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ANALYTICAL HIERARCHY PROCESS BASED MULTI-CRITERIA ANALYSIS AND INFLUENCE TECHNIQUE FOR AGRICULTURAL DEVELOPMENT OF ADHALA RIVER BASIN VILLAGE IN MAHARASHTRA (INDIA)

** Ravindra D. Gaikwad & ** Pandharinath T. Karande*

* *S. N. Arts, D. J. Malpani Commerce and B. N. Sarda Science College Sangamner, Department of Geography, PIN 422605, Affiliated to Savitribai Phule Pune University, Pune, India.*

** *Adv. M. N. Deshmukh Arts, Science and Commerce College Rajur, Department of Geography, PIN 422604, Affiliated to Savitribai Phule Pune University, Pune, India.*

Abstract:

Agricultural development is unique sign for development of agricultural base country. Multi-criteria, Analytical Hierarchy Process (AHP) Based Multi-Criteria Analysis and Influence Technique is suitable for Agricultural Development (AD). Nine criterions Population (POP), Sex Ratio (SR), Total Irrigated Land Area (IL), Total Un-irrigated Land Area (UL), Forest (FOR), Culturable Waste Land (CWL), Area under Non-agricultural Uses (AUNA), Net Area Sown (NSA) and Rainfall (RF) were selected for development indicators of Adhala river basin village in Ahmednagar district, Maharashtra (India). Correlation Matrix use for ranking the criterion selected for influence. Total Un-irrigated Land Area, Net Area Sown and Population, show higher influences on Agricultural development of basin village arrangement in the study area. Further, Culturable Waste Land, Sex Ratio and Area under Non-agricultural Uses were show significant influence in basin. Using AHP techniques for influences were calculated based on weights estimated. Normalized and distribution of specific criteria using the values of influences within the basin village. Agriculture developments influence are classified into very low (< Mean-1STD), low (Mean-1STD to Mean), moderate (Mean to Mean + 1STD), high (Mean + 1STD to Mean + 2STD), and very high (>Mean + 2STD) and agricultural development are classified into high (25.02%), moderate (3.70%) and low (7037%) categories. The methodology is the effective tool for agricultural development of Adhala basin village.

Keywords: *AHP; Ranking; Multi-criteria; Influence; Weights.*

Introduction:

Agricultural development is one of the significant factors representing the overall development of the rural regions (Tschirley, 1998). Study area shows undulating surface and therefore varied agriculture and cropping pattern. The slope decreases towards the East from Western hilly region. Higher rainfall, steep slopes and dense forests are observed in western hilly which is the source of Adhala River. Paddy and *Nachani* are important crops in this area. Further, sugarcane, vegetables and fruits are observed in the eastern where the slopes are less. Gumma et al., 2016 have used weighted integration of multiple thematic layers, Gassman et al., 2007, Daloglu et al., 2014 have used Soil and Water Assessment Tool, Panhalkar, 2011 had use intersect overlay technique with GIS environment, Daloglu et al., 2014 have used agent-based models (ABM) with combination Soil and Water Assessment Tool, have used water balance of irrigation systems for Agricultural development (AD). Further, Analytical Hierarchy Process (AHP) based multi-criteria analysis and influence technique can be useful

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

tool for quick AD prioritization of village. The criterions Population (POP), Sex Ratio (SR), Total Irrigated Land Area (IL), Total Un-irrigated Land Area (UL), Forest (FOR), Culturable Waste Land (CWL), Area under Non-agricultural Uses (AUNA), Net Area Sown (NSA) and Rainfall (RF) are useful parameters select for the period 1981 to 2011 for AD. Rice, *Nachani* and *Vara*i is a rain fed crop grown in hilly slope and foothills area (Su et al., 2014). However, due to the development of irrigation facilities in the area with reduced slope in the east cash crop have changed.

River basin is a hydrological unit (Johnson et al., 2013). It is a unique bio-physical unit. of earth's surface including morphology, soil, surface water, surface geology, near surface atmosphere, vegetation influencing potentials of land use and result of past and present human activity, etc. (Bhagat, 2012; Wani et al., 2008). Watershed contours the natural resources including soil, water, vegetation as well as socio-eco-cultural resources (Ghanbarpour and Hipel, 2011). These resources are being exploited and degraded from last few decades due to over use for increasing population and there needs (UNSCO (2015), Perez and Tschinkel (2003), Iqbal and Sajjad, (2014), Joshi *et al*.,(2006), Wani *et al*.,(2011), Gajbhiye *et al*., 2014). Therefore, many governments, non-governmental agencies and personalities have invested their energies for conservation of these resources. Some of them have used watershed management techniques from decades for conservation of soils, groundwater, vegetation with increasing agricultural productivity (Giordano and Shah, 2014), increase soil moisture and protective irrigation (Bhagat, 2002, Pokharkar, 2011), increasing groundwater level (Pascual-Ferrer et al., 2013), reducing soil (Bhattacharyya et al., 2015) and vegetation degradation (Perez and Tschinkel, 2003, Bishop et al., 2012, Kaur et al., 2014) with public participation (Perez and Tschinkel, 2003, Montz, 2008, Ghanbarpour and Hipel, 2011, Swami et al., 2012, Giordano and Shah, 2014).

Many projects have adopted the watershed management approach (Tiwari et al.,2008) for conservation for natural resources including soil, water, vegetation, etc. as well as socio-cultural resources for enriching the livelihood of rural peoples (Pangare, 1998, Willett and Porter, 2001, Ali et al.,2010). This is integration of protections and saving of resources (Rockstrom et.al. 2004).

Morphometric analysis of river basin provides useful information for monitoring the groundwater (Kaushal and Belt, 2012, Swami et al., 2012 Jankar and Kulkarni, 2013), surface water (Li, 2009), degradation of soil and vegetation. Land use analysis is measurements and analysis of agricultural activy in relation of land surface, (Shing and Shing, 2011, Iqbal and Sajiad, 2014, Raja and Karibasappa, 2016**).** Theses parameters have been widely used for prioritization analysis of agricultural development at village and regional level.

Study area:

The basin Adhal River (19° 03' 41.8237" N to 19º 33' 29.7577" N and 73º 48' 19.2344" E to 74º 11' 23.5511" E)) in Ahmednagar district (India) distributed inside Akole, Sangamner tehsils was selected for agricultural development of Adhala basin (Figure 1). The River Adhala is main tributary of Pravara River and source region in *Patta fort*, near *Kokanewadi* village located in the Western Ghat. The height varies from 512 to 1472.7 m. and rainfall from 420 to 1620mm. Geologically the study area is the part of Deccan trap with compound pahoehoe, and *som Aa* flows, basaltic and Alluvium. Somewhat deep, drained, and calcareous soils on gentle sloping with moderate erosion. Rice is the main crop in the kharip season for the Western part whereas Grains like *Ragi*, *Nagali*, *Varai*, and *Barly*, Pulses like Pigeon Peas Skinned (*Toor)*, Green Gram Split *(Moong)*, Black Gram *(Udid)*, Moth Bean *(Matk)i*, Horse Gram *(Hulga)*,Pink Lentil *(Masur)*, *Pawta*, *Chauli* Field Bean *(Wal)*, *Ghevda* and Groundnuts are observed as major crops in the kharip season, Wheat, Maize and Sunflower, Vegetables like tomato, cabbage, green bean, cilantro, flowers, brinjal etc. in rabbi season for Eastern part. The Adhala basin has been covered 27 villages (Figure 1) for analysis and AD (Zende et al., 2013).

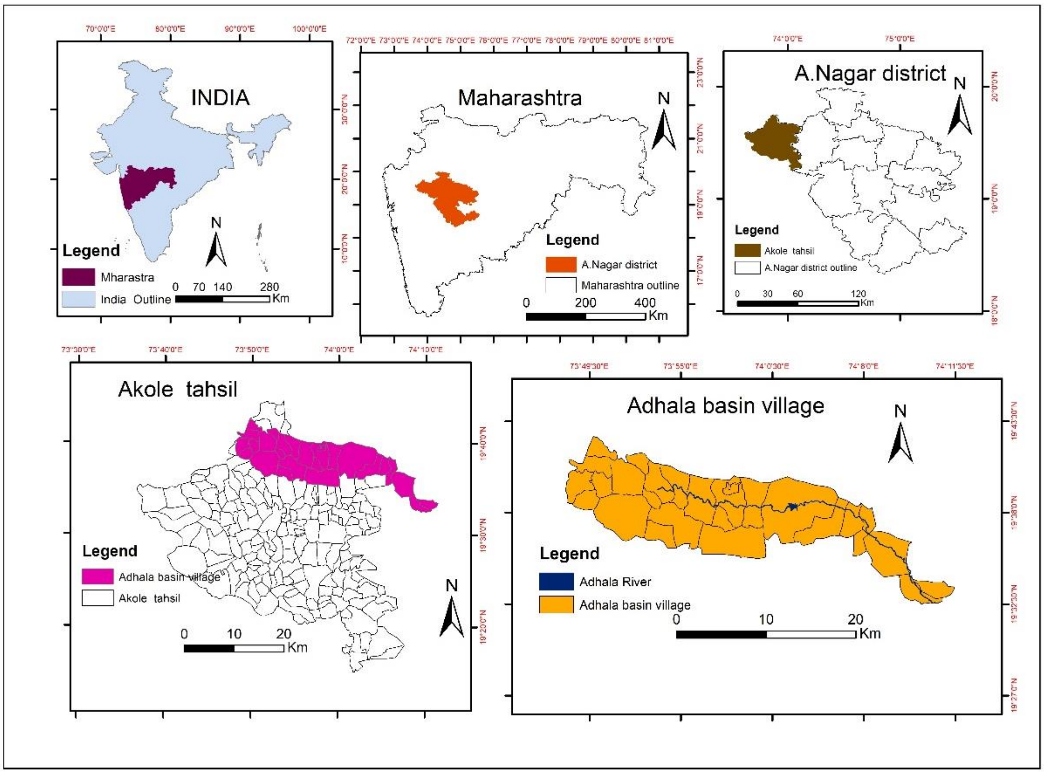

Figure: 1 Study area

Methodology:

Analytical Hierarchy Process (AHP) based multi-criteria analysis and influence technique were used for AD of villages in Adhala River basin. The ranking (Table 7) of the criterion have been performed based on correlation matrix technique. The AD was performed through eight steps: 1) Delineation village boundary with help of Bhuvan shape file, 2) Data collection and analysis for selected criterion, 3) Ranking of the criterions, 4) Pairwise comparison matrix analysis, 5) Normalization of pairwise comparison matrix, 6) Calculations of weights, 7) Village wise normalization of calculated influences, and 8) Calculation of agriculture development according to the villages.

1. **Data base and Software:**

Data regarding selected criterion e.g. Population (POP), Sex Ratio (SR), Total Irrigated Land Area (IL), Total

ISSN: P-2455-0515
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Educreator Research Journal

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

Un-irrigated Land Area (UL), Forest (FOR), Culturable Waste Land (CWL), Area under Non-agricultural Uses (AUNA), Net Area Sown (NSA) and Rainfall (RF) was procured from government censes records available at tehsil offices [Akole, Sangamner,] in the district for the year of 1981 and 2011 and used for multi-criteria and AHP analysis to calculate AD in the villages. GIS layers were prepared based on topographic maps (47E/14 and 47I/12) procured from SOI [survey of India]. NRSC, Bhuvan data was used for delineation of Village boundaries. The data and maps were loaded in GIS software for preparation of layers.

2. **Criterions:**

Population (POP), Sex Ratio (SR), Total Irrigated Land Area (IL), Total Un-irrigated Land Area (UL), Forest (FOR), Culturable Waste Land (CWL), Area under Non-agricultural Uses (AUNA), Net Area Sown (NSA) and Rainfall (RF) were used for multi-criteria analysis using AHP and influence technique to calculate the AD in the study area. The study area has naturally varies of rainfall, slope and soil. Rice, Sugarcane, vegetables, Grains, Pulses and fruits are economically important and principal crops in study area. Therefore, criterions (population, land use and rainfall) selects AD.

1. **Population:**

The availability of human resources depends on composition of population. Characteristics of population in the region including density, number of child (age below 6 years) and old aged, population belongs to SC and ST, literacy and education and workforce were analyzed to understand the demography in study area (Fekete et al., 2019). The distribution of population characteristics were classified into five classes: Very low (< Mean-1STD), Low (Mean-1STD to Mean), Moderate (Mean + 1STD to Mean + 2STD), High (Mean + 1STD to Mean + 2STD) and Very high (>Mean + 2STD).

Population change is significant demographic characteristic affects the AD in the region (Farley and Anna, 2014). Village wise population change has been calculated (Formula 1) and plotted on the map (Figure 2). The total population in the study area was 42410 in 1981 and 60111 in 2011 (Table 1).

$$\text{Population change} = \text{Total population in village 2011} - \text{Total population in same village 1981}$$

(1) In 1981, about 16 villages were classified into the class, low population change (386.70 to1570.84), 5 villages into class Moderate change (1570.84 to 2755.44) (Table 2.4 and Figure 2.11), 03 into class high change (2755.44 to 3940.04), and 01 village into class very high (3940.04<) population change. The higher population change was observed in the areas belong to bank of rivers due to availability of water for irrigation and fertile soils. In 2011, 15 villages were classified into the class, low population change (349.76 to 2226.33), 08 villages into moderate (2226.33 to 4102.90) population change (Table 1 and Figure 2). The negative change in population from 1981 to 2011 was observed in the class <-196.86 and -196.86 to 655.59 wherever 14 villages show positive changes in population growth (Figure 2 and Table 1).

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

Table 1: Distribution of population

. Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<386.70	02	<349.76	01	<-196.86	02
Mean-1STD to Mean	386.70 to 1570.84	16	349.76 to 2226.33	15	-196.86 to 655.59	14
Mean to Mean + 1STD	1570.84 to 2755.44	05	2226.33 to 4102.90	08	655.59 to 1508.04	08
Mean + 1STD to Mean + 2STD	2755.44 to 3940.04	03	4102.90 to 5979.47	02	1508.04 to 2360.49	02
Mean + 2STD<	3940.04<	01	5979.47<	01	2360.49<	01
Total Villages		**27**		**27**		**27**
Mean		1570.84		2226.33		655.59
STD		1184.60		1876.54		852.45
Maximum		5443		9449		4016
Minimum		0.00		368		-362

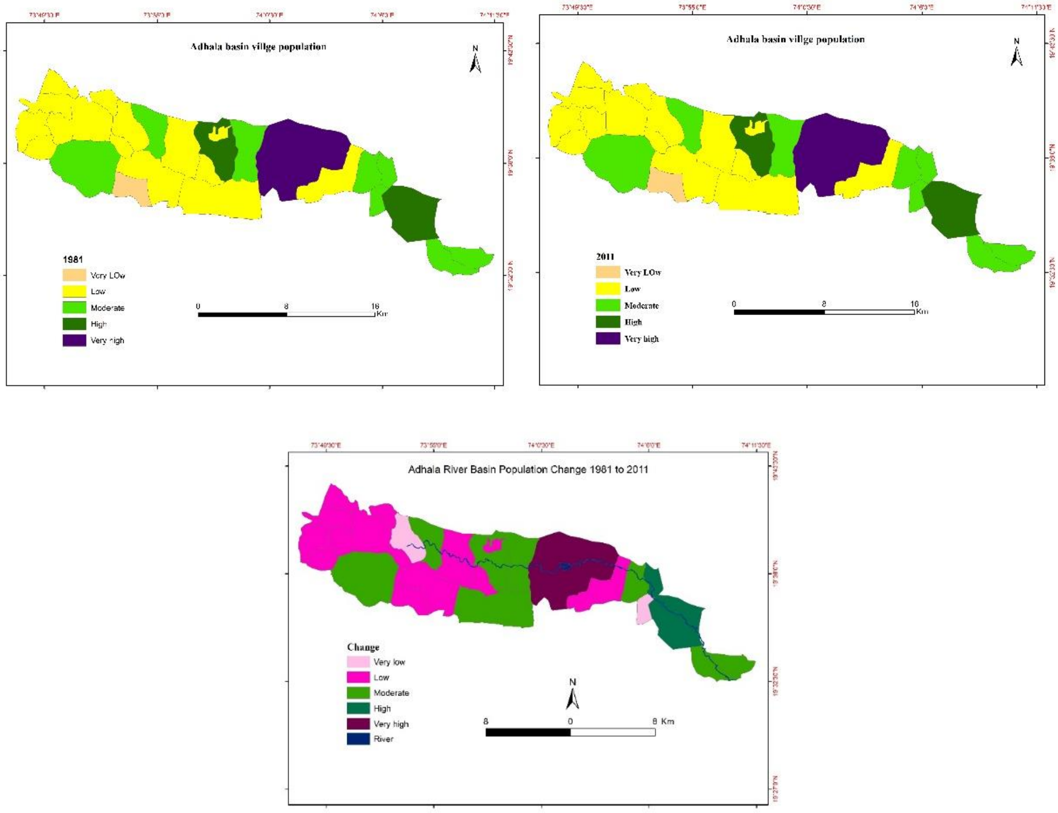


Figure: 2 Distribution of population

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

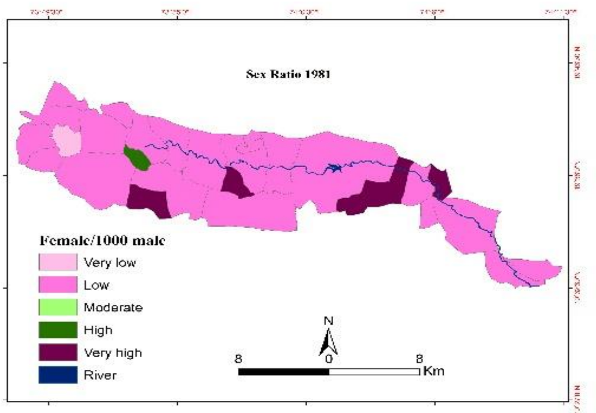
2. **Sex Ratio:**

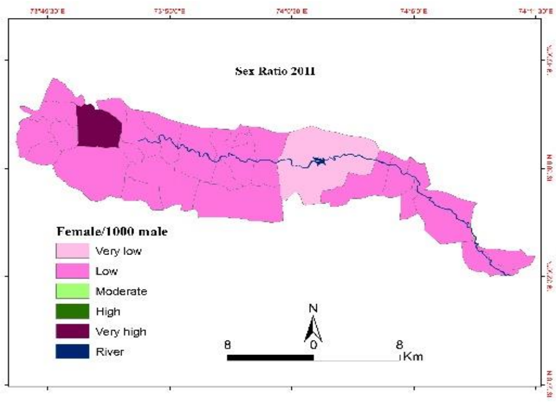
Sex ratio plays a significant role in tribal area binding human resources for development and growth of people's life. The number of female workers is significantly related with the agricultural workers (Huisman *et al.*, 2010). In 1981, 02 villages show very low (<381.63 female/1000 male) and 18 villages show low (381.63 to594.55 female/1000 male) sex ratio of population.

The moderate sex ratio (594.55 to 807.47 female/1000 male) was observed in 05 villages and Dongargaon, Virgaon, Nagwadi, Poparewadi) show (>very high female/1000 male) sex ratio of. In these 30 years sex ratio in the region is slightly increased (Figure 3 and Table 2) in the areas of steep slopes, dry and shallow soils, greater erosion, heavy rainfall, low irrigation, lack of transport facility, lack of education awareness, etc. In the period of 1981 to 2011, 06 villages show very low changes <-208.24 female/1000 male) and 19 villages show low changes (208.24 to 690.5 female/1000 male) in sex ratio. The very higher changes (1657.02< female/1000 male) were observed in the western and parts of the Adhala basin village.

Table 2: Distribution of Sex Ratio

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<381.63	01	<-275.60	01	<-208.24	06
Mean-1STD to Mean	381.63 to 594.55	18	-275.60to 1291.05	25	-208.24 to 690.5	19
Mean to Mean + 1STD	594.55 to 807.47	00	1291.05 to 2857.7	00	690.5 to 1172.76	01
Mean + 1STD to Mean + 2STD	807.47 to 1020.39	03	28.57.7 to 4424.35	00	1172.76 to 1657.02	00
Mean + 2STD<	1020.39<	05	4424.35<	01	1657.02<	01
Total Villages		**27**		**27**		**27**
Mean		594.55		1291.05		690.50
STD		212.92		1566.65		482.26
Maximum		1063.69		9261.41		8798.81
Minimum		456.04		511.91		-72.03





ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

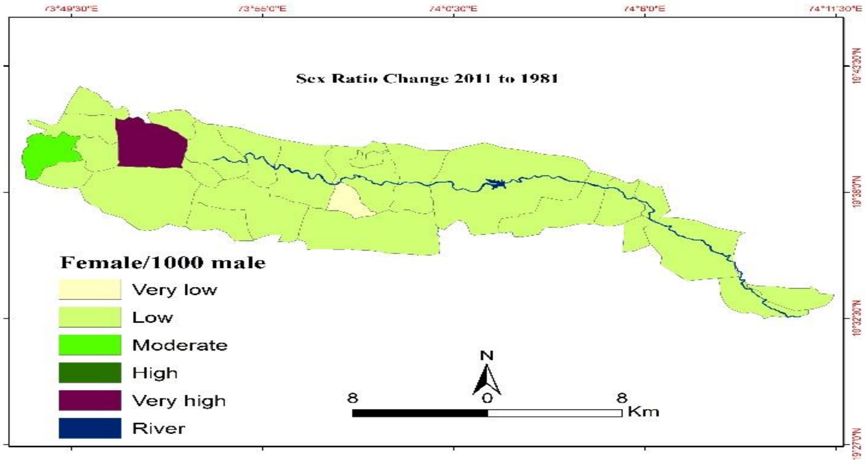


Figure: 3 Distribution of Sex Ratio

i. **Distribution of Total Irrigated Land Area:**

The present analysis shows very low <-73.64 ha/100 ha) Irrigated Land Area in 05 villages, low (-73.64 to 120.96 ha/100 ha) in 13 villages, moderate (120.96 to 315.56 ha/100 ha) in 05 villages, high (315.56 to 510.16 ha /100 ha) in 03 villages and very high (510.16< ha/100 ha) in only 01 villages (Figure 4 and Table 3). In 2011, 01 village show very low (<-66.35 ha /100 ha) area under Irrigated Land, 25 villages show low (-66.3 to 114.18 ha/100 ha), 00 villages show moderate (114.18 to 294.71 ha/100 ha) and very high 9475.24< ha/100 ha) area under Irrigated Land (Figure 4 and Table 3). Further, the growth rate of area under Irrigated Land in 2011 is less than previous thirty years observed in Adhala basin villages from the western hilly part of the study area. 04 villages show very low (< -158.59 ha/100 ha) negative change from 1981 to 2011 and 03 villages show less (-145.01 to 296.81ha/100 ha) negative change.

Table 3: Distribution of total irrigated land area

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<-73.64	05	<-66.35	01	< -158.59	04
Mean-1STD to Mean	-73.64 to 120.96	13	-66.3 to 114.18	25	-158.59 to -6.79	02
Mean to Mean + 1STD	120.96 to 315.56	05	114.18 to 294.71	00	-6.79 to 145.01	18
Mean + 1STD to Mean + 2STD	315.56 to 510.16	03	294.71 to 475.24	00	145.01 to 296.81	03
Mean + 2STD<	510.16<	01	475.24<	01	296.81<	00
Total Villages		**27**		**27**		**27**
Mean		120.96		114.18		-6.79
STD		194.60		180.53		151.80
Maximum		690		855		283.00
Minimum		0.00		0.00		-449.00

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

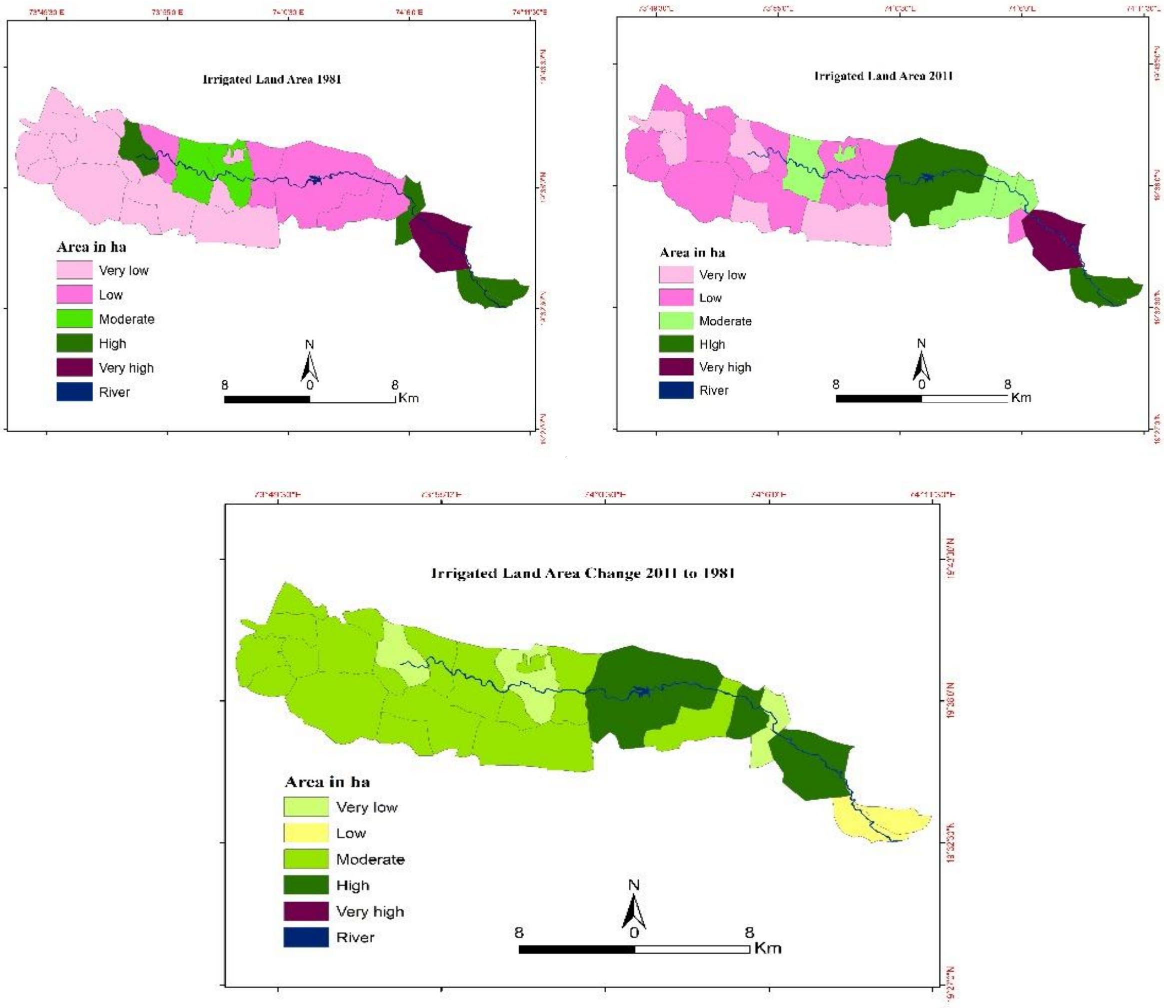


Figure: 4 Distribution of Total Irrigated Land Area

ii. **Distribution of Total Un-irrigated Land Area:**

The present analysis shows very low <-209.57 ha/100 ha) Irrigated Land Area in 01 village, low (209.57 to 334.33 ha/100 ha) in 12 villages, moderate (334.33 to 878.23 ha/100 ha) in 07 villages, moderate (540.59 to 937.20 ha /100 ha) in 07 villages and very high (1422.13< ha/100 ha) in only 02 villages (Figure 5 and Table 4). In 2011, 03 village show very low (<143.98 ha/100 ha) area under unirrigated Land, 12 villages show low (143.98 to 540.59 ha/100 ha), 07 villages show moderate (114.18 to 294.71 ha/100 ha) and 01 village show very high (1333.81< ha/100 ha) area under unirrigated Land (Figure 5 and Table 4). Further, the growth rate of area under unirrigated Land in 2011 is less than previous thirty years observed in Adhala basin villages from the western hilly part of the study area. 04 villages show very low < -283.84 ha/100 ha) negative change from 1981 to 2011 and 05 villages show less 253.86 to 522.71 ha/100 ha) negative change.

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

Table 4: Distribution of Total Un-irrigated Land Area

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<-209.57	01	<143.98	03	< -283.84	04
Mean-1STD to Mean	-209.57 to 334.33	12	143.98 to 540.59	12	-283.84 to -14.99	09
Mean to Mean + 1STD	334.33 to 878.23	07	540.59 to 937.20	07	-14.99 to 253.86	09
Mean + 1STD to Mean + 2STD	878.23 to 1422.13	05	937.20 to 1333.81	04	253.86 to 522.71	05
Mean + 2STD<	1422.13<	02	1333.81<	01	522.71<	00
Total Villages		**27**		**27**		**27**
Mean		334.33		540.59		-14.99
STD		543.90		396.61		268.85
Maximum		2217		1547		517
Minimum		7.19		0.00		-760

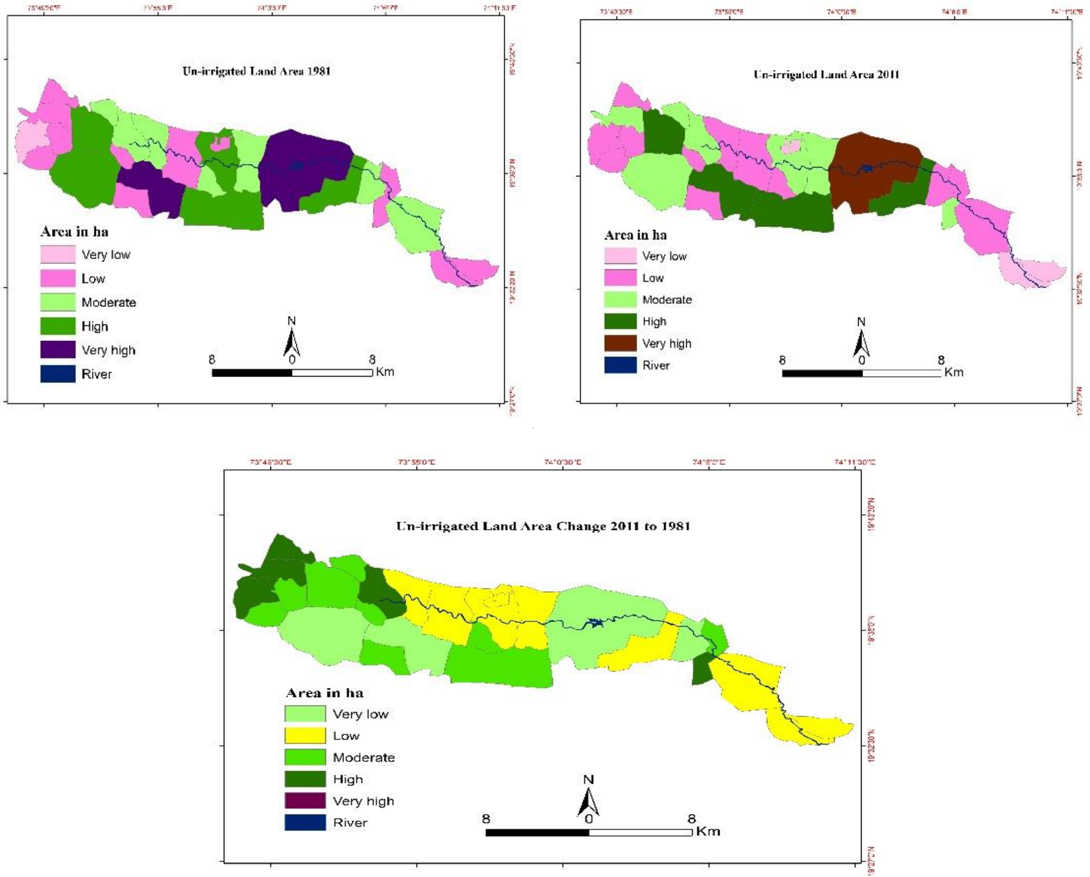


Figure: 5 Distribution of Total Un-irrigated Land Area

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III MAY – JUNE 2024

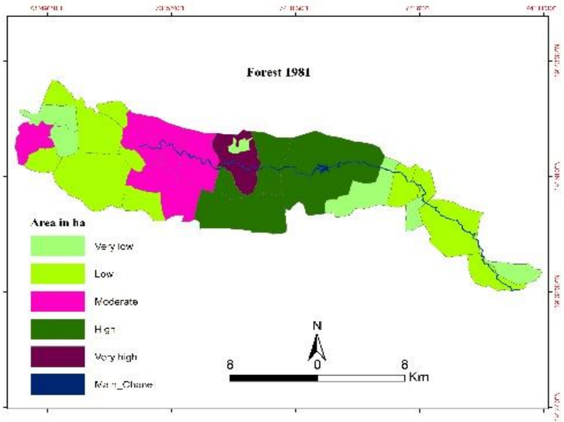
Original Research Article

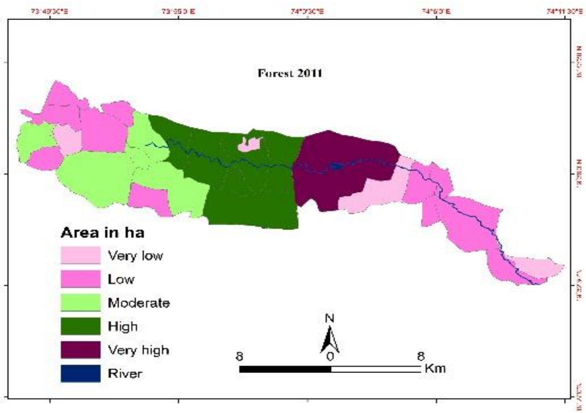
iii. Distribution of forest

Forest is significant resource for human activities spatially in the tribal area for food and other economic activities. The forest cover has more impact on hydrological cycles, soil conservation, climate change and the biodiversity crisis (Rudela *et al.*, 2005). The western part of the study area is hilly and covered by dense forest whereas eastern part shows sparse vegetation with thorny bushes and grass. In 1981, 06 villages were classified in the class, very low (<16.88ha), 11 villages were classified in the class, low (16.88 to 274.91 ha) area covered under forests. 05 villages were classified in the class, high and have good forest cover, (566.70 to 858.71ha) village like Devthan, Sawargaonpat, Muthalne and Nagwadi show high 566.70 to 858.71 ha) area covered by forest. In 2011, 04 villages were classified in the class, very low <13.98 ha), 11villagesin the class, low (13.98 to 228.42ha) and 05 villages in the class, moderate (228.42 to 470.82 ha) forest cover (Table 5 and Figure 6). Change in area under forest cover in 1981 to 2011 was observed as: 02 villages show very less < -175.67 ha) negative change and 19 villages show less (-46.48 to 82.71ha) change in the forest cover (Table 5 and Figure 7).

Table 5: Distribution of area under forest

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<16.88	06	<13.98	04	< -175.67	02
Mean-1STD to Mean	16.88 to 274.91	11	13.98 to 228.42	11	-175.67 to -46.48	05
Mean to Mean + 1STD	274.91 to 566.70	05	228.42 to 470.82	05	-46.48 to 82.71	19
Mean + 1STD to Mean + 2STD	566.70 to 858.71	04	470.82 to 713.22	06	82.71 to 211.90	01
Mean + 2STD<	858.71<	01	713.22<	01	211.90<	00
Total Villages		**27**		**27**		**27**
Mean		274.91		228.42		-46.48
STD		291.79		242.40		129.19
Maximum		1105.37		765		87
Minimum		0.0		0.00		-608.37





ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

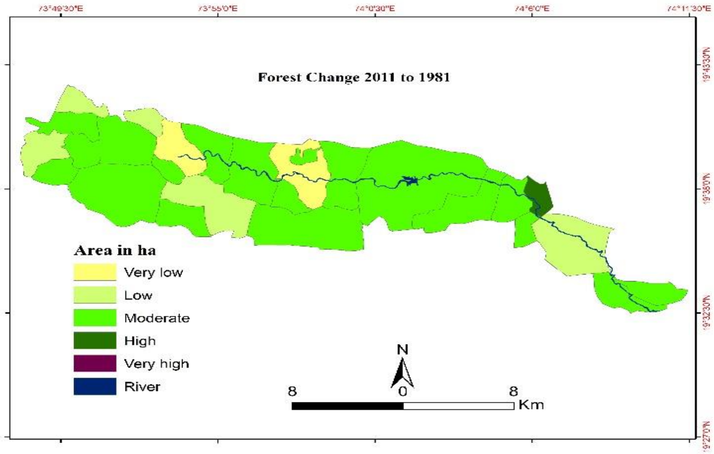


Figure: 6 Distribution of area under forest

iv. Distribution of Culturable Waste Land:

The *culturable* waste land is potential land for agriculture. In the study area (1981), 11 villages showed <-58.91 ha area having potential of agriculture, 09 villages show -58.91 to 52.08 ha area under the class. 5 villages have higher percentage of *culturable* waste (Figure 7 and Table 6). In 2011, the farmers of the region have converted some portion of the land into agriculture therefore the number of watershed decreased from higher categories to lower one as: 13 villages from the class, very low <-17.49 ha) 08 villages from the class, low (-17.49 to 19.97 ha), (Figure 7 and Table 6). The negative change in the area under *culturable* waste was observed in the most of villages in the basin. However, 21 villages showed highly positive change in *culturable* waste lands (Figure 7 and Table 6). It means that the *culturable* waste lands are going to be converted to the agricultural use (Deepak *et al.*, 2016).

Table 6: Distribution of Culturable Waste Land

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<-58.91	11	<-17.49	13	< -148.94	03
Mean-1STD to Mean	-58.91 to 52.08	09	-17.49 to 19.97	08	-148.94 to -32.12	02
Mean to Mean + 1STD	52.08 to 163.07	05	19.91 to 57.43	02	-32.12 to 84.70	21
Mean + 1STD to Mean + 2STD	163.07 to 274.06	01	57.43 to 94.89	02	84.70 to 201.52	01
Mean + 2STD<	274.06<	01	94.89<	02	201.52<	00
Total Villages		**27**		**27**		**27**
Mean		52.08		19.97		-32.12
STD		110.99		37.46		116.82
Maximum		518.81		155		96
Minimum		0.0		0.00		-501.71

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

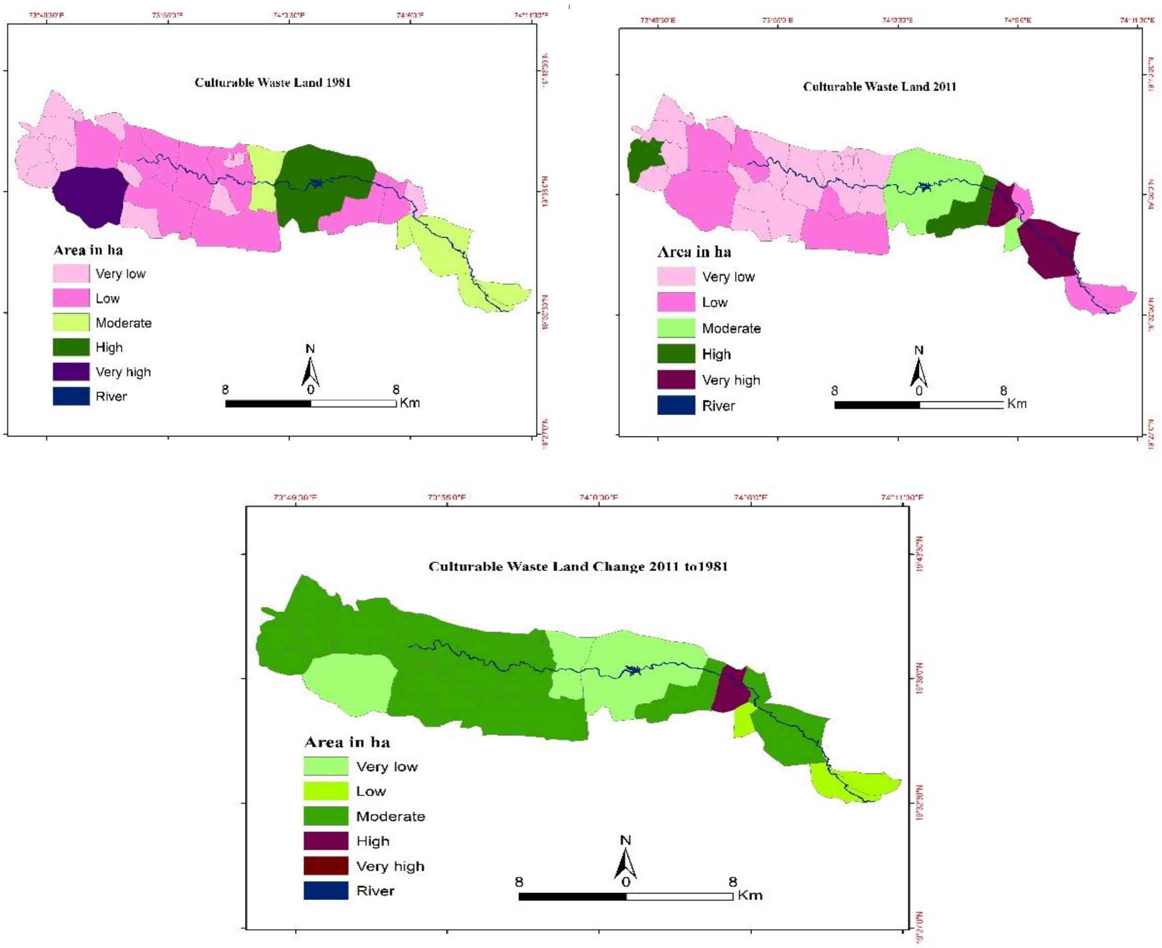


Figure: 7 Distribution of Culturable Waste Land

v. ***Distribution of Net Area Sown:*** The quantity of land under net sown area for cultivation describes the impact of agriculture (Wooda et al., 2004). In the study area (1981), 01 village show in the class, very low (<184.37 ha), 18 villages showed in the class, low (184.37 to 720.28 ha), 03 villages showed in the class, moderate (720.28 to 1276.19 ha), 03 villages showed in the class, high (1276.19 to 18120.10 ha) and 2 villages showed in the class, very high (1812.10< ha) (Table 7 and figure 8). In 2011, 03 villages showed very less (<247.95ha) area in the class, 10 villages showed in the class, low (247.95 to 654.76ha),9 villages showed in the class, moderate (654.76 to 1061.57ha) and 04 villages observed in the class, high (1061.57 to 1468.28ha) of area available for cultivation (Table 7 and Figure 8).

About 5 villages show the negative change in this land use type. 15 villages in class, moderate (-75.51 to 138.64ha) are available for cultivation. However, 3 villages showed highly (138.64 to 352.79ha) positive change, in land available for cultivation (Table 7 and Figure 8). The positive change in this area into agricultural land was observed in 3 villages near to river and very high conversion of this land was observed in 3 villages.

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

OPEN ACCESS

VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

Table 7: Distribution of Net Area Sown

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<184.37	01	<247.95	03	< -289.66	05
Mean-1STD to Mean	184.37 to 720.28	18	247.95 to 654.76	10	-289.66 to -75.51	04
Mean to Mean + 1STD	720.28 to 1276.19	03	654.76 to 1061.57	09	-75.51 to 138.64	15
Mean + 1STD to Mean + 2STD	1276.19 to 18120.10	03	1061.57 to 1468.28	04	138.64 to 352.79	03
Mean + 2STD<	1812.10<	02	1468.28<	01	352.79<	00
Total Villages		**27**		**27**		**27**
Mean		730.28		654.76		-75.51
STD		545.91		406.81		214.15
Maximum		2241.07		1861		303.20
Minimum		7.10		198		-691.26

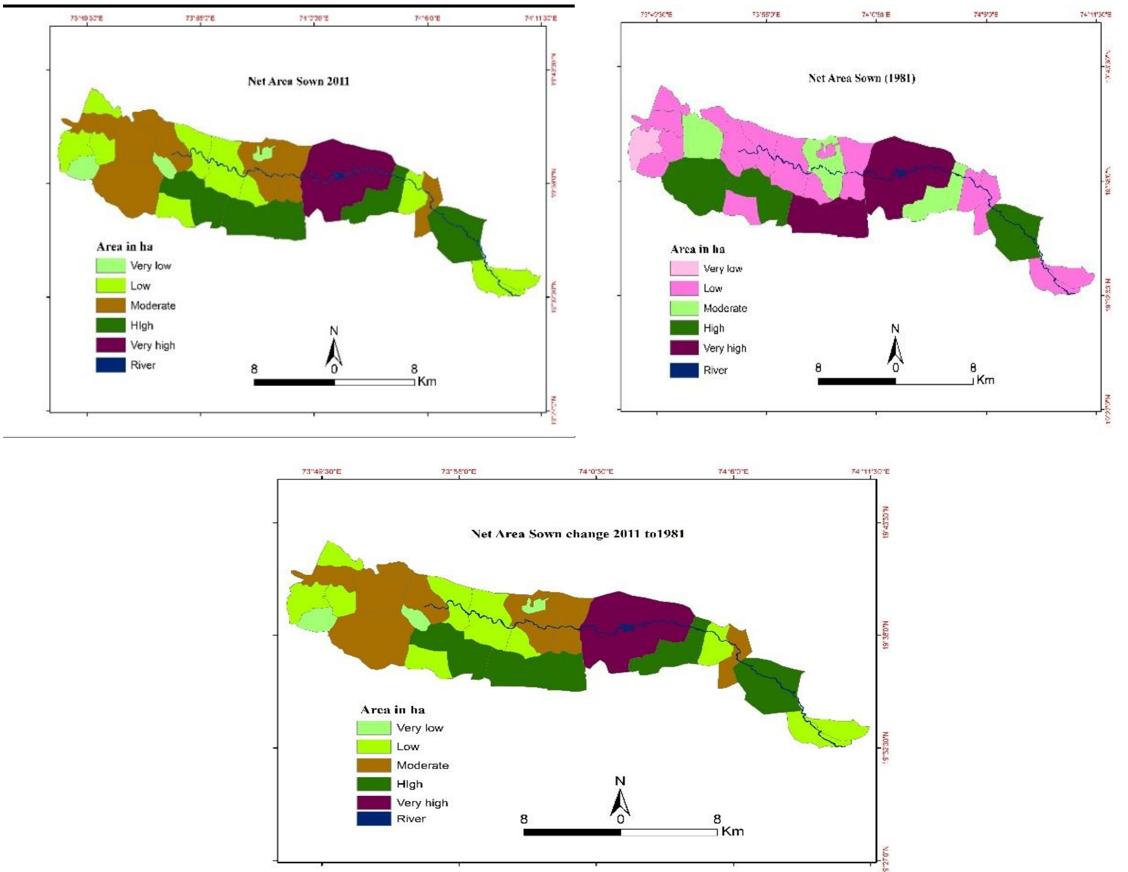


Figure.8: Distribution of Net Area Sown

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

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VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

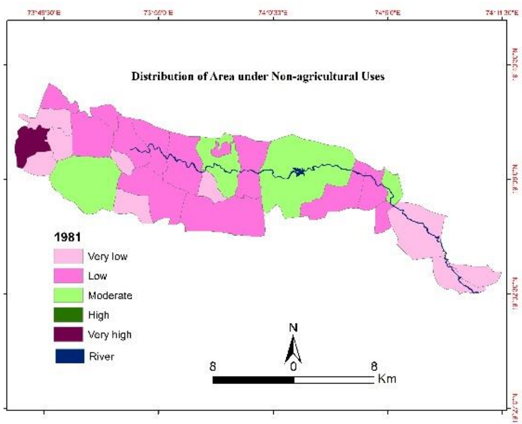
vi. *Distribution of Area under Non-agricultural Uses*

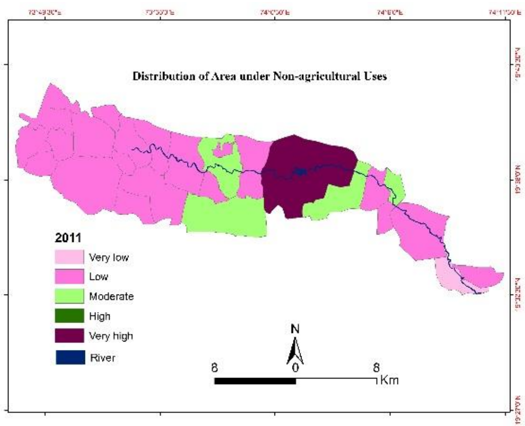
The quantity of land under not agricultural area for cultivation describes the impact of agriculture (Wooda *et al.*, 2004). In the study area (1981), 09 villages show in the class, very low (<-117.40 ha), 13villages showed in the class, low (-117.40 to 117.45 ha), 04 villages showed in the class, moderate (117.45 to 407.28 ha), and 01 village showed in the class, very high (697.11<ha) (Table 8 and figure 9). In 2011, 01 village showed very less (<-127.15 ha) area in the class, 21 villages showed in the class, low (-127.15 to 58.83 ha), 4 villages showed in the class, moderate (58.83 to 244.81ha) and 01 villages observed in the class, very high (430.79<ha) of area available for not cultivation (Table 8 and Figure 9).

About 08 village show the negative change in this land use type. 18 villages in class, moderate (-58.63 to 259.63 ha) are available for not cultivation. However, 01 villages show very highly (577.87<ha) positive change, in land available for not cultivation (Table 8 and Figure 9).

Table 8: Distribution of Area under Non-agricultural Uses

Classes	**1981**		**2011**		**1981to 2011 Change**	
	Influence values	**No. of Villages**	**Classes**	**No. of Villages**	**Classes**	**No. of Villages**
< Mean-1STD	<-117.40	09	<-127.15	01	< -376.88	01
Mean-1STD to Mean	-117.40 to 117.45	13	-127.15 to 58.83	21	-376.88 to -58.63	07
Mean to Mean + 1STD	117.45 to 407.28	04	58.83 to 244.81	04	-58.63 to 259.63	18
Mean + 1STD to Mean + 2STD	407.28 to 697.11	00	244.81 to 430.79	00	259.63 to 577.87	00
Mean + 2STD<	697.11<	01	430.79<	01	577.87<	01
Total Villages		**27**		**27**		**27**
Mean		117.45		58.83		-58.63
STD		289.83		185.98		318.25
Maximum		1538.02		989		617
Minimum		00		01		-1532.32





ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

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VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

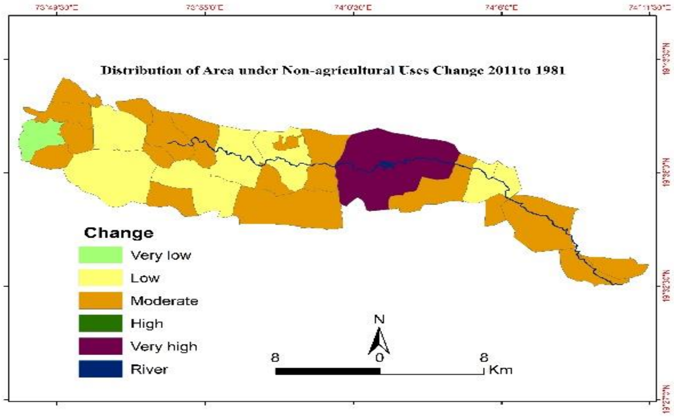

Figure 9: Distribution of Area under Non-agricultural Uses

vii. Distribution of Rainfall

The study region located in tropical zone (Zolekar and Bhagat, 2015) and receives 1207 mm average annual rainfall during Southwest monsoon. The heavy rainfall is observed in the section of the Western Ghat with higher elevation at *Harishchandragad* (4846 mm) and village Kumshet (4644 mm). The rainfall varies from 239 mm (Wadgaon Satwal) at eastern to 4846 mm at western (*Harishchandragad*) border (Figure 2.7, 2.8). During the months of June to October monsoon season show very high rainfall in this area. The rainfall decreases from western part to the East of the Mula basin and receives a maximum rainfall from June to September. The 'Rain Shadow' zone of Western Ghats are observed to the East.

Table 9: Distribution of Rainfall

Classes	1981		2011		1981to 2011 Change	
	Influence values	No. of Villages	Classes	No. of Villages	Classes	No. of Villages
< Mean-1STD	<-117.40	09	<-127.15	01	< -376.88	01
Mean-1STD to Mean	-117.40 to 117.45	13	-127.15 to 58.83	21	-376.88 to -58.63	07
Mean to Mean + 1STD	117.45 to 407.28	04	58.83 to 244.81	04	-58.63 to 259.63	18
Mean + 1STD to Mean + 2STD	407.28 to 697.11	00	244.81 to 430.79	00	259.63 to 577.87	00
Mean + 2STD<	697.11<	01	430.79<	01	577.87<	01
Total Villages		**27**		**27**		**27**
Mean		117.45		58.83		-58.63
STD		289.83		185.98		318.25
Maximum		1538.02		989		617
Minimum		00		01		-1532.32

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

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VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

Analytical Hierarchy Process:

Agricultural development prioritization of Adhal basin village was processed using AHP technique according to following steps: (1) determination of rank, (2) pairwise comparison, (3) normalization of pairwise comparison matrix, (4) calculation of weights and influence, (5) normalization of sub-watershed wise influences and (6) Agricultural development prioritization of Adhal basin village.

1. ***Determination of rank***

Quantitative and qualitative methods were used for assigning the ranks to criterion selected for weighted analysis. The correlation analysis is useful for better understanding of unstandardized parameters than the standardized (Bhagat, 2012). Zolekar and Bhagat (2015), Gaikwad and Bhagat (2018) have used expert opinions and correlation techniques for ranking the parameters in AHP based weighted overlay analysis for land suitability analysis. Further, Aher et al. (2014) have used sum of significant correlation coefficients estimated within the group of criterions for ranking the criterion. Yunus et al. (2014), Farhan and Al-Shaikh (2017) have been classified significant correlation values into four categories: strong correlation from 0.8 to 0.9, good from 0.7 to 0.8, moderate from 0.5 to 0.7 and <0.5. Therefore, ranks of selected criterion have been determined based on sum of significant correlation coefficients (Table 10) estimated within the group of criterions.

Nine criterions Population (POP), Sex Ratio (SR), Total Irrigated Land Area (IL), Total Un-irrigated Land Area (UL), Forest (FOR), Culturable Waste Land (CWL), Area under Non-agricultural Uses (AUNA), Net Area Sown (NSA) and Rainfall (RF) were estimated using Pearson's correlation technique (Yin et al., 2012). 1 to 9 ranks were assigned to selected criterions (Ranjan et al., 2013; Zolekar and Bhagat, 2015; Farhan and Anaba, 2016; Argyriou et al., 2016; Gaikwad and Bhagat, 2018).

Sum of significant correlation coefficients have been estimated more for Total Un-irrigated Land Area (UL) (35.35), Net Area Sown (NSA) (17.67), Population (POP (11.78), and assigned ranks 1 to 3, respectively (Table 11). Moderate values were estimated for Culturable Waste Land (CWL), Sex Ratio (SR) and Area under Non-agricultural Uses (AUNA and ranks given 4 to 6 whereas Rainfall (RF), Forest (FOR), Total Irrigated Land Area (IL) are ranked least (Table 11).

Scholars likes Ghanbarpour and Hipel (2011), Rekha et al. (2011), Feizizadeh el al. (2014), Sepehr et al. (2017) have used multiple criteria decision-making and Pairwise Comparison Matrix (PCM) (Table 10) to calculate the weights and influence (Table 13) of selected criterions. The PCM helps to understand the relationship between the criterions in relation to unirrigated area and influence in development for agricultural in the Adhal basin village (Emamgholi et al., 2007; Ranjan et al., 2014). The criterion values in PCM were divided by total of the column to find the cell values in normalized PCM (Table 12).

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

Table 10: Correlation analysis

Criterions	*POP*	*SR*	*IL*	*UIL*	*FOR*	*CWL*	*NSA*	*AUNA*	*RF*
POP	1.000								
SR	-0.103	1.000							
IL	-0.468	-0.015	1.00						
UIL	0.608	-0.032	-0.57	1.00					
FOR	-0.027	-0.032	0.30	0.12	1.00				
CWL	0.352	-0.051	-0.07	0.46	-0.13	1.00			
NSA	0.456	-0.088	-0.28	0.60	0.13	0.48	1.00		
AUNA	-0.389	0.080	0.14	-0.33	0.06	-0.24	-0.37	1.00	
RF	-0.360	0.198	-0.03	-0.39	-0.01	-0.02	-0.07	0.41	1.00

Table 11: Ranks

POP	*SR*	*IL*	*UIL*	*FOR*	*CWL*	*NSA*	*AUNA*	*RF*
3	5	9	1	8	4	2	6	7

Table 12: Pairwise comparison matrix

Criterion	UIL	NSA	POP	CWL	SR	AUNA	RF	FOR	IL
UIL	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
NSA	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
POP	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0
CWL	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3
SR	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
AUNA	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5
RF	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.3
FOR	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1
IL	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0
Total	2.8	5.7	8.5	11.3	14.1	17.0	19.8	22.6	25.5

Table 13: Weights and influence

Criterion	UIL	NSA	POP	CWL	SR	AUNA	RF	FOR	IL	Sum	Weigts	Influence %
UIL	0.35	0.18	0.12	0.09	0.07	0.06	0.05	0.04	0.04	1.00	0.11	35.35
NSA	0.18	0.09	0.06	0.04	0.04	0.03	0.03	0.02	0.02	0.50	0.06	17.67
POP	0.12	0.06	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.33	0.04	11.78
CWL	0.09	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.25	0.03	8.84
SR	0.07	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.20	0.02	7.07
AUNA	0.06	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.17	0.02	5.89
RF	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.14	0.02	5.05
FOR	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.13	0.01	4.42
IL	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.11	0.01	3.93
										2.83	0.31	

ISSN: P-2455-0515
E- 2394-8450

Educreator Research Journal

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VOLUME–XI, ISSUE–III

MAY – JUNE 2024

Original Research Article

Table 14: Sub- Watershed wise priorities

Village Name	POP	SR	IL	UIL	FOR	CWL	NSA	AUNA	RF	Total	priority
Virgaon	0.10	-0.02	-1.63	6.46	0.00	-0.83	-0.02	-0.51	0.13	3.69	15.00
Dongargad	1.01	0.00	5.68	-20.35	-0.31	-0.07	0.19	0.23	0.11	-13.49	21.00
Samsherp	0.74	0.18	3.75	24.28	2.14	0.10	3.33	0.25	0.16	34.94	3.00
Ghodsarw	0.26	0.21	-2.94	9.26	0.00	0.00	-0.27	0.08	0.15	6.76	11.00
Kombhaln	-0.02	0.18	-0.54	29.53	0.19	0.02	2.71	0.43	0.19	32.70	4.00
Ganore	-0.24	0.18	8.04	-37.56	-0.08	0.70	-0.48	0.04	0.11	-29.29	26.00
Pimpaldar	0.15	0.22	0.00	-22.01	0.00	0.00	-1.32	-0.01	0.28	-22.69	23.00
Tahakari	0.43	0.18	0.11	4.52	0.00	0.02	-0.35	0.40	0.16	5.48	12.00
Pedhewad	0.06	0.18	-0.04	-0.61	0.50	0.00	-0.08	0.17	0.21	0.39	18.00
Chandgirv	0.43	0.19	0.00	-45.16	-0.13	0.00	0.00	-0.01	0.28	-44.40	27.00
Kokanwad	-0.08	0.20	-0.09	-29.35	0.43	0.00	1.21	0.04	0.28	-27.34	25.00
Padoshi	0.24	3.31	-0.43	0.98	0.00	0.00	-0.07	0.34	0.23	4.62	14.00
Dagadwad	0.12	-0.01	-1.20	0.20	-0.14	0.00	0.10	-0.01	0.19	-0.75	19.00
Sangavi	-0.20	0.21	9.63	-24.78	0.90	-0.11	-2.42	0.13	0.19	-16.46	22.00
Ekdare	0.05	0.26	-0.07	-26.18	0.19	-0.76	-2.63	5.70	0.31	-23.13	24.00
Keli Rumh	0.83	0.14	-0.90	8.12	0.09	0.02	0.14	0.16	0.18	8.77	8.00
Sawargaon	0.59	0.18	-2.00	7.25	0.00	1.59	-0.09	0.02	0.15	7.70	10.00
Khirvire	0.65	0.18	-0.39	44.72	0.02	5.11	4.28	0.53	0.23	55.35	2.00
Nagawadi	0.10	-0.03	-0.15	0.52	0.03	-0.15	0.08	-0.16	0.16	0.40	17.00
Jaynawad	0.10	0.23	-0.09	-8.21	0.01	0.00	0.00	-0.01	0.28	-7.69	20.00
Poparewa	0.11	0.01	0.00	0.61	0.05	0.00	0.06	-0.01	0.21	1.05	16.00
Muthalan	0.58	0.17	0.00	-2.51	0.00	0.32	5.99	-0.01	0.26	4.79	13.00
Deothan	2.67	0.01	-6.07	58.52	0.00	2.42	3.29	-2.30	0.14	58.69	1.00
Hivargaon	0.76	0.19	-3.89	30.83	-0.01	-0.98	1.49	0.38	0.11	28.87	5.00
Chikhali	0.51	0.17	0.45	5.38	0.00	1.33	0.71	0.00	0.12	8.66	9.00
Jawale Ka	1.17	0.17	-3.54	10.65	0.50	-0.83	0.55	-0.01	0.11	8.78	7.00
Mangalap	0.6508581	0.1935041	0.2145197	10.2197924	0.0338797	0.9622081	1.2340061	-0.007442	0.111963	13.6132893	6

2. *Weights and influences*

Weights and influences were calculated as average of values of criterions in row of normalized pairwise comparison matrix to get the weights of criterion (Gaikwad and Bhagat, 2018, Zolekar and Bhagat, 2015; Maddahi *et al.*, 2017). Further, influences of the criterion selected for prioritization of Adhal basin village were estimated by calculating the cell values (%) (Gaikwad and Bhagat, 2018) (Equation 2, Table 13).

$$C_i = \frac{W_c}{W_s} \times 100 \qquad (2)$$

C_i = Normalized influence of criterion based on AHP.

W_c = Estimated weights of criterion.

W_s = Sum of estimated weights for all criterions.

C_i = The share of criterion in total influence (100%) of criterion which can be distributed within the criterion according to estimated weights (Gaikwad and Bhagat, 2018).

a. *Watershed wise normalized influence of criterion*

The influences of criterion interpret the share of individual criteria in formations Adhal basin village characteristics (100%) and vary according to Adhal basin village (Silva et al., 2007; Gaikwad and Bhagat,

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E- 2394-8450

Educreator Research Journal

VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

2017). Here, Adhal basin village wise influences of criterion were normalized according to spatial distribution in Adhal basin village (equation 3) (Gaikwad and Bhagat, 2017).

$$NI_{bv} = \frac{C_{bv}}{C_s} \times C_i \qquad (3)$$

NI_{bv}= Basin village wise normalized influence

C_{bv}= Cell value of criterion for the basin village

C_s= Sum of cell values of criterion

C_i= Estimated influence of criterion based on AHP

i. ***Weighted prioritization***

Population, Sex Ratio, Total Irrigated Land Area, Total Un-irrigated Land Area, Forest, Culturable Waste Land, Area under Non-agricultural Uses, Net Area Sown and Rainfall etc. have been widely used by several scholars for Adhal basin village prioritization for agricultural development. These parameters can be useful to decide the level of soil and water degradation and useful for prioritization of sub-watersheds (Aher et al., 2014) using normalized PCM (Ghanbarpour and Hipel, 2011), calculated influence for criterion and Adhal basin village wise normalized influence (Gaikwad and Bhagat, 2017).

$$P_{bv} = \sum_{i=1}^{n} NI_{bv} \qquad (4)$$

P_{bv}= Prioritization of Adhal basin village

NI_{bv}= Adhal basin village wise normalized influence

n = Number of criterion

i = Criterion

b. ***Selection priorities of Adhala River basin village***

Priorities of basin villages for agricultural development (German et al., 2003) were calculated using multi-criteria based AHP method and calculated influence of criterions. Nine criterions were selected and ranked using correlation analysis for estimations of weights and influences. Estimated influences of criterions were normalized based on spatial distribution in selected Adhal basin villages for prioritization. Estimated priorities were classified into three classes (Figure 10): High, moderate and less priority.

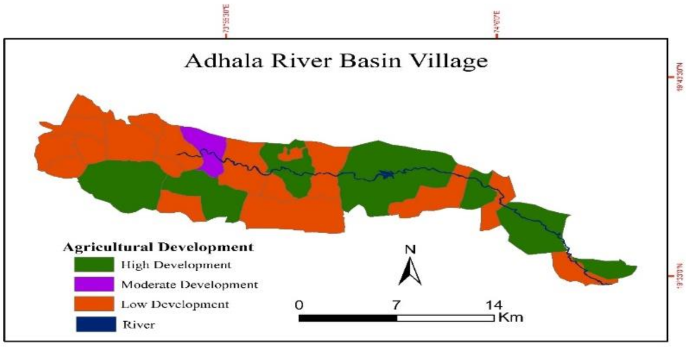

Figure 10: Agricultural development

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Educreator Research Journal

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VOLUME–XI, ISSUE–III MAY – JUNE 2024

Original Research Article

i. ***High priority***

07(25.02%) Adhal basin villages are classified into the class 'High priority' agricultural development (Figure 3.27). These villages show gentle to moderate slopes with very shallow extremely drained loamy calcareous soils and good agricultural activities. These basin villages are located in near stream or reservoir with high rainfall. The productivity of these soils is very high proactivity. These basin villages show good economic condition for agricultural capital. Therefore, these Adhal basin villages should be considered for agricultural development with high priorities.

ii. ***Moderate priority***

01 (3.70% villages) Adhal basin villages were classified into the class, 'Moderate priority' with gentle slopes, calcareous soils with moderate erosion observed in these villages. More surface erodibility and run-off for less rainfall can be interpreted based on estimated Sex Ratio, Area under Non-agricultural Uses and rainfall. Well irrigation is common phenomenon in the villages and more working population is available. Therefore, these villages should also be considered for moderate agricultural development.

iii. ***Less priority***

About 70.37% Adhal basin villages in the basin is classified in 'Less priority' with low irrigation facility, rocky surface, high forest cover and more area under not agricultural land. These Adhal basin villages are located far to the Major River and dams with low groundwater potentials in summer season.

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