it is 120 meters. Band 8 is panchromatic with spatial resolution of 15m.

Landsat 8 Operational Land Imager (OLI) images were acquired for year 2013. The image has a spatial resolution of 30 m for eight spectral bands (Band 1 to Band 5 and Band 9), 15 m for panchromatic (Band 8), and 100 m for the thermal bands (Band 10 and 11). In OLI Band 1 coastal and Band 9 cirrus is useful for coastal and cloud analysis.

Table 1. The spectral resolution of each sensor band.

Spectral domain	Landsat 5	Landsat 7	Landsat 8
Visible	Band 1 (0.45–0.52 µm)	Band 1 (0.45–0.52 µm)	Band 2 (0.45–0.51 µm)
	Band 2 (0.52–0.60 µm)	Band 2 (0.52–0.60 µm)	Band 3 (0.53–0.59 µm)
	Band 3 (0.63–0.69 µm)	Band 3 (0.63–0.69 µm)	Band 4 (0.64–0.67 µm)
Near-infrared	Band 4 (0.76–0.90 µm)	Band 4 (0.77–0.90 µm)	Band 5 (0.85–0.88 µm)
	Band 5 (1.55–1.75 µm)		
Short Wave-infrared	Band 7 (2.08–2.35 µm)	Band 5 (1.55–1.75 µm)	Band 6 (1.57–1.65 µm)
		Band 7 (2.09-2.35) µm)	Band 7 (2.11-2.29) µm)
Thermal	Band 6 (10.40–12.50 µm)	Band 6 (10.40–12.50 µm)	Band 10 (10.60–11.19 µm)
			Band 11 (11.50–12.51 µm)
Panchromatic		Band 8 (0.52–0.90 µm)	Band 8 (0.50–0.68 µm)
Cirrus			Band 9 (1.36 – 1.38 µm)
Coastal			Band 1 (0.43 – 0.45 µm)

Pre-Processing

The pre-processing step of satellite images is composed by geometrical and atmospheric adjustments. So as to reduce the geometric errors, that could be cause wrong interpretation of LC changes. Unalike solar brightness conditions, atmospheric scattering and absorption dynamics could generate variations in radiance values, which are not linked to land cover reflectance modifications [15]. Actually, the basic principle in using remote sensing data for change detection is that changes in land cover must be greater than radiance changes caused by differences in atmospheric conditions, sun angle, vegetation changes and soil moisture [16,17]. To reduce seasonal effects, which frequently cause errors in change detection, remote sensed images have to be selected referring to same month with clear sky conditions, avoiding the uncertainness of inter-annual variability [18,19]. The satellite image maps of Bahawalpur Division and Cholistan in year 1991, 2000 and 2013 are shown in figure 2, 3 and 4 respectively.

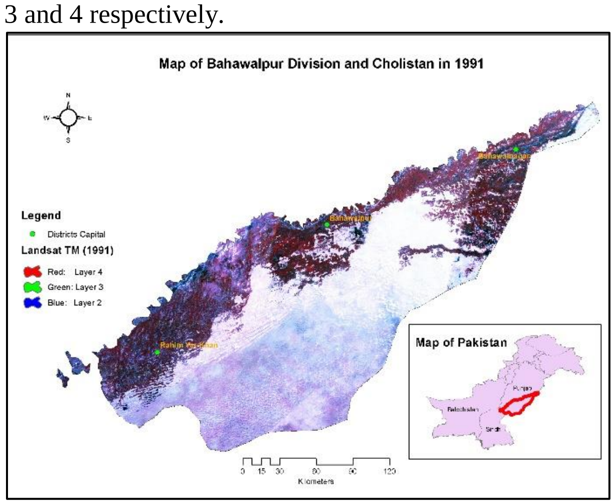

Figure 2. The satellite image map of study area after pre-processing for 1991.

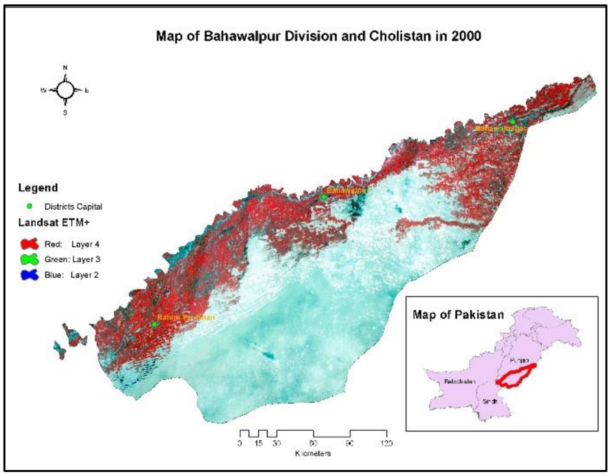

Figure 3. The satellite image map of study area after pre-processing for 2000.

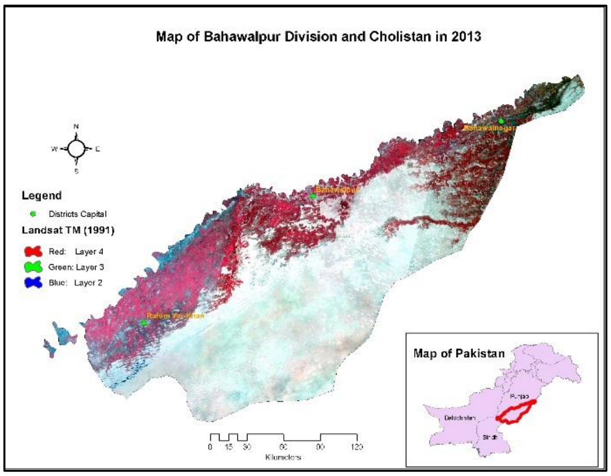

Figure 4. The satellite image map of study area after pre-processing for 2013.

Image Classification

Three image processing techniques are used to map the vegetation cover in Cholistan region. The techniques are (1) Maximum likelihood classifier (2) ISODATA clustering algorithm (3) Normalized difference vegetation index (NDVI).

Maximum Likelihood Classifier (MLC)

The Maximum Likelihood Classifier (MLC) is one of the most extensively used supervised classification technique for the land cover mapping of remotely sensed imagery. This classifier depend on the second-order measurements of a Gaussian probability density function model for every class [20,21]. This classification assumes that the statistics for every class in all bands are bell distribution and computes the likelihood that a particular pixel fits to a specific class. Each pixel is assigned to the class that has the highest probability (the maximum likelihood). During classification, all unclassified pixels are assigned to class membership based on the relative likelihood (probability) of that pixel occurring within each class probability density function [22].

ISODATA Clustering Algorithm

The ISODATA clustering algorithm [23-24] relates the radiometric value of every pixel with predefined number of cluster attractors, group's pixels in classes and moves the class average values in such a way that the maximum of the previously grouped pixels fits to a class. The user interacts with the process at the start, specifying the number of the predefined classes to be formed and the iterations to be carried out and at the end, where he chooses which class represents which surface land cover object and combines or discards the classes with non-realistic representatives.

Normalized difference vegetation index (NDVI)

The Normalized Difference Vegetation Index (NDVI) and other vegetation indices have been effectively used for monitoring biophysical condition and vegetation cover mapping from satellite and airborne sensors [25-29]. The NDVI comprises of a normalized ratio of red (R) and near infrared (NIR) reflectances in the form [NIR − R] / [NIR + R] [30]. Even if narrow band spectral indices provide more spectral information, research has shown that broadband indices can provide similar measurements of vegetation [31-33].

RESULTS AND DISCUSSION

The results achieved through the analysis of multi-temporal satellite images are shown in Figure 2, Figure 3 and Figure 4.

Landcover Status as per Supervised Classification

The land cover maps (figure 5-7) shows spatial distributional pattern of land cover of the Cholistan and Bahawalpur Division for the year 1991, 2000 and 2013. The statistical graphs (figure 8) reveals that in 1991, about 13.12% (5970.51km^2) area was under vegetation, 83.51% (38004.68km^2) under barren land including desert, 0.31% (143.14km^2) under built-up land and 3.06% (1391.61km^2) under water body. During 2000 the area under these land categories was found about 30.90% (14060.75km^2) under vegetation, 67.32% (30638.36km^2) under barren land and desert.

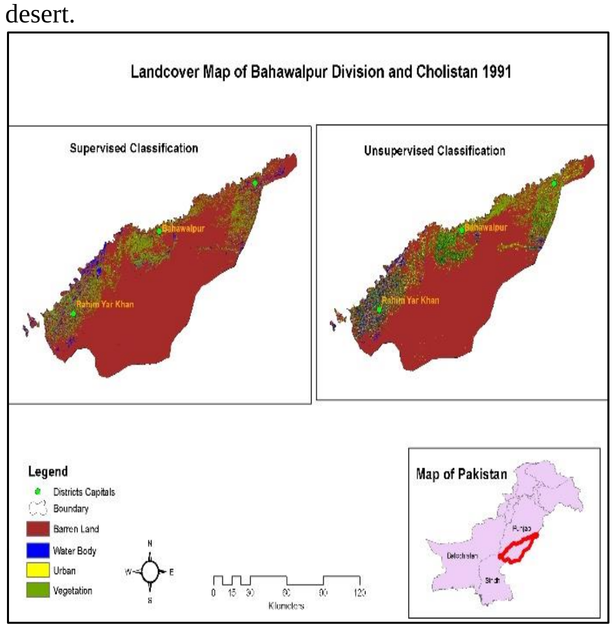

Figure 5. Landcover map of the Bahawalpur Division and Cholistan for 1991

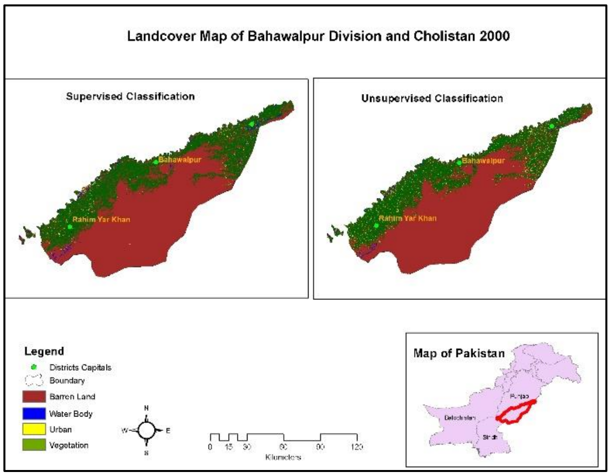

Figure 6. Landcover map of the Bahawalpur Division and Cholistan for 2000.

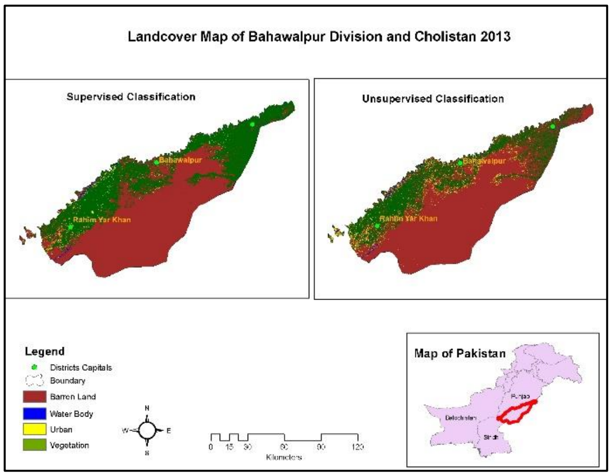

Figure 7. Landcover map of the Bahawalpur Division and Cholistan for 2013.

Beside that 0.94% (425.57km^2) under built-up and 0.85% (385.26 km^2) under water body. In year 2013 about 37.46% (17047.78km^2) under vegetation, 60.55% (27554.54km^2) under barren land and desert, 1.52% (692.27km^2) under built-up and 0.47% (215.35km^2) under water body (Table 2).

Table 2. The landcover statistics as per supervised classification.

Classes	1991	%	2000	%	2013	%
Urban	143.14	0.31	425.57	0.94	692.27	1.52
Barren	38004.68	83.51	30638.36	67.32	27554.54	60.55
Water	1391.61	3.06	385.26	0.85	215.35	0.47
Vegetation	5970.51	13.12	14060.75	30.90	17047.78	37.46
Total	45509.95	100	45509.95	100	45509.94	100

LandcoverStatus as per Unsupervised Classification

The statistical graphs on the basis of ISODATA unsupervised classification technique reveals that in 1991, about 14.38% (7383.33km^2) area was under vegetation, 80.72% (35897.57km^2) under barren land including desert, 1.93% (876.91km^2) under built-up land and 2.97% (1352.12 km^2) under water body. During 2000 the area under these land categories was found about 31.67% (14414.72km^2) under vegetation, 65.74% (29918.23km^2) under barren land and desert, 2.06% (937.94km^2) under built-up and 0.53% (241.80 km^2) under water body. In year 2013 about 37.37% (17007.06km^2) under vegetation, 58.79% (26755.29km^2) under barren land and desert, 3.42% (1556.03km^2) under built-up and 0.42% (188.87km^2) under water body (Table 3).

Table 3. The landcover statistics as per unsupervised classification.

Classes	1991	%	2000	%	2013	%
Urban	876.9195	1.93	937.9458	2.06	1556.035	3.42
Barren	35897.57	80.72	29918.235	65.74	26755.294	58.79
Water	1352.124	2.97	241.8003	0.53	188.8785	0.42
Vegetation	7383.33	14.38	14414.72	31.67	17007.065	37.37
Total	45509.94	100	45509.94	100	45509.94	100

Vegetation status as per NDVI

As per normalized difference vegetation index (NDV)the vegetation in 1991, 2000 and 2013 was 14%, 30.18% and 36.97% respectively. The temporal variation of NDVI in Cholistan and Bahawalpur Division is shown in figure 8.

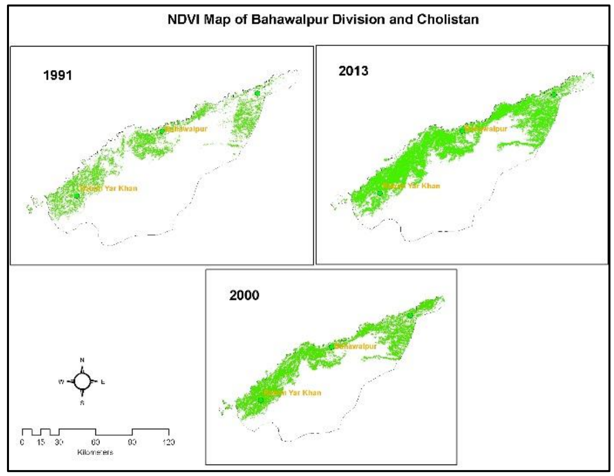

Figure 8. NDVI based vegetation map of the Bahawalpur Division and Cholistan.

It is obvious from themap that there is a significant increase of vegetation in the study area.

Landcover change

The results from supervised, unsupervised and NDVI clearly indicate that vegetation has significant increase in the Cholistan and Bahawalpur division since 1991. As per supervised classification the increase in vegetation cover is almost 24.34% from 1991 to 2013 (figure 9).

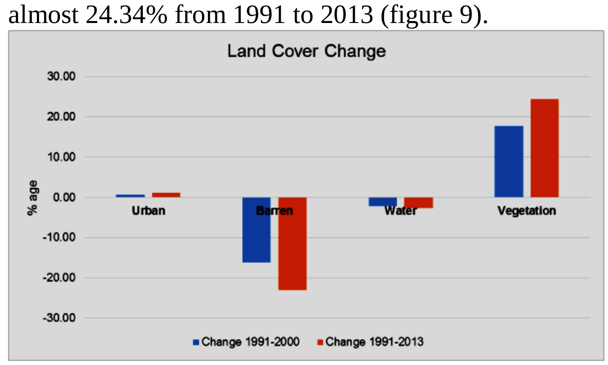

Figure 9. Percent change in landcover of Bahawalpur Division and Cholistan.

This can be directly associated with the implementation of SCARP in Bahawalpur and Cholistan. On the other hand barren land including the desert has been decreased almost 22.96% in the same time period. Also the statistical correlation value of $r = -0.99$ between the vegetation cover and barren land reveals that vegetation is increasing and barren land is decreasing in the study area. There is strong negative correlation between the two landcover classes as shown in figure 10.

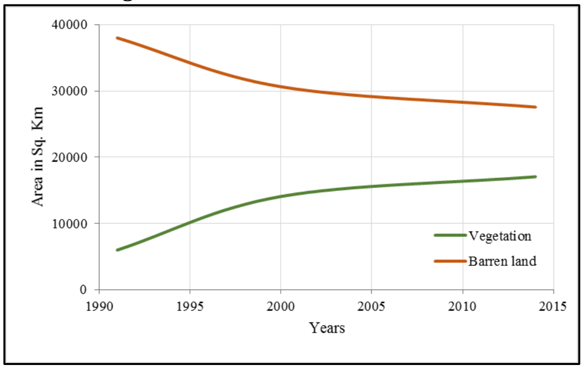

Figure 10. Correlation between vegetation cover and barren land.

The most important change was observed in Fort Abbas tehsil (figure 11). The spatial distribution of that change is towards south-west side. In this region the government has provided subsidy on the water pumps installation to the local farmers under SCARP.

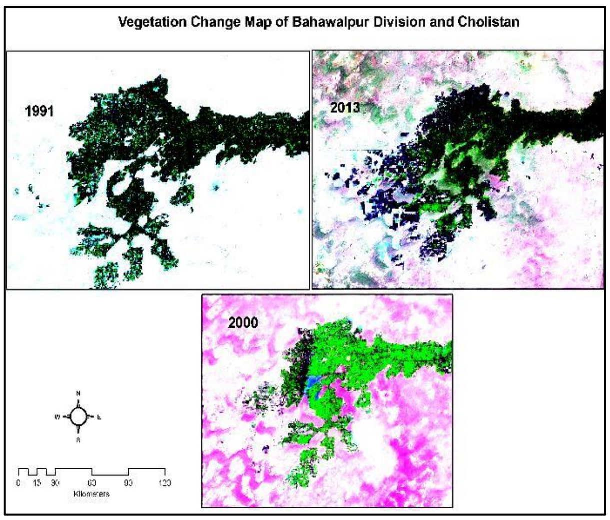

Figure 11. Vegetation change in Fort Abbas tehsil.

The Yazman tehsil has also observed an increase in vegetation cover as shown in figure 12. This can be related to the extension and improvement of three canals in the area named as Shāhiwāla Distributary, Two R Distributary, Dahri Minor. This canal system was established in Yazman under Satluj Valley Project canal system.

Near to Yazman in the Ahmadpur East region vegetation followed the same increasing trend (figure 13) and this region also share same canal irrigation Satluj Valley Project system.

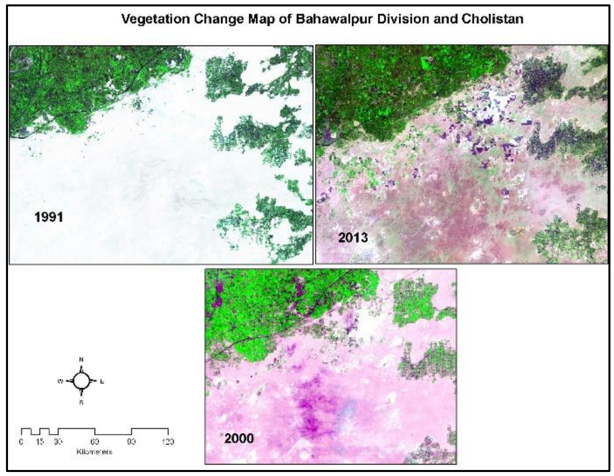

Figure 12. Vegetation change in Yazman tehsil.

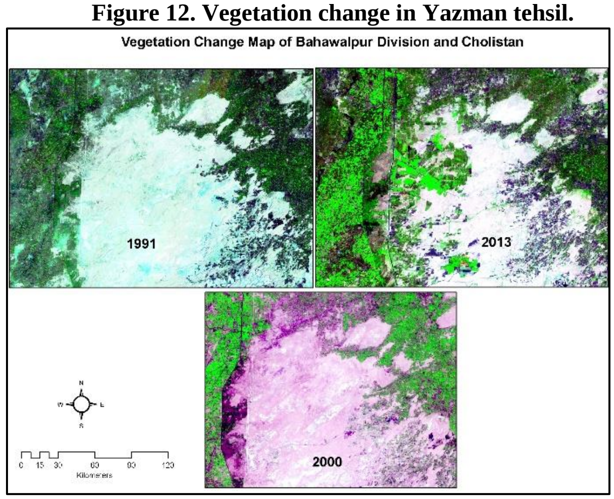

Figure 13. Vegetation change in Ahmadpur East tehsil.

Under the project of SCARP the deep water tube wells were established in the Liaqatpur tehsil. The spatial and temporal analysis of satellite imagery also reveal that in this region the vegetation has been increase considerably as shown in figure 14.

Currently the government is also providing subsidy to the local farmers on installation of solar tube wells under the project Roshan Energy Solar Bahawalpur and Cholistan.

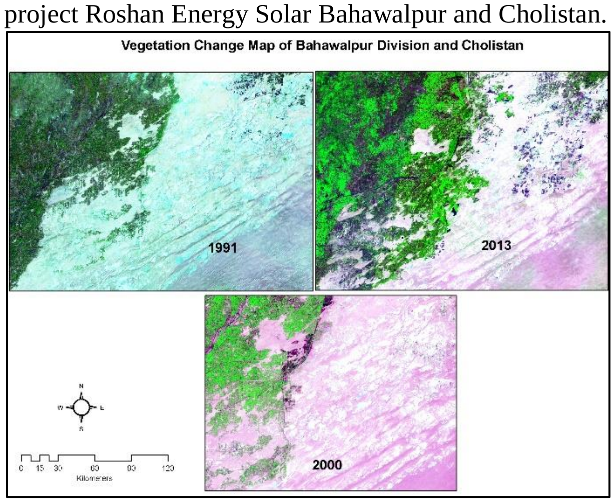

Figure 14. Vegetation change in Liaqatpur tehsil.

CONCLUSION

The study conducted in Cholistan desert and Bahawalpur division to assess the impacts of Salinity Control and Reclamation Projects, (SCARP). Using Geoinformatics techniques and multi temporal satellite imagery landcover change was determined from 1991 to 2013. The major landcover in the study area was barren land and desert which has been decreased by almost 23%. While vegetation cover was found to be increased by 24% since 1991. The increase in vegetation can be associated with the SCARP. There can be no doubt that the SCARP-projects have provided some relief to theaffected lands.The small capacity tube wells installed in the SCARP areas greatly helped in reducing thewaterlogging and salinity conditions.The remote sensing and GIS methods presented here provide a rapid, effective, spatially comprehensive and multi-scalar technique for mapping land cover particularly the vegetation in arid regions which is otherwise not possible to attempt through conventional mapping.

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REFERENCES

[1.] Evenari, Michael, Leslie Shanan, and Naphtali Tadmor. "The Negev. The challenge of a desert." The Negev. The challenge of a desert. (1971).

[2.] Anonymous. Pakistan–Cholistan Area Development Project. Report No. 59/53 ADB-PAK 58 (Final version). Food and Agriculture Organization of the United Nations, Rome. (1993).

[3.] Akbar, G., T.N. Khan and M. Arshad. Cholistan desert, Pakistan. Rangelands, **18**: 124-128 (1996).

[4.] World Bank. Punjab groundwater policy—Mission report. WB-SA-PK-Punjab GW Mission report. (1992).

[5.] NESPAK-ILACO. Final Plan, Panjnad Abbasia Salinity Control and Reclamation Project (SCARP-VI) Report, March 1981. (1981).

[6.] Javed, I., and Abdul Hafeez. "DISPOSAL OF DRAINAGE EFFLUENT IN EVAPORATION PONDS OF PAKISTAN." Irrigation in a total catchment context-sharing the river. Proceedings 2nd ICID Asian Regional Conference on Irrigation and Drainage, Moama NSW, Australia, 14-17 March 2004.. International Commission on Irrigation and Drainage (ICID), (2004).

[7.] Mahboob, Muhammad Ahsan, Iqra Atif, and Javed Iqbal. "Remote Sensing and GIS Applications for Assessment of Urban Sprawl in Karachi, Pakistan." Science **34(**3):179-188 (2015).

[8.] Lillesand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. Remote sensing and image interpretation. John Wiley & Sons, (2014).

[9.] Serbin, Shawn P., et al. "Remotely estimating photosynthetic capacity, and its response to temperature, in vegetation canopies using imaging spectroscopy." Remote Sensing of Environment **167**: 78-87 (2015).

[10.] Xie, Yichun, Zongyao Sha, and Mei Yu. "Remote sensing imagery in vegetation mapping: a review." Journal of plant ecology **1**(1): 9-23 (2008).

[11.] Baig, M. Shabbir, M. Akram, and M. Amjad Hassan. "Possibilities for range development in Cholistan Desert as reflected by its physiography and soils." Pakistan Journal of Forestry **30**(2): 61-71 (1980).

[12.] FAO. Pakistan-Cholistan Area Development Project . Report No.59/53 ADB-Pak 58 (Final Version). Food and Agriculture Organization of the United Nations, Rome. (1993).

[13.] Khan, Muhammad Sharif. "An interesting collection of amphibians and reptiles from Cholistan Desert, Punjab, Pakistan." Journal of the Bombay Natural History Society. Bombay **82**(1): 144-148 (1985).

[14.] Chaudhry, S. A. "The Cholistan Desert. A Token Consultancy Report." Cholistan Institute of Desert Studies, Islamia University, Bahawalpur. **34**(1992).

[15.] Song, Conghe, et al. "Classification and change detection using Landsat TM data: when and how to correct atmospheric effects?." Remote sensing of Environment **75**(2): 230-244 (2001).

[16.] Ingram, K., E. Knapp, and J. W. Robinson. "Change detection technique development for improved urbanized area delineation." Technical Memorandum CSC/TM-81 **6087** (1981).

[17.] Jensen, John R. "Urban/suburban land use analysis." Manual of remote sensing **2**:1571-1666 (1983).

[18.] Ramsey, E., R. S. Lunetta, and C. D. Elvidge. "Remote Sensing Change Detection: Environmental Monitoring Methods and Applications." 211-243.(1998).

[19.] Fichera, Carmelo Riccardo, Giuseppe Modica, and Maurizio Pollino. "Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics." European Journal of Remote Sensing **45**(1): 1-18 (2012).

[20.] Richards, J.A., and X. Jia. Remote Sensing Digital Image Analysis, Third edition, Springer, New York, **439**(1999).

[21.] Dean, A. M., and G. M. Smith. "An evaluation of per-parcel land cover mapping using maximum likelihood class probabilities." International Journal of Remote Sensing **24**(14): 2905-2920 (2003).

[22.] Lillesand, T. M., R. W. Kiefer, and J. W. Chipman. "Remote Sensing and Image Interpretation. New York: JohnWiley and Sons." (2004).

[23.] Tou, Julius T., and Rafael C. Gonzalez. "Pattern recognition principles." Pattern Recognition in Physics **1** (1974).

[24.] ERDAS, Inc. "ERDAS field guide." 5-183. (1997).

[25.] Burgheimer, Jonathan, et al. "Relationships between Normalized Difference Vegetation Index (NDVI) and carbon fluxes of biologic soil crusts assessed by ground measurements." Journal of Arid Environments **64**(4): 651-669(2006).

[26.] Ichii, K., Y. Yamaguchi, and A. Kawabata. "Global decadal changes in NDVI and its relationships to climate variables." Geoscience and Remote Sensing

Symposium, 2001. IGARSS'01. IEEE 2001 International. Vol. 4. IEEE, (2001).

[27.] Myneni, Ranga B., et al. "Estimation of global leaf area index and absorbed PAR using radiative transfer models." Geoscience and Remote Sensing, IEEE Transactions on **35**(6): 1380-1393 (1997).

[28.] Running, Steven W. "Modified integrated NDVI for improving estimates of terrestrial net primary production." Orlando'90, 16-20 April. International Society for Optics and Photonics, (1990).

[29.] Tucker, C. J., and P. J. Sellers. "Satellite remote sensing of primary production." International journal of remote sensing **7**(11): 1395-1416(1986).

[30.] Rouse Jr, J_W, et al. "Monitoring vegetation systems in the Great Plains with ERTS." NASA special publication **351**: 309 (1974).

[31.] Broge, Niels Henrik, and E. Leblanc. "Comparing prediction power and stability of broadband and hyperspectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density." Remote sensing of environment **76**(2): 156-172 (2001).

[32.] Elvidge, Christopher D., and Zhikang Chen. "Comparison of broad-band and narrow-band red and near-infrared vegetation indices." Remote sensing of environment 54(1): 38-48 (1995).

[33.] Thenkabail, P. S. "Inter-sensor Relationships Between IKONOS and Landsat-7 ETM+ NDVI data in Three Ecoregions of Africa (en línea)." Center for Earth Observation (CEO). Department of Geology and Geophysics, Yale University, EE. UU (2002).