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Spatio-temporal assessment of land properties on soil moisture and vegetation using resourcesat-2 awifs sensor in hudgi sub watershed, Karnataka, India

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Abstract

Soil moisture is an important parameter that has importance in climate, vegetation and drought. Soil moisture can be used as a direct indicator to dryness, Land Surface Temperature and vegetation status which are indirectly related to soil moisture and consequently affect the degree of dryness. This paper explains the estimation of soil moisture in the form of NDMI model and Vegetation health in the form of NDVI Models using ResourceSat-2 Awifs sensor. The objective of this study is to assess temporal variation in moisture mapping as well as vegetation mapping using remote sensing data for Hudgi micro watershed for the period of 2015 and 2017 years for three different crop seasons that are Kharif (June to September), Rabi (October to March) and summer season (April and May). The years selected are based on their rainfall that are minimum rainfall and average rainfall. These remote sensed generated maps are correlated with the study of Land Resource Inventory (LRI) for physical parameters of soil such as erosion, gravelliness, slope, Texture and depth. These physical parameters are calculated or noted by ground trothing field observations. Using these field observations soil phase map are generated based on soil taxonomy which include soil depth, soil texture, soil slope, soil gravelliness and soil erosion. The Study area Hudgi micro watershed consists of 19 soil series and 58 different mapping units.

The multispectral satellite image ResourceSat-2 with Awifs sensor were used to generate remote sensing NDMI and NDVI model and these values are correlated with physical parameters of soil and soil mapping units for two years and 3 different crop seasons using zonal static analysis tool of ArcGIS 10.4.1 software. NDMI values range within -1 to +1, where negative values indicates high water stress or lesser moisture content, whereas positive value indicates low water stress or higher moisture content same as NDMI, values of NDVI range within -1 to +1 where negative values indicate loss of vegetation or contaminated vegetation, whereas positive value indicates healthy and dense vegetation.

The result of Hudgi micro watershed indicates that this method can be efficiently applied to estimate temporal assessment of soil moisture and vegetation health using NDMI and NDVI model using multispectral satellite image ResourceSat-2 with Awifs sensor.

Keywords: NDMI, NDVI, resourcesat-2 awifs sensor, hudgi micro watershed, land resource inventory, soil taxonomy, soil series, zonal statics, ArcGIS software

Introduction

Availability of optimum soil moisture at different and important growth stages of a crop or any vegetation is crucial among all other requirement to complete its life cycle (Rajesh Kumar Soothar *et. al.* in 2021 & Aakansha Chadha *et. al.* in 2019)^[31, 32]. Role of other essentials like soil nutrients will effective under sufficient soil moisture status which ultimately decides qualitative and qualitative parameter of crop health and productivity (Pauline Welikhe *et. al.* in 2017)^[20].

Soil and land characters like soil texture, structure, infiltration rate, maximum water holding capacity, drainage, soil depth, slope etc, have direct positive correlation with optimum soil moisture content and health of vegetation (V.K. Dadhwal *et. al.* in 2015, D. S. Kamat *et. al.* in 2015)^[7]. Assessment and monitoring of soil moisture at different temporal stage will be an important indicator of potential of soil and land of given area (Mohamed A.E. Abdel Rahman *et. al.* in 2016, Qingsheng Liu *et. al.* in 2015 & C. Y. Niu *et. al.* in 2015)^[2, 3, 6].

No doubt, application of geo statistical tools like NDMI and NDVI will help in drawing inference on status of moisture and vegetation for a given area but these important indicators are highly dynamic and influenced by several factors below and above the ground (Josef Lastovicka *et. al.* in 2020) ^[1]. A comparative study of these influential factors on NDMI and NDVI will enlighten the concept towards better understanding and application of the outcome effectively in management of natural calamities like drought, flood and degradation of natural resources.

Surface and subsurface features of soil and land were characterized by conducting land resource inventory (LRI) through detailed soil survey (Jaya N. Surya *et. al.* in 2018) ^[4] Properties such as soil texture, depth, severity of erosion status in Hudgi sub watershed in Bidar district of Karnataka state, were assessed for their influence on NDMI and NDVI under normal and deficit rain fall situations to find out most influential factor among properties of soil on these geo statistical indicators (Alberto C. de C. Bernardi *et. al.* in 2017)

Study area

Hudgi sub watershed encompassing seven micro watersheds in

Humnabad Taluka of Bidar District, Karnataka, India and is located in between 17° 44' 0.388" North latitude and 77° 09' 33.575" East longitude covering the total geographical area of 5830.26 ha. The average annual rainfall is 780mm and temperature with daily mean temperature of 27.3 °C make the study area favorable for many crops during normal distribution. The topology of the study area is slightly undulating to plain terrain having maximum elevation of 684 MSL and minimum elevation of 640 MSL. Ten major soil series are identified in the study area indicate wide range in some soil and land characters like soil texture, depth, erosion, susceptibility, etc developed on different physiographic position on laterite constituting 79% of TGA.

Character wise soil of the area texturally vary from sandy loan to clay, depth wise belong to very shallow to very deep, slope range from gently to very gently sloping, and with gravel cover percentage ranging from non-gravelly to very gravelly. Remaining 21% of lands are covered under waterbody, habitation, forestry and rockout crop. Major crops grown were Soybean, Red gram, Green gram, Black gram, Bengal gram, Jowar, sesamum, sugarcane, wheat and safflower.

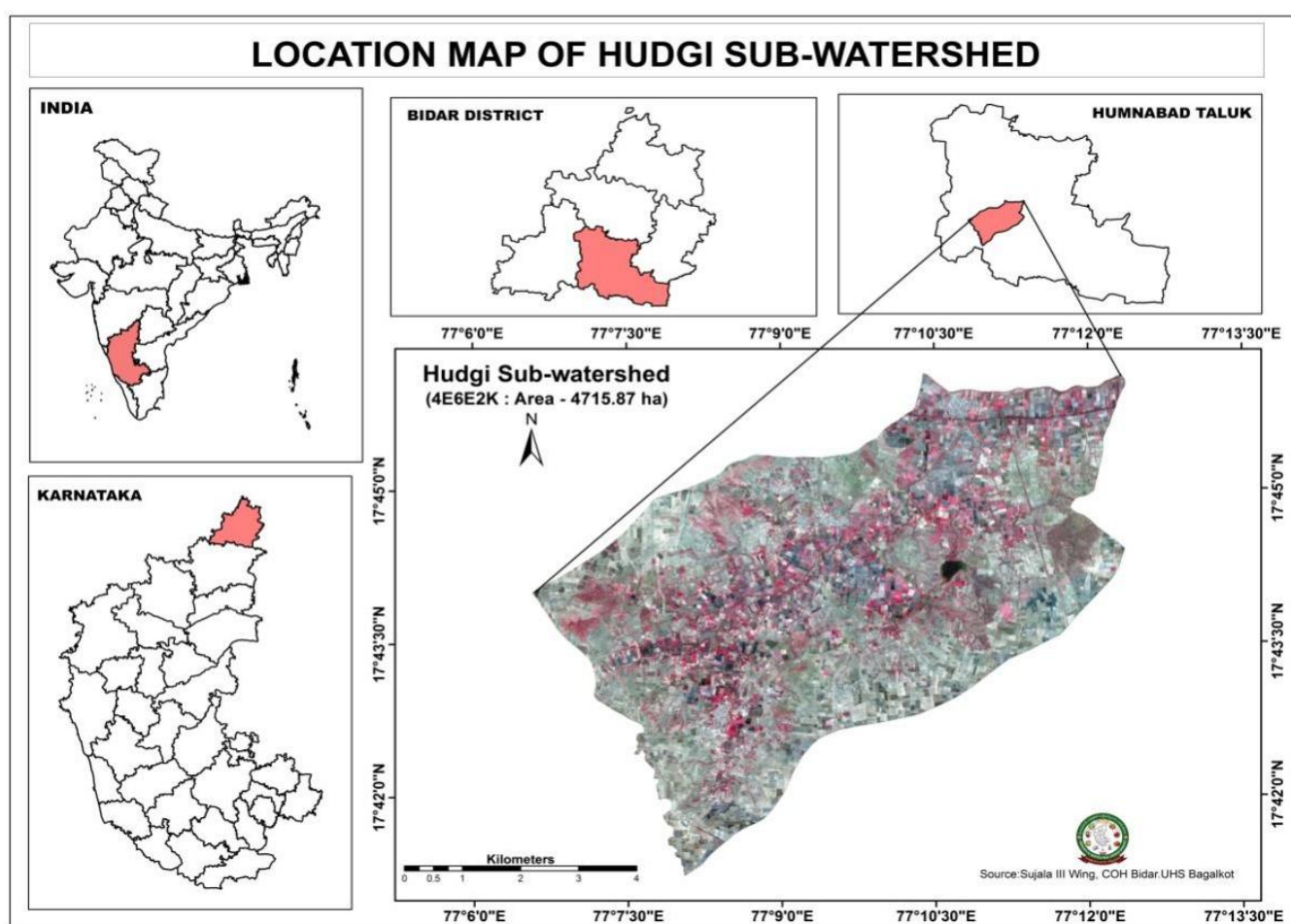
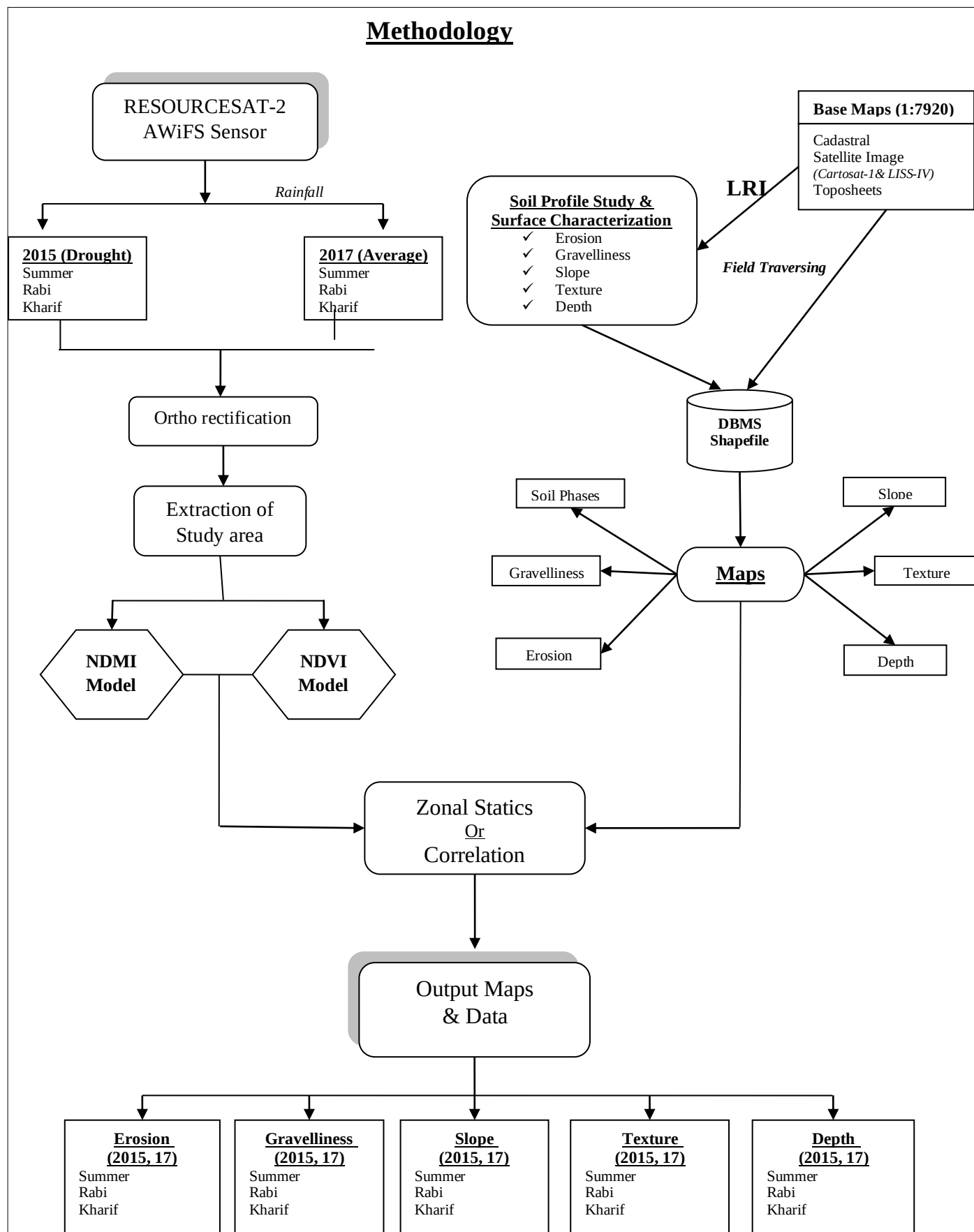


Fig 1: Location map of hudgi subwatershed

Materials and data used



Data used

Satellite image was obtained from ResourceSat-2 Awifs sensor which has enhanced capabilities of 12 bits vs 10 bits with revisit

period of 5 days and resolution of 56m with three electro optical cameras as its payload and these multispectral pushbroom scanners are with linear array CCDs as detectors. The data is

acquired using four spectral bands which are Band 2 as Green, Band 3 as Red, Band 4 as NIR and Band 5 as SWIR (N.B. English *et. al.* in 2016, David B. Lobell *et. al.* in 2002) [25]. Major application of this sensor is agricultural crop discrimination and monitoring, yield estimate or crop acreage, precision farming, forest mapping, water resource rural development and so on (Meisam Amani, BahramSalehi *et. al.* 2017) [30]. For present study data used was of two years that is 2015 and 2017 for three different crop seasons which are Kharif (June to September), Rabi (October to March) and summer season (April and May) as to have a comparative studies in rainfall deficit year (2015) and normal rainfall year (2017).

To obtain physical parameters of soil, Land Resource Inventory (LRI) field visit were carried out on along with grid points provided on cadastral map and base map. Cadastral map and base map were provided by KRSRAC along with its Shapefile so that field observations are inserted on them for preparation of maps such as Soil Depth map, Surface Soil Texture Map, Soil Gravelliness, Soil Slope, and Soil Erosion. Using all these physical properties of soil, Soil Phase map was generated based on its Taxonomy. Soil Phases are unit of soil that are designed according to the purpose of survey which are carried to recognize name of soil and landscape properties that are used in criteria of soil taxonomy as well as soil phase are used to recognize and name at relatively higher categorical level with soil properties that are used as differentiate with lower categorical level. The soil Phases recognized along with Soil series and all other physical properties that are included in this study are elaborated in below listed tables.

Ex: BLR m B2 g1

BLR = Soil Depth

m = Soil Texture

B2 = Soil Slope

g1 = Gravelliness

Table 1: Brief description of soil series identified in study area

Sl no	Soil Series Name	Depth in cm	Sl no	Soil Series Name	Depth in cm
1	Ainapur (ANR)	75-100	11	Muttakheda (MKD)	
2	Bhadrapur (BDP)	0-25	12	Madhanal (MNL)	100-150
3	Babalgaoon (BGN)	>150	13	Mustari (MST)	50-75
4	Ballur (BLR)	0-25	14	Mutangi (MTN)	75-100
5	Devigiri (DGR)	100-150	15	Mustariwadi (MWD)	>150
6	Dhupat Mahagaon (DMN)	75-100	16	Pashapur (PPR)	50-75
7	Kouta B (KBB)	100-150	17	Rampur (RMP)	0-25
8	Kodambal (KDM)	25-50	18	Raipalli (RPL)	>150
9	Kouta K (KKK)	50-75	19	Udawah (UDH)	75-100
10	Madargi (MDG)	25-50			

Normalized difference moisture index

Two spectral bands mainly Near Infra-Red (NIR) and Short Wave Infra-Red (SWIR) Bands of ResourceSat-2 Awifs sensor are used to estimate moisture content of soil as SWIR sensor mainly reflects changes in water content as well as spongy mesophyll structure in canopy, NIR sensor reflects leaf internal structure and leaf dry matter content. The amount of water available are largely controlled by the spectral reflectance varies in SWIR intervals of electromagnetic spectrum and NDMI values range within -1 to +1, where negative values indicates

high water stress or lesser moisture content, whereas positive value indicates low water stress or higher moisture content and NDMI is Calculated using following formula.

Table 2: NDMI = (NIR - SWIR) / (NIR + SWIR)

NDMI	Interpretation
-1 - -0.8	Bare soil
-0.8 - -0.6	Almost absent canopy cover
-0.6 - -0.4	Very low canopy cover
-0.4 - -0.2	Dry Land or very low canopy cover, wet
-0.2 - 0	High water stress or low canopy cover, low water stress
0.2	High water stress or mid-low canopy cover, low water stress
0.2 - 0.4	High water stress or average canopy cover, low water stress
0.4 - 0.6	No water stress
0.6 - 0.8	No water stress
0.8 - 1	No water stress/ waterlogging

Normalized difference vegetation index

Same as NDMI model, NDVI model uses two spectral bands which are Near Infra-Red (NIR) and Red Bands, where Red Band absorbs vegetation as it is visible band. NDVI is used for understanding vegetation density in form of greenness and assessing changes in plant health. NDVI values range within -1 to +1 where negative values indicate loss of vegetation or contaminated vegetation, whereas positive value indicates healthy and dense vegetation and NDVI is calculated using following formula. (Alberto C. de C. Bernardi *et. al.* in 2016, S. E. Nicholson and T. J. Farrar in 1994) [24]

Table 3: NDVI = (NIR - Red) / (NIR + Red)

NDVI	Interpretation
0 - 0.1	Bare soil
0.1 - 0.2	Almost absent canopy cover
0.2 - 0.3	Very low canopy cover
0.3 - 0.4	Low canopy cover, low vigour or very low canopy cover, high vigour
0.4 - 0.5	Mid-low canopy cover, low vigour or low canopy cover, high vigour
0.5 - 0.6	Average canopy cover, low vigour or mid-low canopy cover, high vigour
0.6 - 0.7	Mid-high canopy cover, low vigour or average canopy cover, high vigour
0.7 - 0.8	High canopy cover, high vigour
0.8 - 0.9	Very high canopy cover, very high vigour
0.9 - 1	Total canopy cover, very high vigour

Land resource inventory

Land Resource Inventory (LRI) was carried by adopting the methodology as per NBSS LUP and USDA. Surface feature like soil texture, slope, erosion status, the percentage of gravel cover at recorded and surface representative soil samples were collected at the interval of 250 meters through intensive filed traversing. Sub surface characters of sub watershed were assessed through study of soil profiles for establishment of soil series. On geo reference base map (Cadastral map) of 1:7290 with help of field and lab analysis data, polygons drawn on the base map during detailed soil survey were confirmed (Jaya N. Surya *et. al.* in 2018 & S.K. Singh *et. al.* in 2016) [4, 5]. Polygon of soil mapping units drawn on base map during detailed soil survey were confirmed with the help of characterization of soil through interpretation surface and profile soil sample lab data and spatial data from Carto Sat-I and LISS-IV at the same Scale. Various layers such as soil texture, depth, slope, erosion, gravel percentage of study area were generated on GIS Platform.

Zonal statistics or correlation

Zonal Statistics through ArcGIS was used to calculate statistical values of each zone defined by dataset of another zone of two different raster file where output generated is single output values. LRI maps and remote sensing maps are correlated with each other using this zonal statistics tool and output data were generated in the form of correlated values and Correlated graphs. (Li Shen *et. al.* in 2015, Stefan Kuzevic *et. al.* in 2015 &

João Serrano *et. al.* in 2015)^[21]

Results and discussion

The study area Hudgi Sub watershed was covered under Land resource inventory for the ground data with respect to surface and sub surface characters like soil depth, texture, surface gravelliness, slope and erosion status. Results of interpretation of all the above said parameters are explained as below.

Table 4: Mean values of NDMI & NDVI in hudgi subwatershed as influence by soil depth, erosion, slope, texture, gravelliness

Factors	NDMI						NDVI					
	2015			2017			2015			2017		
	Kharif	rabi	summer	Kharif	rabi	summer	Kharif	rabi	summer	Kharif	rabi	summer
Depth	0.160	0.046	0.021	0.160	0.189	0.052	0.399	0.242	0.170	0.499	0.486	0.260
Erosion	0.144	0.036	0.015	0.251	0.159	0.042	0.386	0.227	0.166	0.490	0.467	0.254
Gravelliness	0.147	0.038	0.017	0.252	0.166	0.044	0.389	0.231	0.165	0.494	0.471	0.254
Slope	0.146	0.035	0.014	0.254	0.161	0.042	0.389	0.228	0.166	0.493	0.471	0.256
Texture	0.164	0.048	0.023	0.258	0.196	0.054	0.402	0.243	0.172	0.500	0.488	0.259

Soil depth

Through resource inventory it is found that the soils of study area belong to 6 different classes. Out of total geographical area of sub watershed, 1080 ha (22.90%) belongs to very shallow, 1216 ha (25.78%) belongs to shallow, 695 ha (14.74%) belongs to moderately shallow, 494 ha (10.48%) belongs to moderately deep, 389 ha (8.26%) belongs to deep and 413 ha (8.76%) belongs to very deep soil depth.

Surface soil texture

It is revealed from the study of soil texture that, soils of Hudgi sub watershed consist of surface soil texture from sandy clay to clay soil textural classes. The dominant texture sandy clay occupies 3513 ha (74.49%) and clay is 774 ha (16.42%) (Saeid Gharechelou *et. al.* in 2016)^[17]

Soil gravelliness

It is confirmed from the results that the surface gravelliness of the study area belongs to non-gravelly to very gravelly classes.

An area of 1478 ha (31.34% of TGA) belong to non-gravelly class. Remaining 1393 ha (29.54 % TGA) is covered with gravelly class, and 1416 ha (30.02 % of TGA) belongs to very gravelly class.

Slope

The slope classes of the study area ranged from nearly level in the lowland to very gently sloping uplands in the sub watershed. An area of 754 ha (15.99%) is covered with gently sloping classes whereas an area of 3533 ha (74.92%) belong to very gently sloping classes.

Soil erosion

It is found that the present study area is suffering from moderate to severe soil erosion hazard. Out of total area surveyed 3057 ha (64.83%) is affected with moderate erosion hazard and an area of 1230 ha (28.08%) was found suffering from severe erosion hazard.

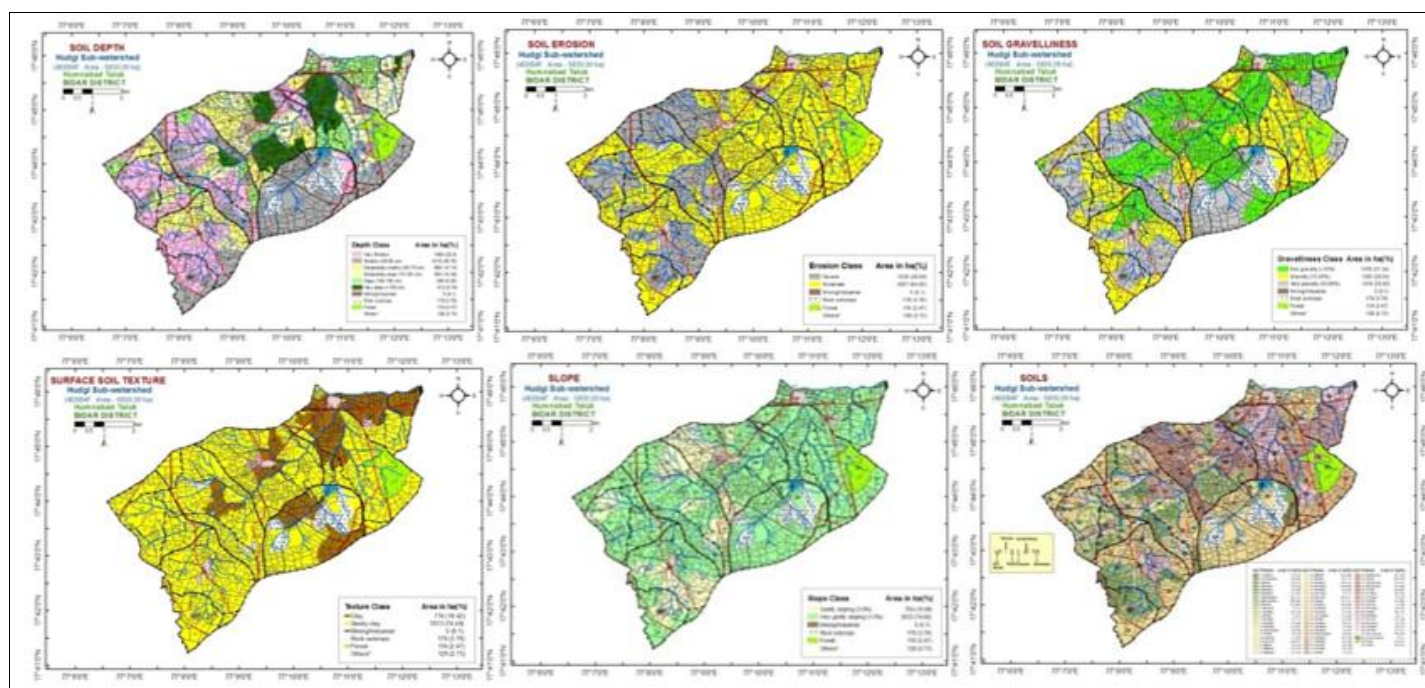


Fig 2: Physical parameters of study area

Influence of soil depth, erosion, gravelliness, slope, and texture on NDMI

It is found that the correlated NDMI values in 2015 varies between 0.144 to 0.164 in Kharif season, 0.035 to 0.048 in rabi season and 0.015 to 0.023 in summer season respectively. All the higher values of NDMI were recorded under the influence of Texture and the least values were found influenced more by erosion hazards. (Josef Lastovicka *et. al.* in 2020, Meng-Lung Lin *et. al.* in 2011, Maria Casamitjana *et. al.* in 2011)^[1]

During normal rainfall year that is in 2017, the correlated values

of NDMI varied between 0.160 to 0.258 in Kharif season, 0.159 to 0.196 in Rabi season to 0.042 to 0.054 in summer season. (Hasan Sabri ÖZTÜRK *et. al.* in 2018, David O. Simelane in 2007)^[16, 18]. It is found that among all the factors positive influence of texture was observed as all the higher values of NDMI were recorded under the influence of soil texture as compare to other factors. (J. W. Metzler *et. al.* in 2011, Muhammad Mansur Aliero *et. al.* in 2018, Mohammad Ashraf *et. al.* in 2015)^[11, 13]

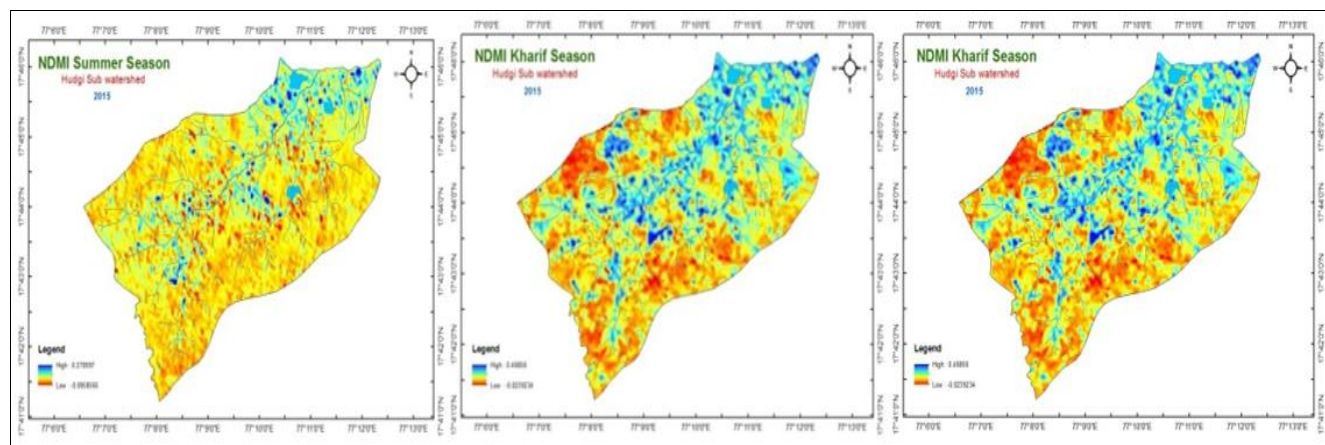


Fig 3: NDMI at Rainfall Deficit year

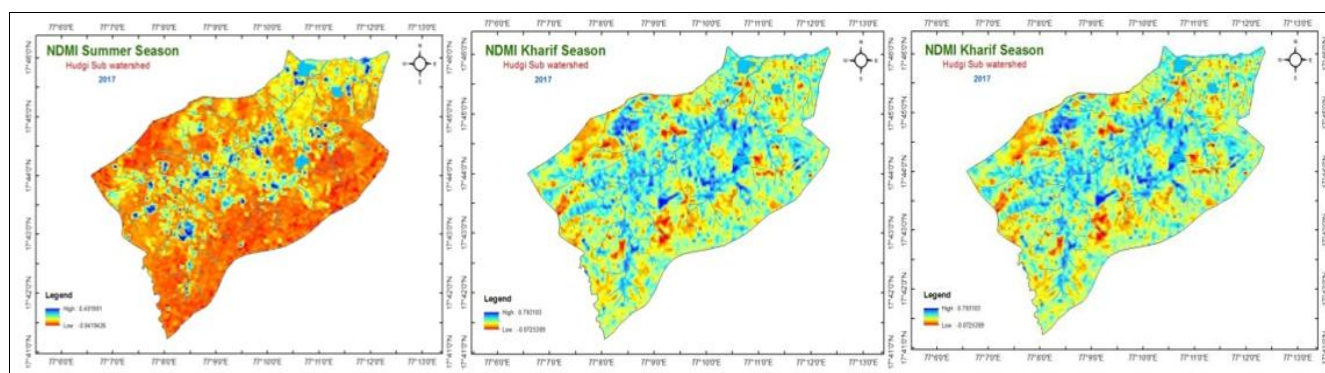


Fig 4: NDMI at normal rainfall year

Influence of soil depth, erosion, gravelliness, slope, and texture on NDVI

During rainfall deficit year that is in 2015 it is observed that correlated NDVI values varied between 0.386 to 0.402 in Kharif season, 0.227 to 0.234 during Rabi season and 0.165 to 0.172. The highest values of NDVI were recorded under the influence of soil texture whereas the lowest values were observed under

the influence of erosion. (Josef Lastovicka *et. al.* in 2020 & Meng-Lung Lin *et. al.* in 2011, Marjan Firoozy Nejad *et. al.* in 2019)^[1, 12].

Whereas during 2017 that is normal rainfall year the correlated NDVI values ranged between 0.490 to 0.500 in Kharif season, 0.467 to 0.488 in rabi season and during summer the correlated values ranged from 0.254 to 0.260.

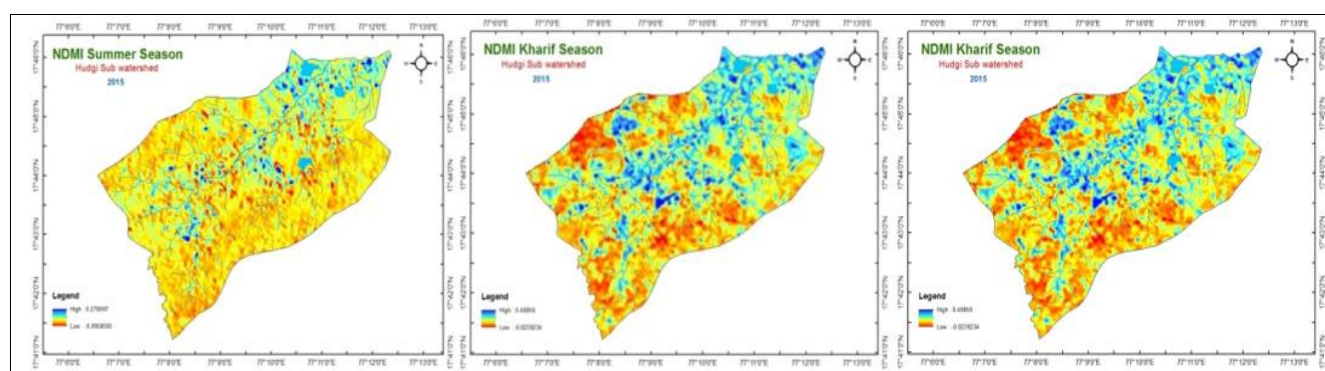


Fig 5: NDMDI at rainfall deficit year

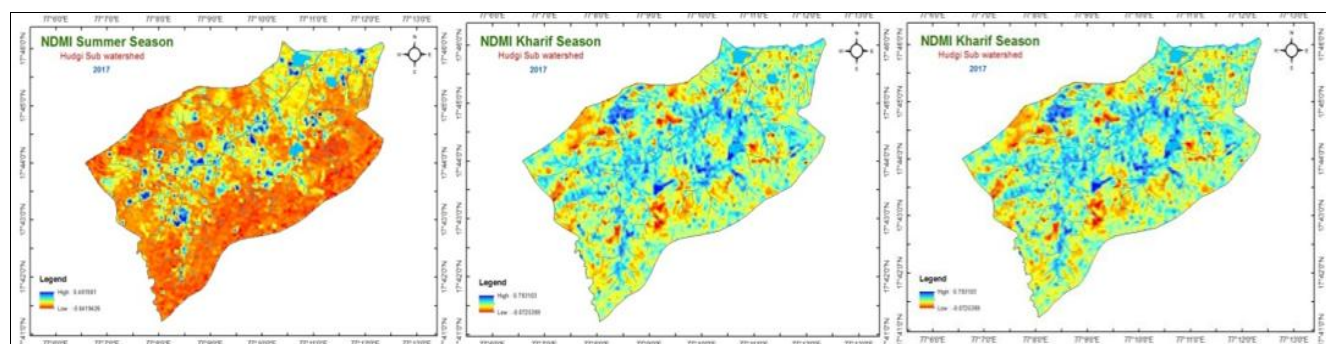


Fig 6: NDMI at normal rainfall year

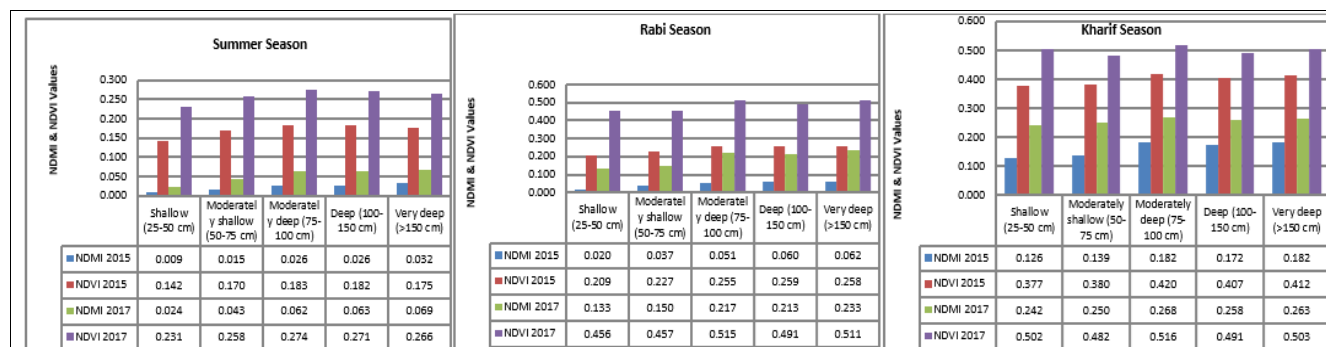


Fig 7: Gravelliness classes

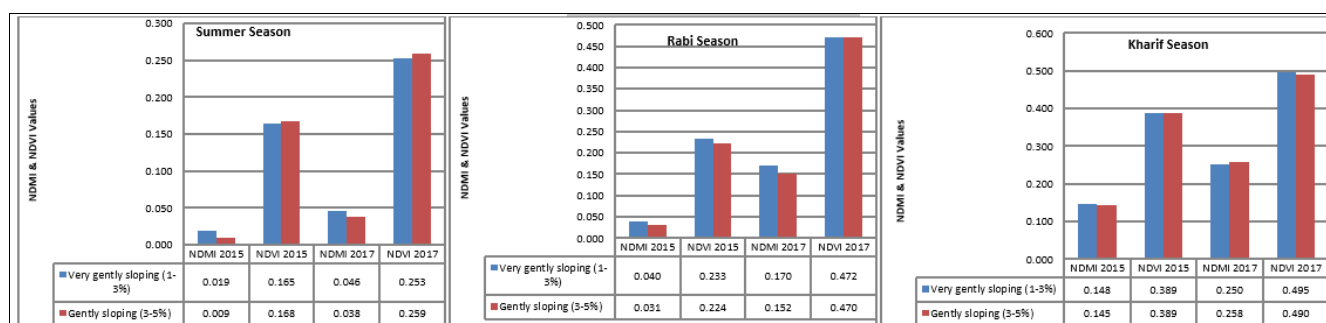


Fig 8: Slope classes

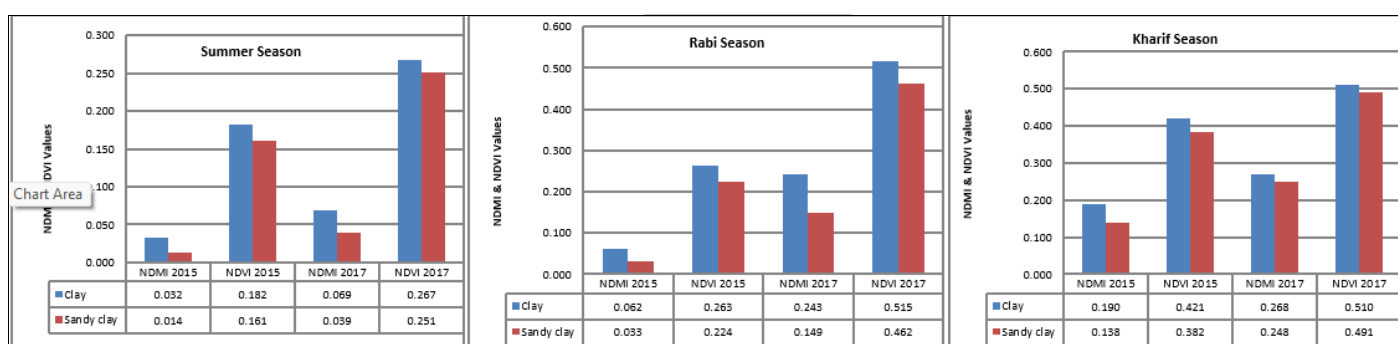


Fig 9: Texture classes

Assessment of soil series and soil phase level status of NDMI and NDVI

Land Resource Inventory through surface sampling and soil profile study supported by lab analytical data, 19 soil series were established of each soil series have been documented in the farm of soil mapping unit. (Celalettin Duran *et al.* in 2015, Muhammad Mansur Aliero *et al.* in 2018) [11, 14].

Within soil series several mapping units have been mapped as imported indicator of status of phases of soil series. Basic soil

forming processes like addition and losses will decide status of mapping unit of soil series. As different phases of soil series will decide the capacities of soil, major soil series and their respective mapping units were used for NDMI and NDVI under different seasons and rainfall conditions. (Maria Casamitjana *et al.* in 2011, Mohammad Ashraf *et al.* in 2015, J. W. Metzler *et al.* in 2011) [13].

Out of 19 soil series established 58 soil mapping units were identified to indicate the status of phase level variation with

respect to texture, depth, slope, extent of erosion, surface gravelliness and stoniness in the form of numerical and numbers. (Jozef Deckers *et. al.* in 2011 & Tzu-Shun Lin *et. al.* in 2016).

Out of 19 soil series established in study area, major soil series on the bases of area coverage seven soil series were selected which are covering an area of more than 200 ha. Apart from this all soil mapping units identified and delineated under selected series were identified and assessed for NDMI and NDVI during Rainfall deficit year (2015) and normal rainfall year (2017). The result of assessment is explained as under which is distributed in area of 928.68 ha. Kodambal (KDM) soil series with six mapping units were assessed from status of NDMI in summer Kharif season during rainfall deficit year (2015) and rainfall normal year (2017). It varies from -0.0019 on soil mapping unit KDM iB3g1 to 0.0241 on mapping unit KDMiB2 in summer season during rainfall deficit year where as it ranged from -0.0061 on KDMiB3g1 to 0.0712 on KDMiB2 during rainfall sufficient year (2017).

During Kharif season NDMI ranged from 0.0378 on KDMiB3g1 to 0.1750 on KDMiB2 in summer season (2015) whereas it ranged from 0.1342 on KDMiB3g1 to 0.2995 on KDMiB2 during rainfall normal year (2017).

Similarly BDP soil series, which has occupied 607.61 ha when assessed from NDMI during summer to Kharif seasons of rainfall deficit year (2015) and rainfall normal year (2017) following status, was observed NDMI ranged from 0.0043 on BDPiB3g1 during summer season and deficit rainfall year (2015) whereas during normal rainfall year in summer season the NDMI ranged from 0.0072 on BDPiB3g2St3.

During Kharif season when mapping units of BDP series were assessed for NDMI in rainfall deficit year (2015) and rainfall normal year (2017) following results were observed.

The NDMI ranged from 0.0600 on BDPiB2g2St3 to 0.2014 on

BDPiB3g1 during rainfall deficit year (2015) whereas it ranged from 0.1677 on BDPiB3g2St3 to 0.2745 on BDPiB3g during rainfall normal year (2017).

Muttangi (MTN) soil series covering on area of 324.86 ha units was assessed for the status of NDMI in summer and Kharif season during rainfall deficit year (2015) and rainfall normal year (2017). NDMI value varies from 0.0168 on MTNiB2g1 to 0.0310 on MTNiB2g2 during summer season under rainfall deficit year (2015) whereas during normal rainfall (2017) it ranged from 0.0464 on MTNiB2g2 to 0.0862 on MTNiB2. These mapping units of Muttangi soil series when assessed for NDMI during Kharif season it varied from 0.1658 on MTNiB2g2 to 0.1944 on MTNiB2 mapping units during rainfall deficit year (2015) whereas it ranged between 0.2367 on MTNiB2g2 to 0.3089 on MTNiB2 mapping unit.

(MDG) soil series covering an area of 286.88 ha with five mapping units was assessed for status of NDMI in summer and Kharif season during rainfall deficit year (2015) and rainfall normal year (2017).

During summer season (2015) NDMI values varied from 0.0043 on MDGiB2 to 0.0098 on MDGiC3g2St3 mapping unit. Whereas the range varied from 0.0017 on MDGiB2 and 0.0423 on MDGiB2 at normal rainfall period (2017)

During Kharif season, the status of NDMI was assessed under scare and normal rainfall years it ranged from 0.1109 on MDGiB3g1 to 0.1334 on MDGiB2g1 mapping units, when the average annual rainfall was scarcity level (2015) whereas during normal rainfall year (2017) the NDMI ranged from 0.2175 on MDGiC3g2St3 to 0.2527 on MDGiB2g2 mapping units.

(KKK) soil series covering an area of 276.72 ha with three mapping units was assessed for status of NDMI in summer and Kharif season during rainfall scarcity year (2015) whereas it range from 0.0045 on KKKiB2g2 to 0.0805 on KKKiB2 during rainfall normal year (2017).

Table 5: Seasonal NDMI and NDVI of soil mapping units

SL. No.	SOIL_PHASE/ Soil Mapping Unit	NDMI_Sum_15	NDVI_Sum_15	NDMI_Rabi_15	NDVI_Rabi_15	NDMI_Khar_15	NDVI_Khar_15
1	ANRiB2g1	0.001	0.174	0.034	0.254	0.127	0.389
2	ANRiC3g2St3	0.004	0.152	0.018	0.210	0.121	0.370
3	BDPiB2	0.016	0.179	0.046	0.248	0.146	0.385
4	BDPiB2g1	0.004	0.131	0.009	0.185	0.102	0.356
5	BDPiB3g1	0.040	0.204	0.062	0.262	0.201	0.426
6	BDPiB3g2	0.012	0.176	0.040	0.235	0.141	0.384
7	BDPiB3g2St3	0.008	0.116	0.013	0.132	0.060	0.291
8	BDPiC3g2St3	0.004	0.156	0.013	0.204	0.123	0.378
9	BGNiB2	0.034	0.176	0.075	0.283	0.175	0.407
10	BGNmB2	0.019	0.139	0.021	0.166	0.103	0.325
11	BLRiB2g1	0.014	0.141	0.039	0.210	0.108	0.347
12	BLRiB3	0.016	0.228	0.058	0.262	0.126	0.352
13	BLRiB3g1	0.020	0.191	0.036	0.233	0.142	0.386
14	BLRiB3g2	0.021	0.136	0.024	0.171	0.101	0.331
15	DGRiB3g1	0.006	0.148	0.026	0.193	0.129	0.370
16	DGRiC3g2St3	0.002	0.153	0.038	0.245	0.170	0.428
17	DMNiB2	0.022	0.143	0.037	0.191	0.122	0.340
18	DMNiB2g1	0.035	0.151	0.057	0.229	0.259	0.494
19	DMNmC3	0.027	0.221	0.074	0.317	0.225	0.470
20	KBBiB2	0.019	0.132	0.022	0.183	0.123	0.360
21	KBBiB2g1	0.028	0.196	0.116	0.357	0.119	0.343
22	KBBiB2g2	0.002	0.122	-0.001	0.168	0.091	0.350
23	KBBmB2	0.043	0.201	0.080	0.277	0.208	0.427
24	KDMiB2	0.024	0.204	0.055	0.274	0.175	0.418
25	KDMiB2g1	0.003	0.144	0.017	0.211	0.135	0.391
26	KDMiB2g2	0.006	0.138	0.014	0.197	0.113	0.365
27	KDMiB3g1	-0.002	0.112	0.002	0.115	0.038	0.276

28	KDMiC3g2	0.001	0.123	-0.001	0.164	0.103	0.357
29	KDMmB2	0.012	0.153	0.040	0.246	0.147	0.395
30	KKKiB2	0.035	0.204	0.069	0.279	0.148	0.375
31	KKKiB2g1	0.011	0.148	0.031	0.215	0.118	0.358
32	KKKiB2g2	0.004	0.121	0.009	0.163	0.071	0.320
33	MDGiB2	0.004	0.108	-0.004	0.176	0.127	0.385
34	MDGiB2g1	0.014	0.140	0.018	0.211	0.133	0.383
35	MDGiB2g2	0.009	0.119	-0.001	0.192	0.131	0.394
36	MDGiB3g1	0.008	0.117	0.006	0.181	0.111	0.357
37	MDGiC3g2St3	0.010	0.162	0.042	0.217	0.129	0.359
38	MKDiB2g1	0.021	0.198	0.072	0.290	0.188	0.427
39	MKDiB3g1	0.014	0.171	0.022	0.211	0.117	0.356
40	MKDmB2	0.030	0.226	0.094	0.331	0.218	0.454
41	MNLiB2g1	0.011	0.193	0.047	0.275	0.160	0.415
42	MSTiB2	0.019	0.129	0.020	0.149	0.104	0.329
43	MSTiB2g1St3	0.016	0.222	0.042	0.274	0.163	0.419
44	MSTiC3	0.014	0.160	0.022	0.198	0.126	0.361
45	MSTiC3g1St3	0.011	0.144	0.023	0.209	0.143	0.389
46	MSTiC3g2St4	0.016	0.217	0.072	0.284	0.221	0.448
47	MTNiB2	0.021	0.195	0.073	0.292	0.194	0.428
48	MTNiB2g1	0.017	0.204	0.042	0.254	0.180	0.426
49	MTNiB2g2	0.031	0.161	0.035	0.224	0.166	0.408
50	MWDiB2	0.016	0.198	0.059	0.297	0.228	0.468
51	MWDiC3	0.002	0.132	0.011	0.144	0.062	0.289
52	PPRmB2g1	0.061	0.164	0.052	0.232	0.202	0.427
53	RMPiB2	0.029	0.190	0.038	0.220	0.165	0.393
54	RMPiB3g1	0.008	0.189	0.048	0.269	0.150	0.395
55	RPLmB2	0.044	0.180	0.071	0.267	0.217	0.445
56	RPLmB2g1	0.013	0.197	0.057	0.272	0.178	0.419
57	UDHiB2g1	0.010	0.155	0.026	0.229	0.117	0.366
58	UDHmB2	0.056	0.210	0.072	0.273	0.237	0.457

Table 6: Seasonal NDMI and NDVI of soil mapping units (2017)

SL. No.	SOIL_PHASE/ Soil Mapping Unit	NDMI_Sum_17	NDVI_Sum_17	NDMI_Rabi_17	NDVI_Rabi_17	NDMI_Khar_17	NDVI_Khar_17
1	ANRiB2g1	0.027	0.262	0.130	0.466	0.272	0.488
2	ANRiC3g2St3	0.011	0.229	0.107	0.450	0.241	0.481
3	BDPiB2	0.046	0.274	0.175	0.474	0.270	0.494
4	BDPiB2g1	0.013	0.214	0.083	0.421	0.216	0.480
5	BDPiB3g1	0.062	0.268	0.202	0.486	0.248	0.503
6	BDPiB3g2	0.055	0.264	0.175	0.477	0.275	0.502
7	BDPiB3g2St3	0.007	0.190	0.005	0.342	0.168	0.415
8	BDPiC3g2St3	0.022	0.242	0.111	0.442	0.249	0.481
9	BGNiB2	0.074	0.286	0.233	0.521	0.287	0.520
10	BGNmB2	0.032	0.224	0.146	0.449	0.247	0.487
11	BLRiB2g1	0.044	0.237	0.146	0.437	0.250	0.464
12	BLRiB3	0.058	0.286	0.089	0.388	0.197	0.438
13	BLRiB3g1	0.044	0.272	0.134	0.435	0.234	0.447
14	BLRiB3g2	0.031	0.223	0.059	0.363	0.168	0.405
15	DGRiB3g1	0.036	0.242	0.127	0.453	0.242	0.479
16	DGRiC3g2St3	0.034	0.254	0.167	0.510	0.261	0.539
17	DMNiB2	0.046	0.221	0.132	0.424	0.233	0.478
18	DMNiB2g1	0.060	0.200	0.312	0.575	0.283	0.515
19	DMNmC3	0.088	0.333	0.272	0.564	0.325	0.536
20	KBBiB2	0.039	0.205	0.171	0.478	0.242	0.484
21	KBBiB2g1	0.061	0.281	0.211	0.462	0.280	0.438
22	KBBiB2g2	0.016	0.205	0.094	0.424	0.225	0.447
23	KBBmB2	0.082	0.273	0.253	0.493	0.254	0.481
24	KDMiB2	0.071	0.299	0.242	0.505	0.295	0.501
25	KDMiB2g1	0.025	0.228	0.134	0.461	0.254	0.494
26	KDMiB2g2	0.020	0.228	0.107	0.431	0.225	0.489
27	KDMiB3g1	-0.006	0.189	-0.055	0.320	0.134	0.405
28	KDMiC3g2	0.007	0.195	0.093	0.451	0.231	0.492
29	KDMmB2	0.044	0.260	0.211	0.514	0.285	0.547
30	KKKiB2	0.081	0.295	0.183	0.439	0.260	0.464
31	KKKiB2g1	0.032	0.236	0.113	0.420	0.224	0.461
32	KKKiB2g2	0.005	0.203	-0.026	0.351	0.174	0.418

33	MDGiB2	0.002	0.184	0.134	0.510	0.244	0.570
34	MDGiB2g1	0.014	0.217	0.129	0.451	0.235	0.503
35	MDGiB2g2	0.005	0.207	0.115	0.474	0.253	0.527
36	MDGiB3g1	0.003	0.216	0.065	0.415	0.226	0.472
37	MDGiC3g2St3	0.042	0.253	0.091	0.413	0.218	0.471
38	MKDiB2g1	0.071	0.298	0.267	0.546	0.295	0.536
39	MKDiB3g1	0.056	0.287	0.170	0.452	0.256	0.458
40	MKDmB2	0.102	0.331	0.299	0.583	0.328	0.555
41	MNLiB2g1	0.060	0.316	0.221	0.529	0.284	0.530
42	MSTiB2	0.041	0.223	0.105	0.418	0.224	0.448
43	MSTiB2g1St3	0.051	0.321	0.224	0.536	0.282	0.526
44	MSTiC3	0.035	0.236	0.138	0.449	0.259	0.489
45	MSTiC3g1St3	0.039	0.244	0.130	0.463	0.239	0.502
46	MSTiC3g2St4	0.079	0.327	0.290	0.570	0.332	0.534
47	MTNiB2	0.086	0.301	0.275	0.548	0.309	0.539
48	MTNiB2g1	0.059	0.295	0.220	0.521	0.271	0.522
49	MTNiB2g2	0.046	0.247	0.177	0.497	0.237	0.513
50	MWDiB2	0.109	0.349	0.285	0.576	0.319	0.559
51	MWDiC3	0.011	0.203	0.017	0.357	0.160	0.431
52	PPRmB2g1	0.073	0.211	0.235	0.507	0.231	0.485
53	RMPiB2	0.057	0.267	0.164	0.466	0.258	0.497
54	RMPiB3g1	0.037	0.255	0.195	0.484	0.290	0.511
55	RPLmB2	0.073	0.245	0.256	0.508	0.239	0.483
56	RPLmB2g1	0.082	0.311	0.310	0.595	0.307	0.545
57	UDHiB2g1	0.015	0.246	0.094	0.430	0.197	0.478
58	UDHmB2	0.094	0.283	0.273	0.540	0.270	0.506

Discussion

Similar results were observed by Josef Lastovicka *et.al.* In June 2020^[1] where under NDVI values reflected the availability of sufficient soil moisture for optimum growth of crop plants. During NDVI & NDMI when water is the limiting factor, more available water the plants grow better resulting in higher values within season NDVI level & higher of season crop and root biomass at the north west side compare to south east side of field.

Lower value of NDVI where recorded in sandy soil texture in their study that is “Botswana” area by (S. E. Nicholson *et.al.* in 1994)^[24] where they had carried linear relationship between NDVI and rainfall. Here the author reported that strong correlation between NDVI values and soil texture, where they recorded higher NDVI values in fine texture soils and lower NDVI values in sand rich coarse texture soils belonging to arenosols.

Conclusion

In our study area, we evaluated the changes in NDMI and NDVI Models using ResourceSat-2 Awifs sensor for two years that are 2015 (rainfall deficit year) and 2017 (rainfall average year) for three different crop seasons that are Kharif, Rabi and summer season for Hudgi sub watershed that lies under Humnabad Taluk of Bidar District, Karnataka. This NDMI and NDVI values had successfully correlated using kriging method of ArcGIS software with physical properties of soil that we had obtained by ground trothing.

It is found that the higher values of NDMI were recorded under the influence of Texture at Kharif season of 2017 and the least values were recorded under the influence by erosion hazards at summer of 2015. The correlated NDMI and NDVI values compared with soil series it is noted that Kodambal soil series (KDMiB3g1) recorded with less NDMI and NDVI values in all crop season for 2017 year and higher values were recorded in Mustariwadi (MWDiB2g1) at summer season, Dhupat Mahagaon (DMNiB2g1) at Rabi season and Mustari(MSTiC3g2St4) for Kharif season for NDMI values at

year 2017, and higher values for NDVI were recorded in Mustariwadi (MWDiB2g1) at summer season Raipalli (RPLmB2g1) for Rabi season and Madargi (MDGiB2) for Kharif season for 2017 year. And for the year of 2015 it is recorded that the NDMI values of Kodambal soil series (KDMiB3g1) has lesser values in summer and Kharif season and Madargi (MDGiB2) for Rabi season. Similarly higher values for NDMI are recorded for Pashapur soil series for summer season Kouta B. (KBBiB2g1) for Rabi season and Dhupat Mahagaon (DMNiB2g1) for Kharif season. Same as for NDVI Kouta B. (KBBiB2g1) soil series were recorded lesser values for Rabi and Kharif season and Madargi (MDGiB2) for summer season, and higher NDVI values are recorded Ballur (BLRiB3) for summer, Kouta B. (KBBiB2g1) for Rabi season and Dhupat Mahagaon (DMNiB2g1) for Kharif season.

The present study demonstrated the usefulness of integrating ResourceSat-2 AWiFS satellite imagery with Land Resource Inventory (LRI) data for evaluating the spatial and temporal variability of soil moisture and vegetation condition in the Hudgi sub-watershed, Bidar District, Karnataka. The application of NDMI and NDVI successfully captured seasonal and inter-annual variations in soil moisture availability and vegetation health during a drought year (2015) and a normal rainfall year (2017).

The analysis revealed that rainfall variability had a significant influence on both moisture availability and vegetation growth across all crop seasons. Comparatively higher NDMI and NDVI values were observed during the normal rainfall year, indicating improved soil moisture conditions and healthier vegetation, whereas reduced values during the drought year reflected moisture stress and poor crop vigor. Among the evaluated land characteristics, soil texture emerged as the most influential factor, with clay-rich and finer-textured soils consistently exhibiting greater moisture retention and higher vegetation indices. In contrast, areas affected by severe soil erosion, coarse surface conditions, and higher gravelliness showed relatively lower NDMI and NDVI values because of their limited water-holding capacity.

The study also confirmed that soil series and mapping units derived through detailed LRI surveys effectively explained the spatial variability in moisture distribution and vegetation performance. Variations among soil mapping units highlighted the importance of local soil characteristics in controlling crop response under different rainfall conditions. The combined interpretation of remotely sensed indices and field-based soil information therefore provides a more comprehensive understanding of watershed behaviour than either approach alone.

Overall, the study establishes that integrating remote sensing, GIS, and detailed soil resource information is an efficient approach for monitoring watershed health, identifying moisture-stressed areas, and supporting site-specific land and water management. The findings can assist planners and decision-makers in developing sustainable agricultural practices, prioritizing soil and water conservation measures, improving drought preparedness, and enhancing watershed management in semi-arid regions. Future studies may further improve the accuracy of soil moisture assessment by incorporating higher-resolution satellite data, longer temporal datasets, and field-based soil moisture observations for validation.

The present study assessed the spatial and temporal variations in soil moisture and vegetation dynamics in the Hudgi Sub-watershed, Humnabad Taluk, Bidar District, Karnataka, using NDMI and NDVI derived from ResourceSat-2 AWiFS imagery for two contrasting rainfall years, namely 2015 (rainfall-deficit year) and 2017 (normal rainfall year). The analysis was carried out for the three major agricultural seasons-Kharif, Rabi, and summer. The satellite-derived indices were integrated with Land Resource Inventory (LRI) data, and their relationships with soil physical properties were evaluated using GIS-based spatial analysis in ArcGIS.

The results demonstrated that soil texture exerted the strongest influence on moisture availability and vegetation health. The highest NDMI values were observed during the Kharif season of the normal rainfall year (2017), particularly in areas with favourable soil texture, whereas the lowest values occurred during the summer season of the drought year (2015) in locations affected by severe soil erosion. These findings indicate that both rainfall distribution and inherent soil characteristics play a crucial role in controlling seasonal soil moisture conditions.

Analysis at the soil series and mapping unit level revealed considerable spatial variability in NDMI and NDVI. The Kodambal soil series (KDMiB3g1) consistently exhibited the lowest NDMI and NDVI values across most seasons, indicating comparatively poor moisture retention and vegetation performance. Conversely, higher NDMI values during 2017 were recorded in the Mustariwadi (MWDiB2g1), Dhupat Mahagaon (DMNiB2g1), and Mustari (MSTiC3g2St4) soil mapping units during the summer, Rabi, and Kharif seasons, respectively. Similarly, the highest NDVI values were observed in Mustariwadi (MWDiB2g1) during summer, Raipalli (RPLmB2g1) during Rabi, and Madargi (MDGiB2) during the Kharif season.

During the rainfall-deficit year (2015), the lowest NDMI values were recorded in the Kodambal (KDMiB3g1) mapping unit during the summer and Kharif seasons, while the Madargi (MDGiB2) mapping unit exhibited the lowest values during the Rabi season. In contrast, relatively higher NDMI values were observed in the Pashapur soil series during summer, Kouta B. (KBBiB2g1) during Rabi, and Dhupat Mahagaon (DMNiB2g1) during the Kharif season. For NDVI, lower values were recorded

in the Kouta B. (KBBiB2g1) mapping unit during the Rabi and Kharif seasons and in the Madargi (MDGiB2) mapping unit during summer. Higher NDVI values were associated with the Ballur (BLRiB3), Kouta B. (KBBiB2g1), and Dhupat Mahagaon (DMNiB2g1) mapping units during the summer, Rabi, and Kharif seasons, respectively.

Overall, the study confirms that the integration of remote sensing indices with detailed soil resource information provides an effective approach for assessing seasonal soil moisture dynamics and vegetation conditions. The findings demonstrate the importance of soil texture, erosion status, and rainfall variability in influencing moisture availability and crop performance. This integrated methodology can support watershed planning, precision agriculture, drought monitoring, and sustainable land and water resource management in semi-arid regions.

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