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DEPLETING MALIR RIVER WATER RESOURCES & ITS ANALYSIS THROUGH NDWI – A SPATIOTEMPORAL ANALYSIS

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ABSTRACT

Karachi is the most industrially evolved and crowded city of Pakistan. Karachi is an interfluve between two seasonal rivers the lyari and Malir river. A major part of Karachi basin is occupied by alluvium of Malir River which is basically a seasonal river but act as a sewage drain within the limits of Karachi due to the continuous flow of untreated sewage and industrial waste through its basin into the Arabian Sea. The river has been in a critical situation in recent years due to decreasing surface water and increasing salinity. This study modeled the spatiotemporal changes of Malir river in the period of 30 years (1975 and 2015) using the multi-temporal Landsat 2-MSS and 8 OLI. Landsat imagery is among the most generally utilized wellsprings of information in remote sensing of water resource. In doing so, the applicability of Landsat satellite-derived index called Normalized Difference Water Index (NDWI) were investigated for the extraction of surface water from Landsat data. Overall, the NDWI was used to model the spatiotemporal changes of the river. The results indicate an intense decreasing trend in Malir river surface area in the period 1975–2015, especially 2015 when the river lost about one third of its surface area compared to the year 1975. The results illustrate the effectiveness of the NDWI approach for depletion of surface water sources, especially in detecting the changes between different decades, simultaneously.

KEY WORDS: NDWI, Malir River, Spatiotemporal, Water Resources, Seasonal River.

INTRODUCTION

Karachi, a metropolitan city, is confronting fastest population growth causing ecological, social and economic stresses and challenges. Beside planned development, unplanned urbanization, urban slums, illegal and informal settlements, and encroachments on natural drains have radically changed land fertility and drainage pattern of Karachi. The greater part of the Karachilies between two seasonal rivers Malir and Lyari which play a major role in draining out heavy rainwater from the city.

Malir River basin has total catchment area of about 1,850 square kilometer around southeastern boundary of Karachi. Malir River start from the confluence of Mol and Khaddej)i, as well as three tributaries named Konkar, Thaddo and Sukkan. River flows south-westwards through Gizri Creek discharges finally into the Arabian Sea (Fig -1.1). The central part of the river basin is made-up of sediment deposits comprising coarse conglomerate, sand stone, claystone and limestone, whereas, the lower plain is composed of alluvial deposits and gets braided, wider and shallower. The catchment has a rugged terrain; comprise of rocky waste land covered with sandy soil.Common vegetation with in the basin includes shrub trees and bushes. The subjacent part of the basin has good grass covered with orchards and vegetable patches which gradually reduce southwards. Slums are located on both sides of the river with some industrial units.(Sumaira Zafar, A. Z. ,2015).

Malir River bowl is one of the examples of the blocked conduits where width of the waterways at numerous areas is less than 10 meters and at one area it is totally hindered by a farming field. At present, these streams are seriously influenced by urbanization and awful administration that caused blockages at numerous places.Ground data collection is always an expensive and time-consuming technique. On the other hand, the use of geospatial techniques, as proposed in this paper, is more precise, time and cost effective remote sensing are more effective to be utilized in studying the water resources of Malir River.

Malir River overflows during the monsoon rainfalls. Storm water stays in the surrounding area for extended period of time due to insufficient drainage which damages the infrastructure and property (Farooq, M. A., *et al*.2010).Disposal of untreated industrial and municipal effluent has also severely contaminated the water of Malir River. This may become a serious health issue because most of this water is used to irrigate crops which are used by the citizens of Karachi (ZUBAIR, A., *et al*. 2009).

The Malir basin started shrinking, which was once the highly fertile plain of Karachi. It served for the purpose of market gardening during 1960s due to ample rainfall with the passage of time the changing climatic conditions decreases the precipitation receive during the monsoon season. This led to the shrinkage of Malir River belt and its associated cultivated land; most of which is now converted to either animal fodder fields or recreational farmlands and residential schemes such as Saadi town, etc.

Spatio temporal analysis was applied to the multivariate data to investigate the similarities and probable changes among the water and vegetation in 3 decades.

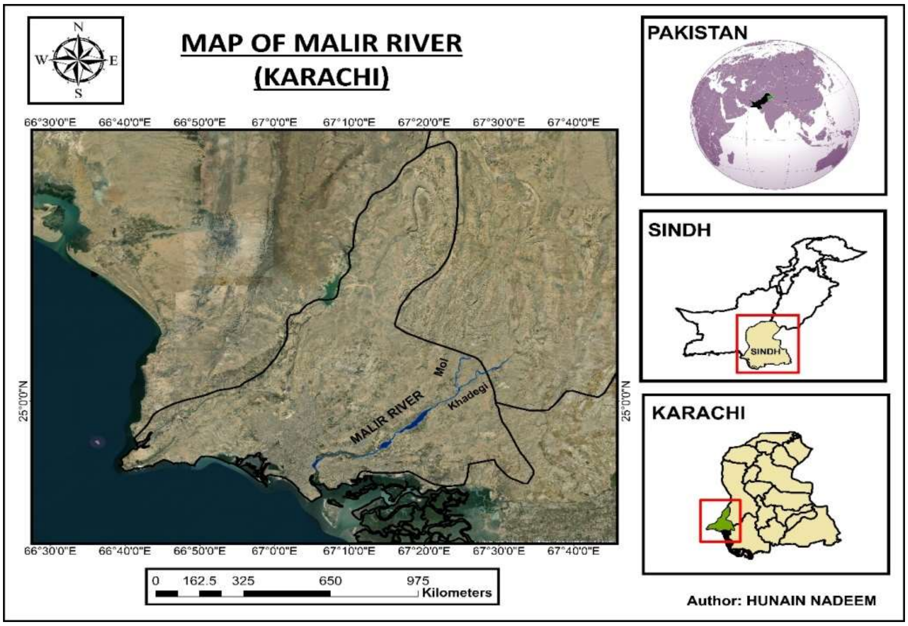

Figure 1: map shows the study area of Malir River in Karachi.

CLIMATE

Pakistan has a semi-arid climate and located at the periphery of monsoon regime. The southern portion of Pakistan receives secondary monsoonal rainfall that starts from July and continue till September. Thecity has a relatively mild climate with very low precipitation, major rainfall occurs in the month of July and August (monsoon season), winters are mild, while the summers are hot. However, the sea breeze maintains the humidity level. The total average rainfall in Karachi is less than 180 mm per year based on last 30 years record. The analysis is carried out between September 1975 and Oct2015

OBJECTIVES

The main objective of the study is to investigate the level of aridity prevailing in the study area. For acquirement of this purpose following objectives have been carried out:

- To study thedegradation of MalirRiver basin and associated area.
- To analyze the spatiotemporal changesin the moisture conditions in Malir basin and
  its surrounding area through NDWI.
- To identify the vegetation along the river bed as a supportive evidence.

MATERIAL AND METHODS

Remote sensing (RS) data and GIS are proved to be very efficient techniques forresolving different geospatial problems. Satellite acquired information can be used to highlight theproblem. As Melesse, et al (2007) and Lee, et al (2018) mentioned that for environmental changes Remote sensing provide the most reliable information at different scales i.e. local, regional and global scales for the satellites provide long-collected repeatable and real time data. A number of algorithms for the extraction of water are applied for the satellite imageries (Nath & Deb, 2010 and Acharya & Lee, et al. 2016). Landsat images are very effective for this study because it provides required multiple bands and electromagnetic spectrum. Inthis study **Normalized Difference WaterIndex**is applied to investigate the declining moisture conditionand their impact on natural drainage pattern in Malir River basin.Along with NDWI, NDVI Normalized Differentiated Vegetation Index is also calculated to show the related fluctuating land use and land cover pattern, as supporting evidence. Several studies implied different Indices to focus specifically on water bodies as compared to surrounding surfaces like Lu et al.

Data Used For this Study

Satellite images are used to calculate NDVI and NDWI with the interval of 30years. Hence Landsat 2 MSS image of 1975and Landsat 8 OLI image for 2015 from USGS, are acquired for the analysis. The description and band information of images are provided below:

Landsat 2 MSS

Landsat 2 was launched in 22 January 1975. Its original name is ERTS-B (Earth Resource Technology Satellite B), It was renamed as Landsat 2 before its launch.It carried the samesensors as Landsat 1. The Return Beam Vidicon (RBV) and the Multispectral Scanner System (MSS). In this analysis we use the MSS sensor of Landsat 2 because it is capable to detect four different spectral bands which are necessary to calculate NDVI & NDWI.The 80-meterground resolution in the four spectral bands of (MSS). The formula used for the calculation ofNDVI is:

$$NDVI = (NIR- Red\} \backslash (NIR+ Red\}$$

Band 5 (visible red) have wavelength(0.6 to 0.7 µm) and Band 6 (Near-Infrared)have wavelength (0.7 to 0.8 µm) are being utilized.

The formula used for the calculation of NDWI is:

NDWI = (Green -NIR} \ (Green +NIR}.

Band 4 (visible green) have wavelength (0.5 to 0.6 µm) and Band 6 (Near-Infrared) are being utilized.

Landsat 8 OLI

It was launched on 11 February 2013. It carries two sensors namely The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The OLI sensor contains nine bands which has the resolution 30m except pan has 15m while TIRS contain two bands having resolution100m.For NDVI we use this formula is:

NDVI = (NIR - Red} \ (NIR + Red}

In Landsat 8Band 4 (Red) having wavelength (0.64 - 0.67 µm) and Band 5 (Near-Infrared) having the wavelength (0.85 - 0.88 µm) are being utilized.

For NDWI we use this formula

NDWI = (Green - NIR} \ (Green + NIR}.

In Landsat 8 Band 3 (visible green) having the wavelength (0.53 - 0.59 µm) and Band 5 (Near-Infrared) having the wavelength (0.85 - 0.88 µm) are being utilized.

2.2 Data Proessing

An essential component of ensuring data integrity is the accurate and appropriate analysis of the data. Which can be performed through ArcGIS. Which is an accurate tool to analyze and calculate the NDWI & NDVI.

RESULTS AND DISCUSSION

First, an evaluation is conducted for the detailed comparison and discussion of the problem in the study area within thirty years time period. Soil moisture is an effective component in land surface-atmospheric processes, and prolonged soil moisture deficiencies often lead to drought induced vegetation stress. The application of NDWI provides consolidated evidence that strongly support the study by indicating the negative values of water index. After applying in the study area, following results are obtained which are in conformance to the notion of prevailing aridity in study area; leading to ultimate desertification.

In the general comparison of NDWI in both the years show that in 1975 the water index is high while in 2015 it is comparatively very less specially in the lower reaches of Korangi creek (Fig-3.1). The precipitation pattern also reveals the good moisture conditions in the previous decades as compared to the current years (Fig. 3.2). The abrupt high values of rainfall in the present century (2006-13) are due the generation of cyclones that frequently develop in the Arabian Sea during the monsoon season and disturbed the normal pattern of rainfall. But this cyclonic rainfall is unable to overcome the soil moisture deficiencies. Since evenly distributed rainfall is required for an area to be moist and fertile.

In urban areas the values of NDWI < 0.3 represent Non-water and >= 0.3 represent Water. (K., S. 2013). According to this statement, the difference in between the three decades can be easily perceived. An indication of aridity that affect the normal pattern of climate because the ample water or soil moisture content help to support good vegetation cover which leads to evapo-transpiration and cloud formation giving rise to precipitation.

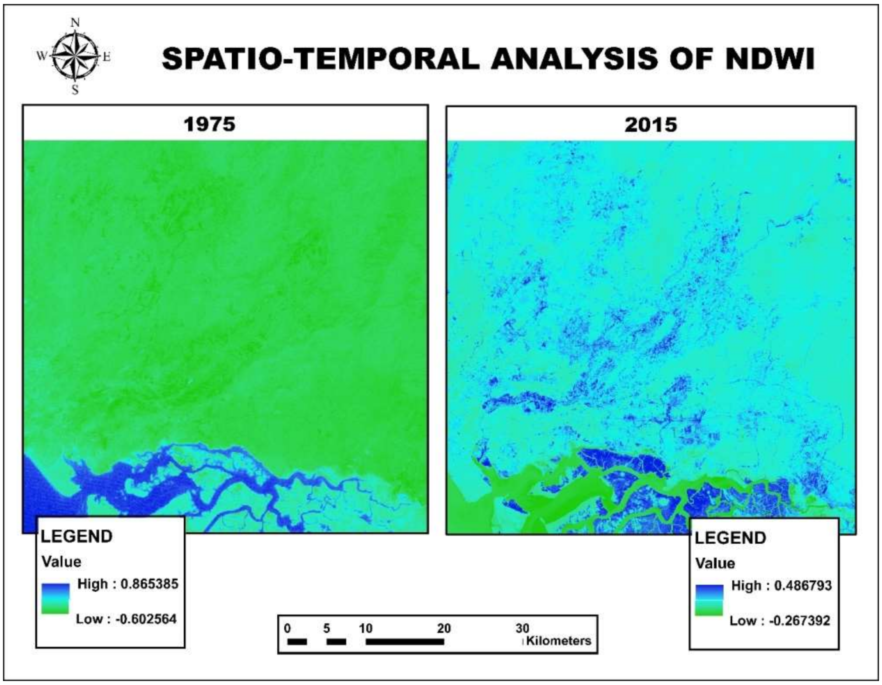

Figure 3: NDWI of 1975 & 2015 - Malir River in Karachi

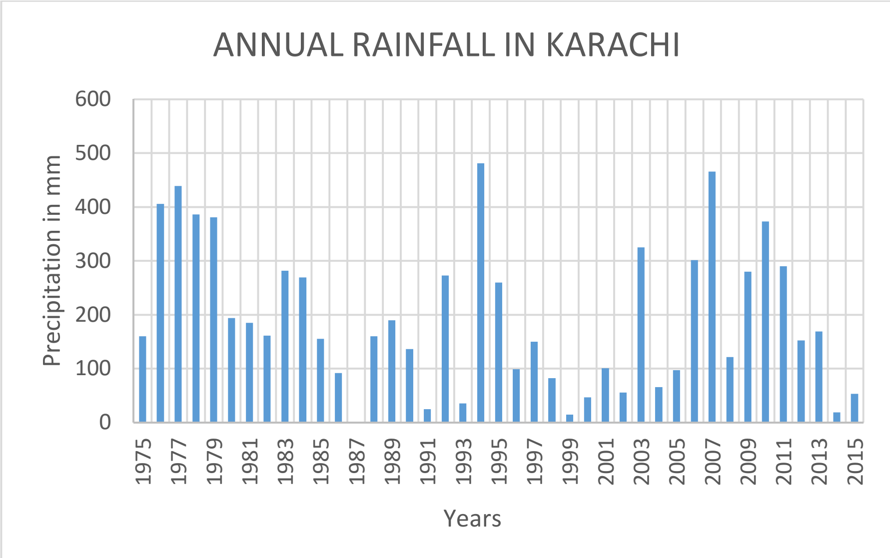

Fig 3.2 : graph showing the precipitation from 1975 till 2015.

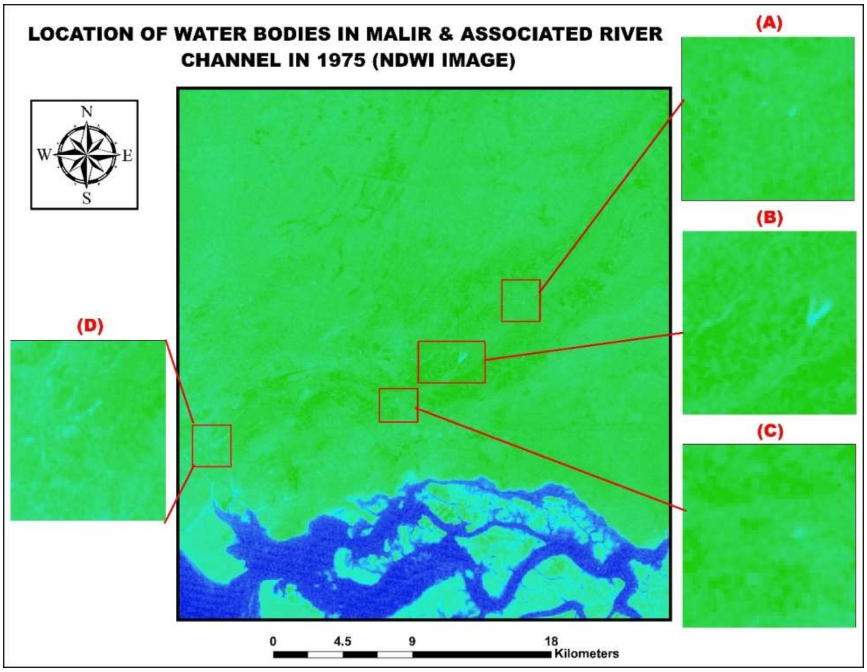

Fig 3.3: Landsat 2 MSS NDWI image with water reference points. Each red box represents surface water bodies in the channel of Malir River in 1975.

According to the Fig 3.3- (A) represent the water in small pockets in the upper reaches of Malir River. In Fig. 3.3-(B) water can be easily seen at the confluence of Malir River with its tributary. FIG.3.3- (C) show the water in the mid of the river channel but haven't very high value because of the turbidity of water due to the addition of treated chemicals waste from the industries. Furthermore, the Fig 3.3- (D) shows the water in the lower region of the Korangi creek. But the entire channel has the sufficient water for agriculture and domestic use.

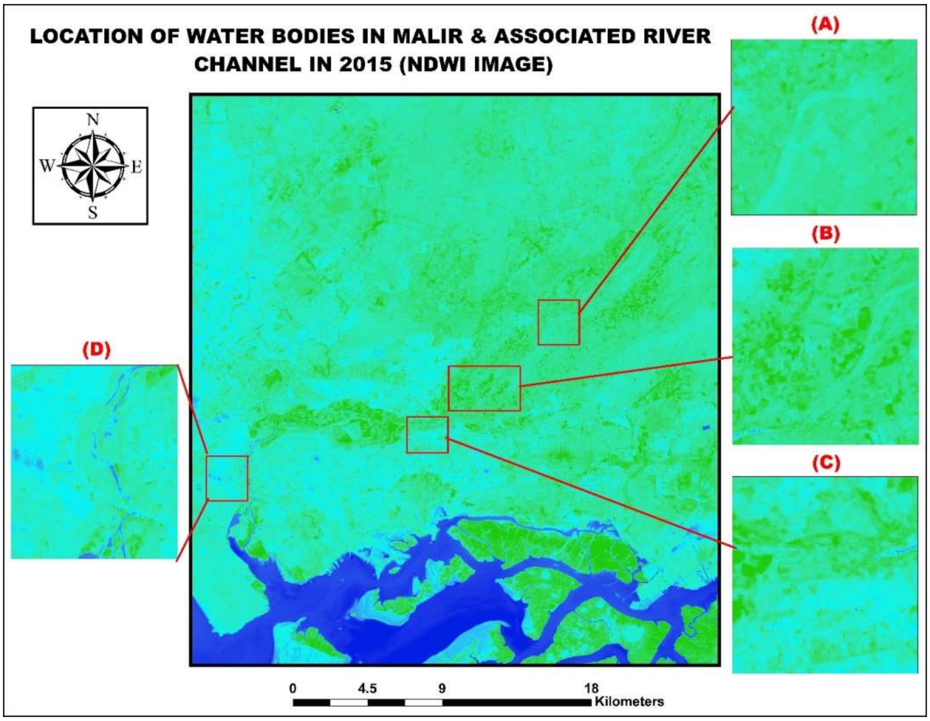

Fig 3.4 : Landsat 8OLI NDWI image with water reference points. Each red box represents

surface water bodies in the channel of Malir River in 2015.

In Fig 3.4 same places are focused and enlarged which were taken in 1975 so a good comparison can make. Fig.3.4- (A) represent the water in the upper reaches of Malir River which is comparatively very less from 1975. In Fig.3.4- (B) the confluence of tributary with Malir River on left side is completely dry while in the right side the bed of Malir River which hold the water due to healthy vegetation in 1975 contain little soil moisture. Fig.3.4- (C) show the mid of the river channel is completely dry as compared to the 1975. Furthermore, Fig.3.4- (D) shows the water in the lower region of the Korangi creek. But the entire channel is completely dry.

NDVI

By applying NDVI , a very clear picyure of the area is obtained. The bed of Malir River and other open areas can be eaily differentiated from the vegetated and cultivated areas (Fig 3.5). Hence in the year 1975 the higher values of NDVI depicts extensive vegetation cover and denser cultivated areas around the Malir River bed which indicated good moisture condition ; since the cultivation is purely dependent upon under ground water resources which are replenished by the surface runoff. While in the year 2015 the values are quite low and the cultivation around Malir River seems less dense and covers limited area, infact cultivation is now practised in the bed of Malir River especilly in the southern portion.

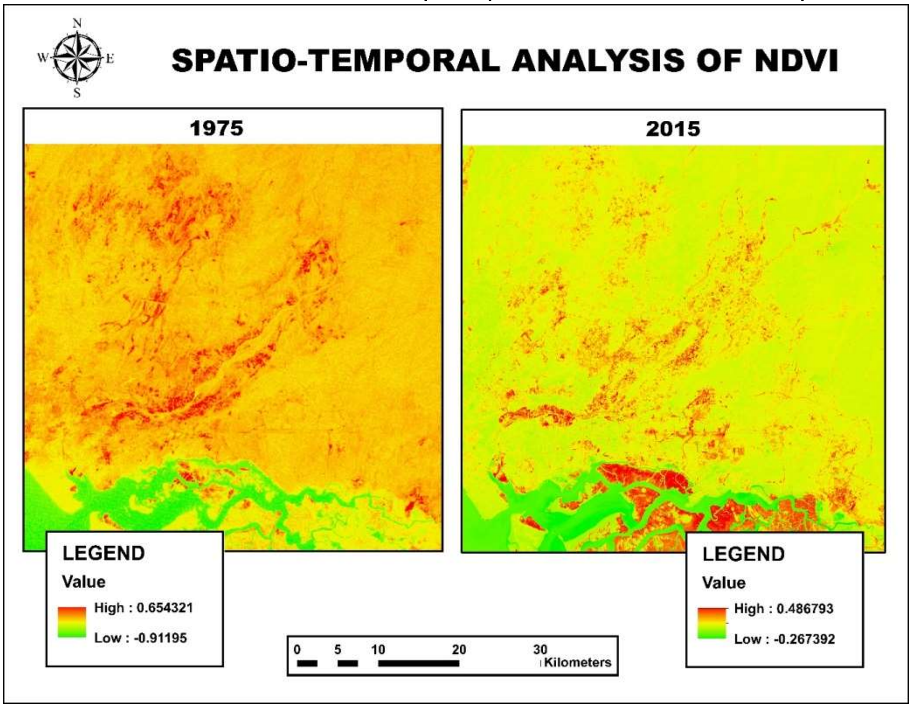

Fig 3.5: Comparison of NDVI in 1975 & 2015 - Malir river in Karachi

CONCLUSION

By applying NDWI & NDVI on Landsat images of Karachi following results can be concluded that the occupation of Malir plains with planned development, Industries and slum areas have occupied the old Malir River beds which had been inactive due to the scarce rainfalls in Karachi in 2015 and precedent years. The comparison of NDVI & NDWI maps shows that the river channel has swelled causing a substantial decrease in soil moisture and also the natural waterways are disturbed in an area. Agriculture is another factor in an area that not only blocked the drainage channels but decrease its width in many locations. It is hoped that clearing of development in the channel of the Malir River basin, restriction on scouring of sand and gravel for the purpose of construction as well as on the disposal of sewage and chemical waste in river will help to improve its soil fertility and moisture content which on the longer run will have positive impact that also help to reduce the aridity of the area.

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APLICATION OF UNMANNED AERIAL VEHICLES (UAV) FOR PRECISION AGRICULTURE, IN SELECTED WHEAT FIELDS OF RAJANPUR

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ABSTRACT

Precision agriculture is an innovative approach of agricultural management, that incorporates latest technology to monitor the crop production process and taking measures to optimize agricultural production. Winter wheat is a significant crop planted in the arid region of Rajanpur district, Punjab, Pakistan, whose 83% of the total population is rural based and relies on agriculture as their main source of living. This study aims to perform the comparative analysis of biomass levels using UAV and Landsat imagery and to explore possibility of application of drone technology in assessing wheat crop stress in winter wheat fields lying in different desertification vulnerability zones of Rajanpur. Landsat 8 imagery of 30 m resolution and DJI Phantom 3 captured imagery with 12 MP (8.6m) resolution were the data sets used in this study. The images were captured during field survey in February 2019. The results concluded that the UAV captured imagery provided detailed biomass variance, through NDVI analysis of the farms under study, as compared to the generalized NDVI results obtained through Landsat 8 images. Also, the results of the wheat crop stress analysis calculated through UAV imagery, concluded that Fatehpur UC, suffered greatest wheat crop stress of 34.83%, the wheat filed in Asni UC, suffered second highest wheat crop stress with a value of 8.41% and finally, the wheat field in Kot Mithan UC suffered least wheat crop stress of 4.76%, thus affirming that UAV proved efficient tool in demarcating the exact regions in small fields, suffering from crop stress. Such timely knowledge can lead to efficient measures to be taken by the farmers in a timely manner to save the crop from economic failure. Future studies can be focused on precise monitoring of crops that could lead us towards precision agriculture.

KEY WORDS: Unmanned Aerial Vehicles (UAV), Landsat 8, Crop stress, NDVI, desertification vulnerability

INTRODUCTION

As the population explosion continues, the world continues to face the constant threat of food insecurity and resultant advancement in agricultural sector remains indispensable. Agricultural development has socio-economic benefits, as it boosts agricultural yields, provides occupation opportunities, and reduces imbalance between rural urban employments *(Norasma et al.,* 2019). Precision agriculture is an innovative approach of agricultural management, that incorporates latest technology to monitor the crop production process and taking measures to optimize agricultural production (Trivelli *et al.,* 2019) and is one of the top agricultural revolutions (Mulla, 2013). It can be defined as “an agricultural system in which the management practice is performed at the right place, with the right intensity, and at the right time” (Maes and Steppe, 2019). Development in Unmanned Aerial Vehicles (UAV) have recently provided a boom to the precision agriculture, as this technology combines with image data analytics to provide solutions to issues posed by climate change, lack of potential available arable lands, and demand of freshwater (Radoglou-Grammatikis, Sarigiannidis, Lagkas, and Moscholios, 2020).

Assessing vegetation health through the remote sensing techniques is one of the main PA applications, however, access to satellite images is very expensive and their resolution and resultant quality is not satisfactory. The satellite images may be affected from cloud cover and other distortions. However, UAV or drones provide economical and practical solution to field monitoring (Radoglou-Grammatikis *et al.,* 2020), by providing high quality images and enabling crop monitoring in different stages of crop development. Similarly, UAVs can generate images of higher spatial resolution (<1m) at a temporal frequency that enables timely response in accordance to field status (Elarab, Ticlavilca, Torres-Rua, Maslova, and McKee, 2015). They offer the opportunity for various images to be captured of the same field using multiple camera filters, which provide detailed information regarding the crop health and helps in pin pointing the areas of field that require specific attention, of particular type (Norasma *et al.,* 2019).

According to Maes and Steppe (2019) UAV technology has proved to be a ‘game changer’ in precision agriculture. UAVs can be used in various ways for precision agriculture, e.g. crop monitoring, estimation of crop height, pesticide spraying, soil analysis etc. (Mogili and Deepak, 2018). Similarly, the UAV captured imagery is even used for early detection of crop diseases (Albetis *et al.,* 2017). Thus, through UAV use, precision agriculture can be efficiently practiced as, the cost of use of pesticides; fertilizers, water can be reduced, and can be provided to particularly those areas of field where they are actually needed.

UAV captured imagery is used by the farmers to assess the stresses and variabilities their crops go through. This is achieved by calculating vegetation indices through the captured images. NDVI can easily be calculated thorough UAV imagery, and it provides valuable information regarding the biomass levels, which in turn help in reaching meaningful conclusions regarding crop diseases, pest infestation, water stress, deficiency of particular nutrients and other factors that might affect crop productivity (Radoglou-Grammatikis *et al.,* 2020; Xue and Su, 2017). The RGB imagery in winter wheat fields is particularly important for the early weed detection and lodging detection (Maes and Steppe, 2019).

Winter wheat is a significant crop planted in the arid region of Rajanpur district, Punjab, Pakistan. 83.10% of its population is rural and relies on livestock herding and agriculture for their living (GoP, 2017). The district has an arid type of climate with rainfall concentrated in monsoon months. The district has a high population growth rate of 3.16 for the period of 1998-2017 (GoP). According to NDMA (NDMA, 2017) , this district has highly food insecure population. The variations in the wheat yield, or crop failure in case of acute water shortage, can lead to economic and health disaster for the locals who highly depend on agriculture as the main source of earning.

The aim of this study was to perform the comparative analysis of biomass levels using UAV and Landsat imagery and to explore possibility of application of drone technology in assessing wheat crop stress in winter wheat fields lying in different desertification vulnerability zones of Rajanpur, as an effort to strive for the goal of precision agriculture in the district.

MATERIAL AND METHODS

Study area

Its lies within 29.2080° north and 70.2408°east longitude (Google Earth) spatial coordinates. The district is divided into 3 tehsils which are further subdivided into 69 union councils (GoP, 2013). Three sample wheat fields, from three different union councils of Rajanpur district were selected, randomly, from each of the Desertification Vulnerability Indexed Zones as identified in the study by (Mazhar, Shirazi, and Javid, 2018).

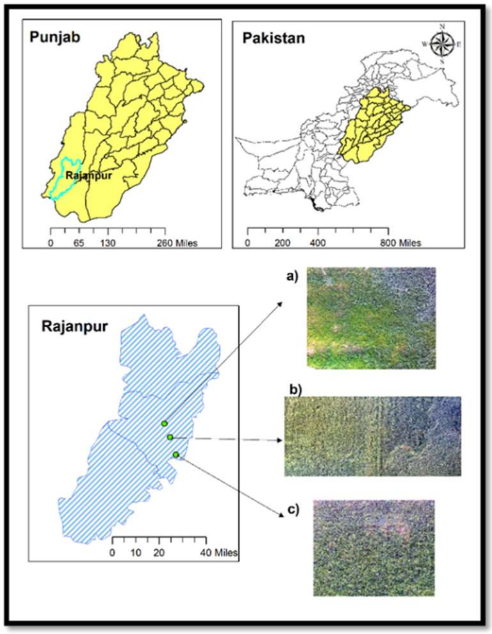

Figure 1: Study area map with orthomosaic images processed through UAV captured images a) Fatehpur b) Asni and c) Kot Mithan

UAV Survey

The survey was conducted using DJI Phantom III Standard quadcopter, in Rajanpur, Punjab, Pakistan from 25-27 February, 2019. DJI Phantom 3, has a built in 2.7K camera. It's Gimbal is 3-axis and is capable of capturing 12 MP still images. Its 12 MP resolution is equal to 8.6m. GPS is used by this UAV for positioning outdoors. The month of February was selected for the survey as the wheat crop of Punjab, usually reaches the flowering stage in this month. Water deficiency in this stage can lead to reduced yields (Naheed and Mahmood, 2009).

A single flight of UAV was performed over each sample field, at midday. The UAV was flown at 15m height above the ground, and the images captured had a resolution of 30.48ppi. The images were in RGB, having a pixel depth of 16 Bit. Before the survey, waypoint routes were generated for the sample fields in *djigo* app. Nadir view angle was chosen for the survey under clear sky conditions. The images obtained through UAV were uploaded on djigo app and the orthomosaics were obtained, and later Agremo app was used to generate the crop stress report.

Landsat 8 imagery

The Landsat 8 images of 30m resolution, OLI/TRIS images were obtained from USGS earth explorer, for the same year and same month. The study area covered four tiles, and the path and rows of the tiles that covered the study area were, 151-39, 151-40, 152-39, 152-40. The georeferenced and atmospherically corrected images were requested and later downloaded from USGS. The images obtained were cloud free.

Normalized Difference Vegetation Index (NDVI) (1)provides a reliable estimation of greenery in a region, presents a meaningful combination of bands associated with the transmission, reflection and assimilation of vegetation (Mazhar et al., 2018). NDVI was calculated from Landsat 8 image, using ERDAS Imagine 2015 software, using the equation provided by Epiphanio and Huete (1995):

$$NDVI = (NIR-R) / (NIR+R) \quad (1)$$

RESULTS AND DISCUSSION

The NDVI results of Landsat image (figure 2), present More than 50% of the district under low NDVI values of -0.495. The entire eastern strip of Rajanpur, is lying under moderate NDVI, while some high NDVI values can be spotted in north eastern and eastern Rajanpur. On the western border of the district lie the Suleiman mountains which justify the low NDVI values for this zone.

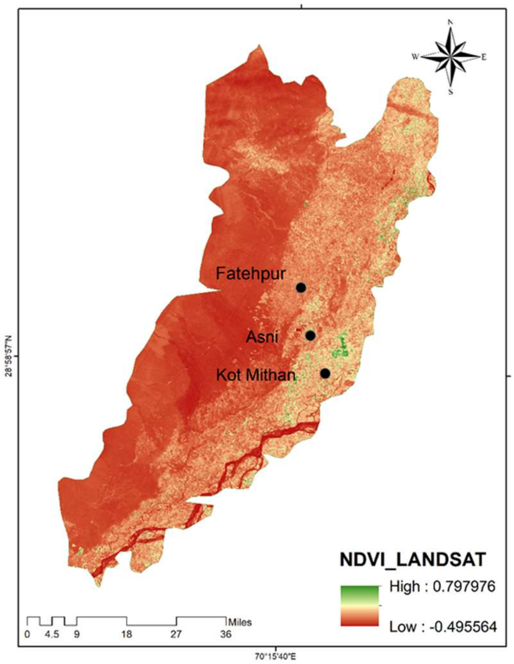

Figure 2: NDVI calculated from Landsat 8 imagery, for Rajanpur District

In figure 3 the comparison of NDVI calculated for wheat field of Fatehpur becomes apparent. The inset maps in a) and b) present zoomed versions of the NDVI value as extracted from the Landsat 8 image, and the result declares entire Fatehpur wheat field, lying in high DVI zone, to be suffering from low NDVI. Whereas figure c) presents the NDVI calculated from the UAV captured image, and shows variation in the NDVI values, ranging from a low NDVI value of -0.740741 in the central patches of the field, to a high NDVI value of 0.196319 in the eastern and western patches of the field.

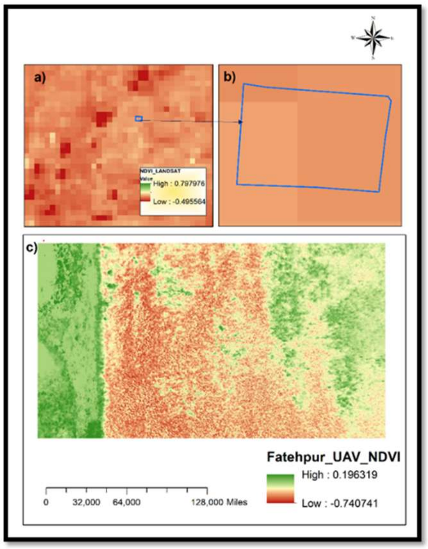

Figure 3: Comparative NDVI for wheat field in Fatehpur UC: a) and b) zoomed NDVI views calculated from Landsat 8 image: c) NDVI obtained from UAV captured image

Figure 4 presents the NDVI comparative maps calculated through Landsat and UAV captured imagery, for wheat field in Asni, a union council which lies in moderate DVI zone. According to b) inset map, the Landsat calculated NDVI present entire Asni field to experience low NDVI of -0.495564, while great variation in this NDVI is visible in the NDVI calculated from the UAV captured image. Almost entire field has vertical zones of low NDVI, having a value of -0.768116, with patches of moderate NDVI in between. Only in the southern small patch of the field, high DVI with a value of 0.158209 can be spotted.

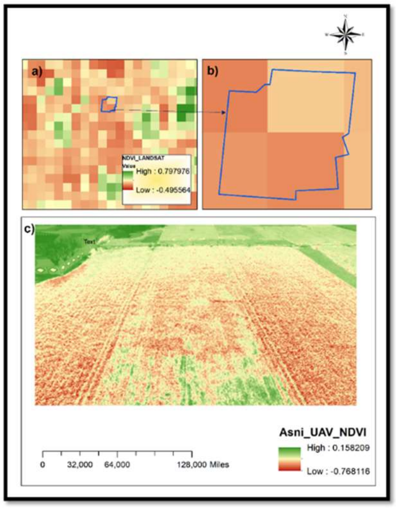

Figure 4: Comparative NDVI for wheat field in Asni UC: a) and b) zoomed NDVI views calculated from Landsat 8 image: c) NDVI obtained from UAV captured image

Figure 5 presents the variation in NDVI calculated for Kot Mithan's wheat field, which was located in the low DVI zone. The inset maps, a) and b) present the zoomed version of the Landsat calculated NDVI, with low NDVI values of -0.495564 covering approximately one fourth of the field, while the remaining field was having moderate NDVI. On the contrary, c) show the UAV based calculated NDVI, with high NDVI of 0.125683 covering almost 70 of the field, and low NDVI with a value of -0.544304 covering small area in the center of the field. Results clearly indicate greater variation visible through UAV captured imagery.

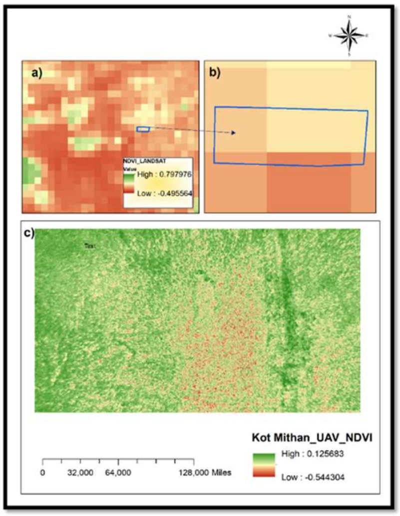

Figure 5: Comparative NDVI for wheat field in Kot Mithan UC: a) and b) zoomed NDVI views calculated from Landsat 8 image: c) NDVI obtained from UAV captured image

Figure 6 presents the results of the crop stress calculated using the orthomosaic images captured using UAV in the sample fields, lying in randomly selected union councils, of each of the DVI zones, in Rajanpur District.

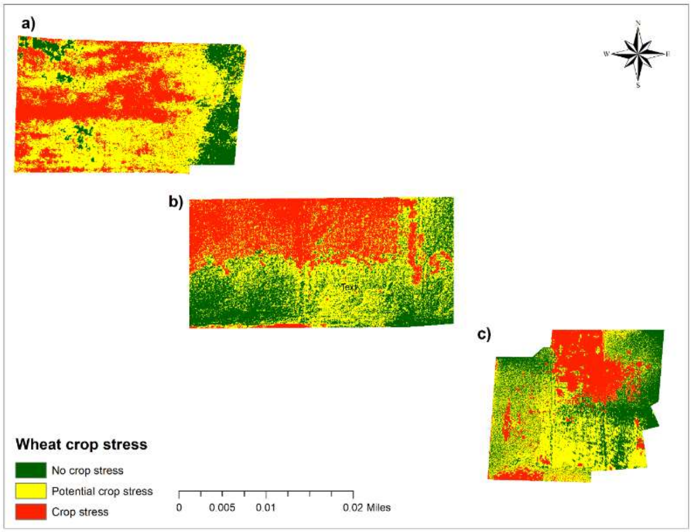

Figure 6: UAV image-based wheat crop stress analysis for Rajanpur District's selected wheat farms a) Fatehpur b) Asni c) Kot Mithan

Table 1 presents the interesting finding that in Fatehpur UC, 34.83% of the wheat field was under crop stress, while a further 51.16% was under potential crop stress. Since this field is located in the high DVI zone, the crop stress analysis further affirms the findings of Mazhar *et al.*, (2018), that the high DVI zone wheat farms are witnessing higher rates of crop stress. Only 13.95% of the sample wheat field in Fatehpur UC was witnessing no stress.

Sample wheat farm in Asni UC experienced 8.41% of crop and 14.48% of potential crop stress, on the contrary much of the farm, i.e. 77.10% was experiencing no crop stress, again affirming the findings of Mazhar et al. (2018), since Asni UC is located in the medium DVI zone.

District	Union Council	DVI Zone	No crop stress (ha)	% No crop stress	Potential crop Stress (ha)	% Potential crop Stress	Crop Stress (ha)	% Crop Stress
Rajanpur	Fatehpur	High	0.01	13.95	0.04	51.16	0.03	34.83
	Asni	Medium	0.16	77.10	0.03	14.48	0.01	8.41
	Kot Mithan	Low	0.06	63.80	0.03	31.42	0.00	4.76

Table 1. Crop stress in selected winter wheat fields of Rajanpur district

Kot Mithan UC lying in the low DVI zone (Mazhar *et al.,* 2018) witnessed a meagre 4.76% of crop stress, while another 31.42% was found to under the potential crop stress category. However, 63.80% of the wheat field in Kot Mithan was found to be experiencing no crop stress.

Similar application of UAV imagery for analyzing the health of winter wheat crop was performed in a study by Christiansen, Laursen, Jørgensen, Skovsen, and Gislum (2017) and Rasmussen, Nielsen, Garcia-Ruiz, Christensen, and Streibig (2013). The findings of similar studies affirm that the variation in the vegetation health at micro level, for e.g. one acre, can only be captured through UAVs, because they have advantage of better resolution and ease of use as compared to satellite data.

CONCLUSION

UAVs can be efficiently used in agriculture sector of Punjab Pakistan, for promoting the precision agriculture, which would result in reducing food insecurity in the country. The current study presented comparative NDVI analysis result of three one acre, winter wheat fields, selected in different Desertification Vulnerability Indexed (DVI) zones in Rajanpur district, Punjab Pakistan. The results presented that variations in results as the Landsat 8, NDVI calculated on the 30m resolution images presented highly generalized results, without giving any detailed information about the biomass levels in different parts of small fields. Whereas the 12 MP UAV captured imagery presented NDVI values with detailed clear variation on the one acre wheat fields, under study. The results would help the farmers to take necessary action in the areas with low biomass levels and prevent reduced crop yields, or even in worst case, crop failures. The results of the wheat crop stress analysis presented the interesting finding that the wheat field in Fatehpur UC, lying in high DVI zone of Rajanpur, suffered greatest wheat crop stress of 34.83%, the wheat filed in Asni UC, lying in moderate DVI zone, suffered second highest wheat crop stress with a value of 8.41%. Finally, the wheat field in Kot Mithan UC, lying in the low DVI zone suffered least wheat crop stress of 4.76%, this affirming that UAV proved efficient tool in demarcating the exact regions in small fields, suffering from crop stress. Such timely knowledge can lead to efficient measures to be taken by the farmers in a timely manner to save the crop from economic failure. Future studies can be focused on precise monitoring of weed attacks, pest infestations, water stress, and soil properties analysis using UAV on small scale, so that the dream of precision agriculture can be fulfilled even in remote areas of Pakistan.

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