VILLAGE LEVEL GEO-ENVIRONMENTAL ASSESSMENT OF SOIL SITE SUITABILITY FOR GRAPES CULTIVATION USING GEOSPATIAL TECHNIQUES

Dnyaneshwar Pawar[1] Pravin Nalawade[2]Kirti Somvanshi[3]

[1]Head and Assistant Professor, Department of Geography, M.V.P. Samaj' Arts, Science and Commerce College, CIDCO, Nashik, MS, India. email-dmauli2007@gmail.com

[2]Head and Assistant Professor, Department of Environment Science, M.V.P. Samaj' KTHM College, Nashik, MS, India

[3]PG student, Department of Environment Science, M.V.P. Samaj' KTHM College, Nashik, MS.

Abstract:-

The current study uses a soil survey database to determine the optimum feasible land surface for grape cultivation to increase and optimize production. Because proper management of land resources requires micro-level assessment, the study area chosen is village Rahud in the drought-prone zone of Nashik district, North Maharashtra, India. The village's current land use and land cover data point to proper soil resource management for fallow land reclamation. In the Nashik district, grapes are an important cash crop. The NBSS and LUP criteria are used to assess the suitability of a soil location for grape production. The study area's varied land use/cover and slope components were used to gather detailed soil samples and measure soil hydrological parameters. The soil sample analysis assessed the regional variance of soil physical, chemical, and hydrological parameters. GIS, remote sensing, GPS, and statistical approaches were used to determine quantitative and spatial variation of soil suitability classes for grape cultivation. The revenue map from the tehsil headquarter was used to create the base map. A raster grid operation and map algebra analysis were used to estimate spatial assessment of various input factors of soil site suitability. The standards raster database in the arc GIS software was used for ranking and parametric evaluation. Physiographical components of soil parameters were assessed for the research area's suitability assessment. In the study area, Highly suitable land accounts for 22.95 % of the entire village, moderately suitable land for 27.11 %, and marginally suitable land for 22.67 %. Fallow land contains marginally appropriate classes and is ideal for converting to suitable categories if the proper soil measures are followed

Keywords: Geoinformatics, Geo-environment, Grapes, Soil Survey, Soil Suitability, Assessment

1. Introduction:

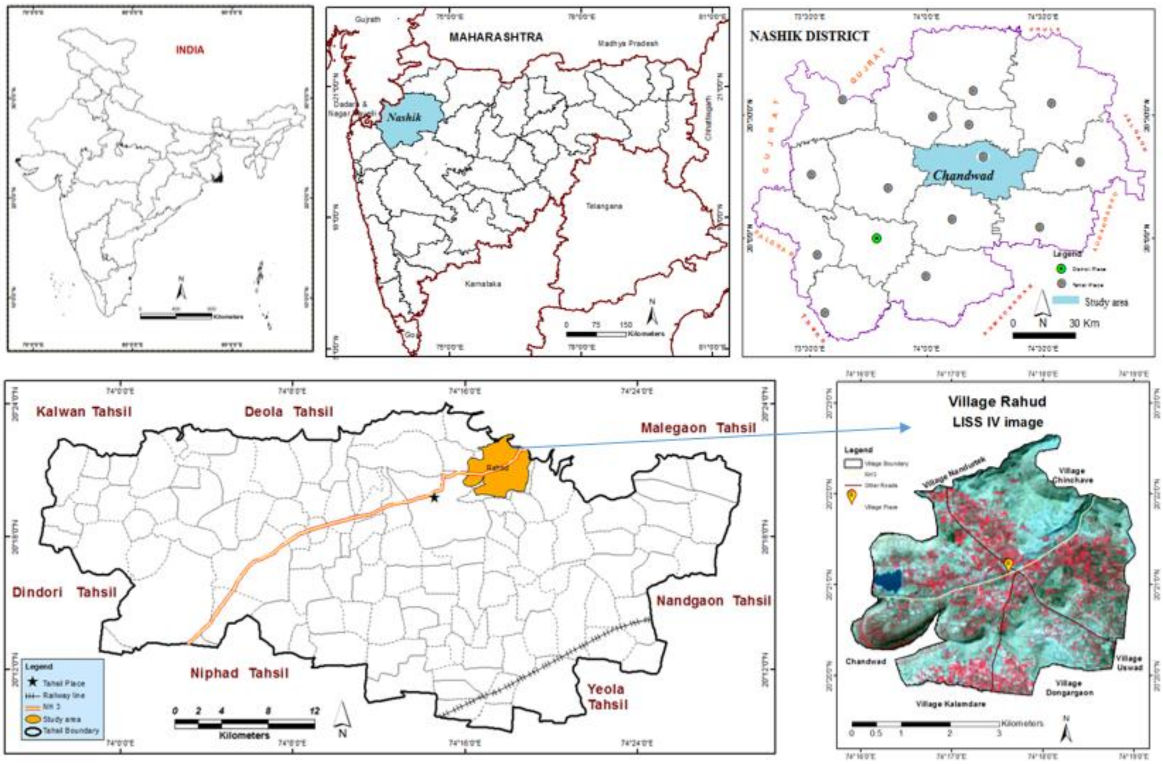
The world's growing population is accountable for a slew of issues. It puts more pressure on natural resources, especially water and land/soil resources. Land resources are first and foremost in ensuring people's food security. The supply of agricultural land per capita is decreasing as the world's population grows. In the 2011-12 financial year, India's arable land was roughly 182 million ha, with 0.15 ha per capita. (Sharam, 2015). This situation necessitates a broad understanding of additional land use options and the identification of suitable land for all crops to achieve long-term agricultural growth. Natural and agricultural resources and management are critical for the rural economy and agriculture growth (Bhaskar et al., 2016; FAO, 2016). Evaluation of soil and land resources, especially the methods of soil capability, land/ site suitability(M.Z. Salem al 2008, Jadab Chandra Halder, 2013), land productivity (Dnyaneshwar N Pawar, 2013, 2015), crop suitability (D. M. Thapa, C.P. Shrivastav, S.C. Shah, K. Sah, 2020; Chiranjit Singha and Kishore Swain, 2016; Hegade et al., 2018; Dnyaneshwar N Pawar et al. 2019), Crop management practices (Suhas P. et al., 2017), agriculture suitability (Ranya Elsheikhet al, 2013) are significant to increasing the production of crops to meet the needs of the growing population. (Dnyaneshwar N. Pawar, 2013, 2015). Finding the best feasible places for cropping and boosting productivity (Pan and Pan, 2012) and the potential utilization of land resources is an essential part of crop soil site selection.

The current study used the National Bureau of Soil Survey & Land Use Planning soil site suitability analysis of grapes production methodology approach (Naidu et al., 2006). In the evaluation and management of lands and soils, Geoinformatics technology is quite useful (Pawar Dnyaneshwar, 2013, 2015; Pawar and Tatar, 2019; Gahlod et al., 2017) GIS and remote sensing techniques are appropriate for digital mapping and soil resource evaluation (Eric and Abrefa, 2011; Pawar and Gaikwad, 2013; Abdollah Pirbalouti, 2009; Pable et al., 2017; Zolekar et al., 2018). With a comprehensive soil survey database, the current study attempted to apply the Geoinformatics technique to assess soil site suitability. (See Figure 2) Determining agricultural farmland and productivity should be the initial step in drought management. (FAO, 2016)

2. Study Area:

The study area is located in North Maharashtra, which is susceptible to drought. For this case study, the village of Rahud was chosen. It is administratively located in the Nashik district of Maharashtra, India, in the Chandwad Tehsil. It is 71 Km east of Nashik district headquarters and 10 Km east of Chandwad. It stretches from latitudes of 20^{0}19'31"N to 20^{0}22'40"N and longitudes of 74^{0}19'20"E to 74^{0}15'30"E. (See Figure 1)

Fig. 1 Location map of the study area (Village *Rahud*)



Village Nandurtek to the north, village Uswad & Kalamdare to the south, village Chinchave to the east, and town Chandwad to the west surround the village Rahud. From the village's centre, National Highway No. 3 passes. The settlement of Rahud covers an area of 18.26 Km2 (1826.25 ha). According to the 2011 census, the village of Rahud has a total population of 2677 people. Between 602 m and 991 m, the study area has moderate to high relief. The lowest elevation, 602 meters, is found near Rahudghat in the east, and the highest height, 991 meters, is located near the hilly area in the west. The research area's land use/land cover extent reveals that agricultural fallow land, wasteland, and scrubland encompass around 50.63 %of the total village area. It is consequently critical to assess land and soil resources to ensure optimum land utilisation and reclamation for long-term agriculture resource management. (See Table 1)

Table 1: Village *Rahud*: Extent of Land use/Land Cover category

Sr No	Land use/Land cover	Geographical Area		
		Hectors	Sq. km.	%
1	Irrigated Land	706.47	7.07	38.68
2	Agriculture fallow land	308.86	3.09	16.91
3	Wasteland	542.96	5.43	29.73
4	Land with scrub	72.87	0.73	3.99
5	Built up land	90.15	0.90	4.93
6	Waterbody	33.76	0.34	1.84
7	Rivers	42.02	0.42	2.30
8	Forest land	29.16	0.29	1.59
	Total area	1826.25	18.2625	100

4. Methods Of The Study:

The following technique outlines both in-field and laboratory components. Figure no- 2 chart shows the methodology adopted in the present study. The database and its sources used for the current research are listed in table no -2.

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.12, Dec 2022
Research Paper UGC CARE Listed (Group -I) Journal

Table 2: Soil-site characteristic data and its sources for the present study

Database	Source
Soil drainage	Fieldwork (Field measurements of infiltration rate and hydraulic conductivity)
Physical & Chemical properties of soils	Fieldwork and laboratory analysis (Collection of soil samples and its analysis in the laboratory)
Elevation	Survey of India, Topographical map
Slope	ASTER GDEM
Soil Texture and Erosion	NBBS, LUP, 2016
Village boundary	Revenue map from Panchayat office of Tehsil Headquarter
Land use/Land cover	IRS P6 LISS IV satellite image

4.1 Field components:

The ratings of assign for soil-site characteristics of grapes cultivation adopted from the NBBS & Land Use Planning (2006) Government of India. Soil site characteristics of grapes cultivation include climate, soil texture, soil drainage, soil pH, NPK, EC, Organic carbon, slope etc. Soil survey, soil sample analysis, and remote sensing data were used to estimate these features. The current study's technique is depicted in detail in a methodology chart (Fig.3). Geoinformatics techniques are employed to determine the study's accuracy and mapping. Soil samples were collected, and the soil's infiltration rate and hydraulic conductivity were measured during pre-monsoon fieldwork. The sampling sites were chosen using GPS according to the slope and land use/land cover difference in the study area (Fig.2).

Fig. 2. Methodology chart of the present study

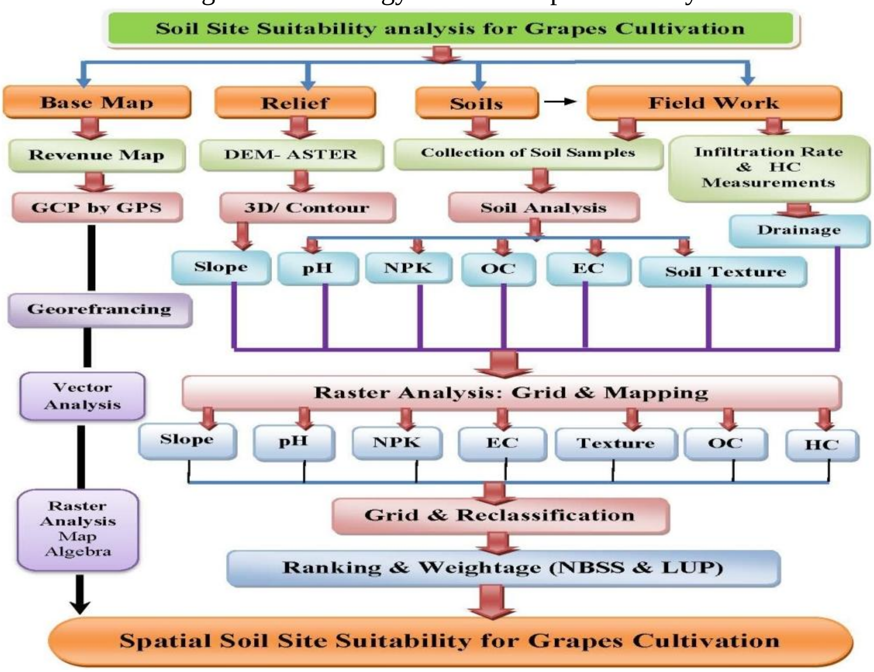
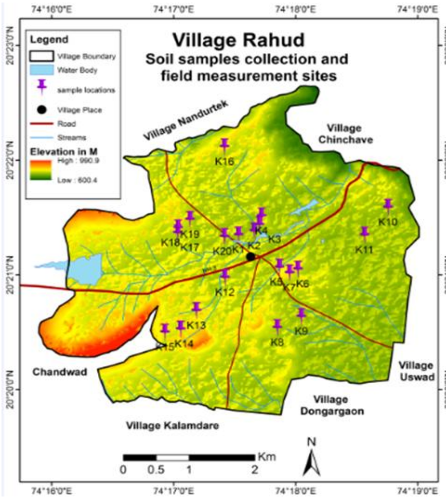


Fig. 3 Soil sample collection and field measurement location in the study area



4.2 Lab components:

Analyze a soil sample to determine the soil properties needed for grape growing. In GIS software, all databases are created in raster standard grid format. Reclassification and ratings were assigned for the spatial fluctuation of different input factors (Table 4). The final spatial site appropriateness of grapes cultivation in the research area was estimated using the map algebra function of the raster calculator in GIS software.

5. Analysis of input parameters of soil site suitability for grapes cultivation:-

5.1. Climateregime:

The weather influences any agricultural process. Long, hot, dry summers and chilly winters are required for grape production. The study area's climate is typically monsoon, with a narrow range of rainfall and temperature. The study region is extremely hot in the summer, and in the winter, it is freezing. The maximum temperature in the summer is 42.50 degrees Celsius, while the minimum temperature in the winter is more or less than 5.00 degrees Celsius. The average rainfall in the research area from 2004 to 2018 was 815.9 mm. spatial rainfall variation and its intensity affects productivity and crop production (Sanjay C., 2018). The climate in the research region is ideal for grape cultivation. The aerial extent of the village is small. Therefore, the rating for grape adaptability given to a geographical variation of rainfall and temperature is th

5.2 Slope:

DEM and LISS IV remote sensing data help assess soil and agriculture management at the village level. (Duraisamy et al., 2018). ASTER DEM was used to create a percentage slope map of the study area. The resampling method has been used to rank the slope raster values. The slope map was used to locate erosion hazards in the area. (see Table 3 and Fig. 4)

Table 3: Village *Rahud*: Area under % slope category

Sr. No.	Percentage Slope	Area in Hectare	Area in Percentage
1	< 1	28	1.51
2	1 to 10	1108	60.65
3	10 to 20	489	26.80
4	20 to 30	132	7.20
5	> 30	70	3.82
	Total Area	1826	100

The area's gentle slope contributes minimal erosion risk, but more than 10% of slopes pose a substantial risk. A gradient of less than 3%, or a gentle slope, is ideal for grape growing. The 3 to 5% slope suggested that the land was moderately suitable for farming. Approximately 87 % of the study area is covered by 1 to 20% of sloping fields.

5.3 Soil Drainage:

The infiltration and hydraulic conductivity variation assess the study area's soil drainage properties. The data on soil drainage obtained through detailed fieldwork was conducted in the study area. In the laboratory, a spatial variation map is created, and then a raster data rating is assigned using the resampling approach. Grape cultivation benefits greatly from a high infiltration rate. The study area's infiltration rate fluctuation map depicts 0.5 to 3 cm/2min. Each category's area has been computed. The infiltration variation of the studied region reveals that most of the area is in a highly suitable class, i.e. 53%. (9.71 Km2). (Fig.5)

5.4 Soil pH:

Soil Site Suitability Analysis is increasingly essential because of the physical and chemical features of the soil (Mandal et al., 2018). The soil analysis data used for the research area's pH map. A spatial variation map of soil pH is used to acquire grid-wise pH values for the relative pH ratings. The classes have been created, and ratings of suitability classes have been assigned based on the Grapes crop requirements' suitability criteria. Soil pH in the study region ranges from 6 to 8.5. An average pH of 6.5 is suitable for agricultural cultivation (Zolekar et al., 2015). The pH 6 to 7 are more suitable for grapes cultivation

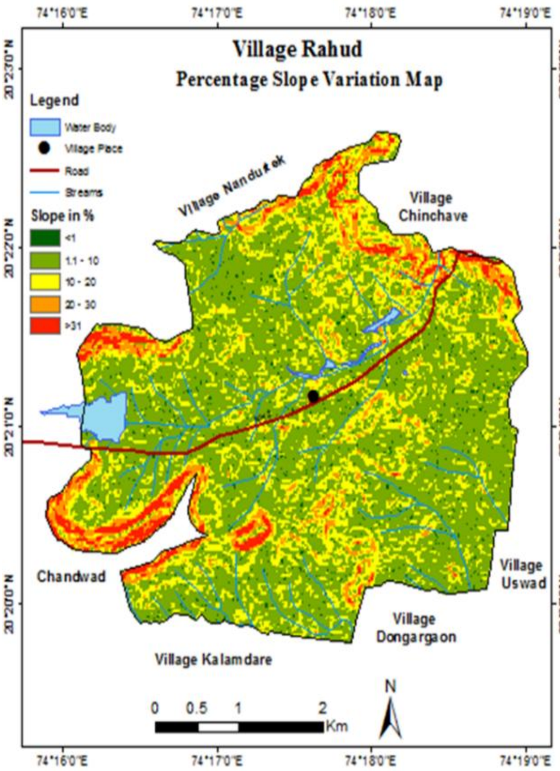


Fig. 4: Slope map of the study area

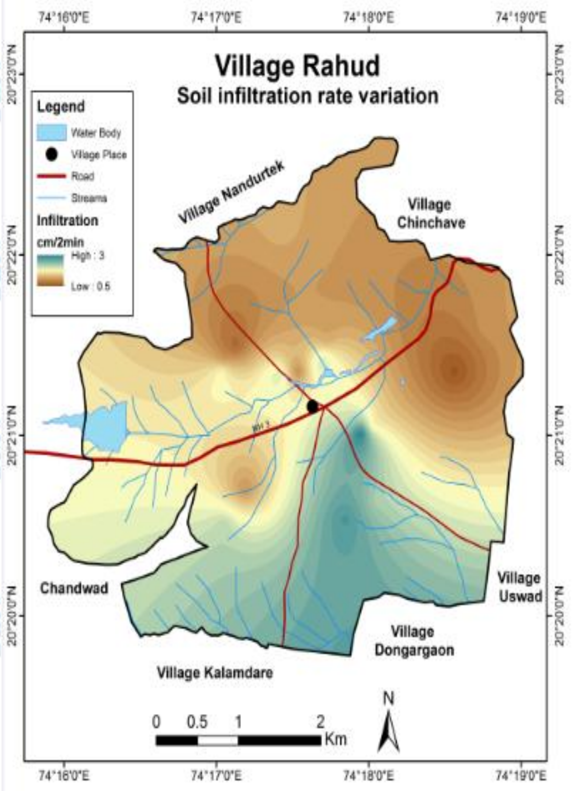


Fig. 5: Infiltration rate variation map of the study area

5.5 Electro-Conductivity (EC):

Soil Electrical conductivity is the third parameter used to classify grape site suitability. Geo-coordinates and GSI relative soil EC ratings were used to create the electrical conductivity map. The EC variation in the study area ranges from 0.1 to 1 Ds/m. It indicates a rising tendency in the northwest and a decreasing trend in the northeast of the research region. The highest EC, 1 Ds/m, is found in the northwest, while the lowest EC, 0.1 Ds/m, is located in the northeast. The map is rated and graded according to the NBSS and LUP criteria for grape suitability classes. (See Table 4)

5.6 Soil NPK:

In the soil suitability analysis for grape growing, NPK is a vital input component. Using soil analysis data, nitrogen, phosphorus, and potassium maps are created.

Nitrogen (N) is a chemical element that occurs naturally in the environment. Nitrogen is one of the soil's most significant chemical features for suitability classification because it ensures that energy is accessible when and where the plant needs it for optimal output. Soil data were used to create a map depicting the nitrogen variance in the research area. Nitrogen levels range from 73 to 594 kg/ha in the studied area. As a result, the research area's nitrogen spatial distribution map reveals that the soil is ideal for growing grapes.

Phosphate (P):-Phosphate is another chemical feature of soil used to classify its suitability. Phosphate levels vary from 17 to 139 kg/ha in the studied area. According to the geographical distribution map of phosphorus, most of the soil in Rahud village is highly favorable for grape growth.

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.12, Dec 2022

 UGC CARE Listed (Group -I) Journal

Potassium (K):-Potassium is another important chemical property for the Grapes crop site suitability assessment. Potassium levels in the study area range from 227-860 kg/ha. Potassium levels are rising in the research area's Centre and northern regions.

5.7 Organic Carbon (OC):

The soil suitability categorization uses the percentage organic carbon map of the study area as an input parameter. The fluctuation of OC in the research area is seen on the OC map, which shows a range of 2 to 1.1 %.

5.8 Soil Texture: (Sand, Silt, clay, loam)

Data on soil physical qualities, such as sand, silt, and clay, created a soil texture map. The textural qualities of soils are estimated through soil sample analysis. The percentage variation maps of sand, silt, and clay were used to create a soil textural map of the study area. The study area's percentage sand variation ranges from 80% to 90 %. The percentages of silt and clay range from 2% to 35% and 3 % to 5%, respectively. The study region's gentle slope land has the most sand, whereas the hill summit surface area has the most clay.

Table 4: Ratings and resampling of input parameters of soil site of grapes cultivation

Input parameter	Characteristics & Ratings		Input parameter	Characteristics & Ratings	
Erosion Hazard	Slope	Ratings	Soil drainage	Infiltration rate	Ratings
	< 3%	4		(>3 cm/2 min)	4
	3 to 5%	3		(2 -3 cm/2 min)	3
	5 to 10%	2		(0.5-2 cm/2 min)	2
	> 10%	1		(< 0.5 cm/2 min)	1
Nutrient availability pH	pH	Ratings	Nutrient availability (Nitrogen)	Nitrogen (N) (ppm)	Ratings
	6.5-7.5	4		High >30	4
	6.0-6.4 to 7.6-8.0	3		Medium 30-15	3
	4.0-5.9 to 8.1-8.5	2		Law <15	2
				No available	0
Nutrient availability Phosphate	Phosphate (P) (ppm)	Ratings	Nutrient availability Potassium	Potassium (K)(ppm)	Ratings
	High >30	4		High >30	4
	Med. 30-15	3		Medium 30-15	3
	Law <15	2		Law <15	2
	No available	0		No available	0
Organic Carbon	OC %	Ratings	Soil Texture	Soil Texture	Ratings
	<1.5	4		Scl, l, sl, cl	4
	1.5-5.0	3		Sl, sc, sic, sicl, c	3
	5.0-7.5	2		C (s<60%)	2
	>7.5	1		C (>60%), s	1
Electro-Conductivity	EC (**dS/m**)	Ratings	unsuitable land use/land cover	Land use/cover	Ratings
	Non-saline	4		Rocky land	0
	Upto 1	3		Area under forest	0
	1-2.5	2		Waterbody	0

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.12, Dec 2022
Research Paper UGC CARE Listed (Group -I) Journal

	>2.5	1		Built up land	0

6. RESULTS:

The long-term agricultural land use planning and management, a consistent and precise assessment of soil resources is essential (Ennaji et al., 2018). The results of the parametric evolution technique for calculating soil suitability for grape cultivation were used to create a soil site suitability map for the study area. It is accomplished through the use of GIS software. Different colours are assigned to each class to restrict the regions occupied by suitability classes. The suitability index is created for the classification of suitable courses and the measuring of their range. (See Fig. 5 and Table 5)

6.1 Highly Suitable (S1):

The dark green indicates the spatial distribution of highly suitable Class (S1) of grapes growing, which accounts for around 4.19 Km2 (419 ha., 22.95 %) of the total land surface area of village Rahud. (See Figure 6) This category includes the village's central and northwest areas. (See Fig. 6 and Table 5)

Fig. 6:Spatial soil site suitability of grapes cultivation in the study area

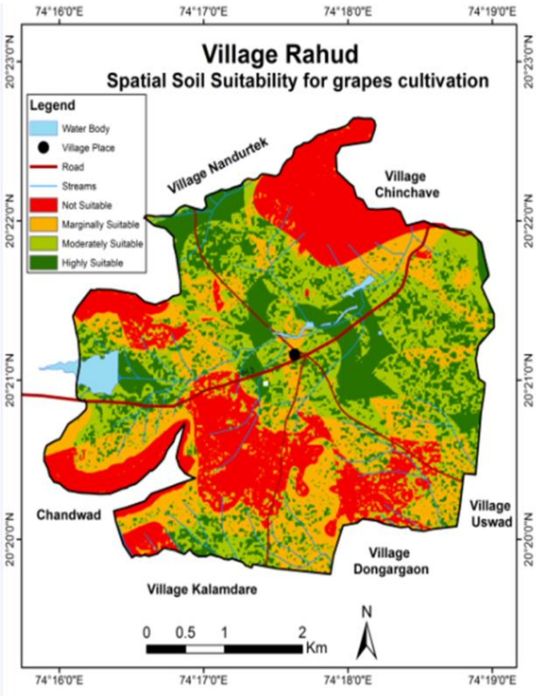


Table 5: Village *Rahud*: Extent of suitability classes for grapes cultivation

Sr. No.	Suitability class	Area in Hectors	Area in Percentage
1	Highly suitable	419	22.95
2	Moderately suitable	495	27.11
3	Marginally suitable	414	22.67
4	Not suitable	469	25.68
	Waterbody	29.25	1.59
	Total area	1826.25	100

6.2 Moderately Suitable (S2):

The analysis suggests that around 4.95 Km2 (495 ha., 27%) of the total area is moderately appropriate for grape growing (S2). A light green colour shows the study area's grape site suited for this class on the map. The reasonably suitable grapes cultivation class covers the study region's middle and eastern parts. (See Fig. 6 and Table 5)

6.3 Marginally Suitable (S3):

The soil site suitability for grapes cultivation in the third category is marginal. In the village of *Rahud*, the results show that 4.14 Km2, (414 ha or 23%) of the land is marginally suitable for grape growing (S3). The spatial distribution of the suitability map and land use land cover map reveals that most of the village's fallow lands are marginally suitable. The study area's grape site suited for this class is yellow. The west and south portions of the study area are only marginally suited for grape growth. (See Fig. 6 and Table 5)

6.4 Not Suitable for agriculture (S4):-

About 4.69 Km2, (469 ha., 25.68 %) of the study area is unsuitable for grape growing. The dark red spots on the map indicate unsuitable terrain, including scrub, boulders, escarpments, steep slopes, and erodible land. (See Fig. 6 and Table 5)

7. CONCLUSIONS:

Geoinformatics techniques are essential in the accurate and quick processing of large amounts of data and the mapping of site suitability analysis for grape growing. The LISS IV image and Digital Elevation Model remote sensing database provide a GIS research and mapping data source. For providing a database for implementing the policy of sustainable land resources and agriculture development at micro-level areas of the drought-prone zone, cartographic representation of data in the form of spatial variation maps of percentage slope, soil physical, chemical, and hydrological properties, and the soil site suitability maps has been used. The NBSS & LUP of India's criteria for soil site suitability analysis of grape production is adequate. Still, they require a broad and reliable soil survey database to be applied in any geographical area. This research is essential for enhancing grape output and converting fallow land to agricultural land. The village of Rahud's socioeconomic growth results from increased productivity and long-term agricultural land planning in the area. The potential of soil suitability for grapes cultivation and development in the research area is determined by a geo-environmental evaluation of the soil site suitability analysis of the study region.

8. REFERENCES

1. B. P. Bhaskar, S. G. Anantwar, S. S. Gaikwad and S. V. Bobade(2016) Land resource assessment for agricultural development in Seoni district (Madhya Pradesh), India. Journal of Applied and Natural Science 8 (2): 750 - 759
2. C. Sanjay, P Bhasker, SL Damodare and AP Abhale(2018). Statistical analysis of seasonal rainfall variability in Nasik district by using GIS interpolation technique. Journal of Pharmacognosy and Phytochemistry.7(4): 2072-2077 E-ISSN: 2278-4136 P-ISSN: 2349-8234
3. ChiranjitSingha and Kishore Chandra Swain (2016). Land suitability evaluation criteria for agricultural crop selection: A review. Agricultural Reviews, 37 (2) 2016: 125-132. Print ISSN: 0253-1496 / Online ISSN: 0976-0539. www.arccjournals.com
4. D. M. Thapa, C.P. Shrivastav, S.C. Shah, K. Sah(2020). Land suitability evaluation using gis for vegetable crops atSharadanagar, Chitwan, Nepal. Tropical Agrobiodiversity, 1(1): 42-46. DOI: http://doi.org/10.26480/trab.01.2020.42.46
5. Dnyaneshwar N. Pawar and Sunil W. Gaikwad (2012) characterization and appraisal of land resources of micro watershed for sustainable development using GIS techniques. National conference proceeding 3 to 5 Dec. 2012, organized by Shri Shiv Chhatrapati College, Junnar, Maharashtra, India. Pp 111-116 ISBN 978-93-81354-40-7.
6. DhanshreePable, et al (2017) Application of geospatial techniques in soil suitability analysis for major crops of Nizamabad district, Telangana. Agropedology 2017, 27 (02) 139-144
7. Dnyaneshwar N. Pawar and BhagyshreeTatar(2019)Application of geoinformatics in soil-site suitability assessment for grape cultivation-A case study of village Haste Dumala, Nashik M.S. E- research Journey. International Peer refereed & Indexed Journal. ISSN-2348-7143. Impact factor-6.261. Page No. 81-90.
8. Dnyaneshwar N. Pawar(2015) Pedogeomorphology based spatial land productivity assessment - a geoinformatics approach. Special issue III, Scholars World International Refereed Multidisciplinary Journal of Contemporary Research. Maaz Publications, Malegaon Pp. 126-132. ISSN 2319-5789.
9. DuraisamyVasu, et al(2018)a comparative assessment of land suitability evaluation methods for agricultural land use planning at village level. Land use policy0264-8377/ © 2018 Elsevier Ltd. All rights reserved.
10. Eric K. Forkuo, Abrefa K. Nketia (2011) Digital soil mapping in GIS environment for crop-land suitability analysis. International Journal of Geomatics and GeosciencesVolume 2, No 1, 2011 Pp 133-146. ISSN 0976 – 4380
11. FAO (2016) Characterization of the agricultural drought-prone areas on a global scale. FAO, Rome, 2016. ISBN 978-92-5-109286-6
12. Hegde et al (2018)Land evaluation for suitability analysis of site-specific pigeon pea (Cajanuscajan) Sorghum (Sorghum bicolor)-a case study of matki-3 micro watershed, Gulbarga District, Karnataka, India

International Journal of Agriculture Sciences. ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 13, 2018, pp.-6584-6591.https://doi.org/10.1016/j.landusepol.2018.08.007

13. Jadab Chandra Halder(2013)Land suitability assessment for crop cultivation by using Remote Sensing and GIS. Journal of Geography and Geology; Vol. 5, No. 3; 2013. Pp 65-74 ISSN 1916-9779 E-ISSN 1916-9787. http://dx.doi.org/10.5539/jgg.v5n3p65
14. N. S. Gahlod, SonamBinjola, Ravi and V. S. Arya(2017) Land-site suitability evaluation for tea, cardamom and rubber using Geospatial technology in Wayanad district, Kerala. Journal of Applied and Natural Science 9 (3): 1440 - 1447 (2017) ISSN: 0974-9411 (Print), 2231-5209
15. Naidu et al (2006) Manual soil suitability criteria for major crop. NBSS Publ. No.129, NBSS & LUP Nagpur, 118 PP. National Bureau of soil survey and land use planning, AmaravatiRoad, Nagpur, India
16. Pan, G., Pan, J.(2012) Research in cropland suitability analysis based on GIS. Computer and Computing Technologies in Agriculture 365, 314–325.
17. RajendraZolekar(2018) Integrative approach of RS and GIS in characterization of land suitability for agriculture: a case study of Darnacatchment. Arabian Journal of Geosciences (2018) 11:780 https://doi.org/10.1007/s12517-018-4148-4
18. RajendraZolekar, Vijay Bhagat(2015) Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. Elsevier Computers and Electronics in Agriculture 118 (2015) 300–321. http://dx.doi.org/10.1016/j.compag.2015.09.016
19. RanyaElsheikhet al (2013) Agriculture land suitability evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops.Computers and Electronics in Agriculture 93 (2013) 98–110 Elsevier B. V. 0168-1699.http://dx.doi.org/10.1016/j.compag.2013.02.003
20. SatyabrataMandalet al (2018) Soil site suitability analysis using geo-statistical and visualization techniques for selected winter crops in Sagar Island, India Applied Geography 122 (2020) 102249. https://doi.org/10.1016/j.apgeog.2020.102249
21. Srinivasarao, Ch., Lal, R., Prasad, J.V.S.N., et al. (2015) Potential and challenges of rainfed farming in India. Adv. Agron. 133, 1–69.
22. Sharma Vijay Paul(2015) Dynamics of Land Use Competition in India: perceptions and realities. IIM
23. Suhas P. Wani, K.H. Anantha&Kaushal K. Garg(2017) Soil properties, crop yield and economics under integrated crop management practices in Karnataka, Southern India. World Development Vol. 93, pp. 43–61, 2017 0305-750X. Elsevier. http://dx.doi.org/10.1016/j.worlddev.2016.12.012
24. WidadEnnaji, et al (2018) GIS-based multi-criteria land suitability analysis for sustainable agriculture in the northeast area of Tadla plain (Morocco). J. Earth Syst. Sci. (2018) 127:79. https://doi.org/10.1007/s12040-018-0980-x