Geospatial Approach for Land and Water Resource Development Planning for Dausa District of Rajasthan

Sagar Subhashrao Salunkhe[1]*, Subhajit Roy[1], Suparn Pathak[2], & Rakesh Paliwal[1]

[1]Regional Remote Sensing Centre West, NRSC, ISRO, Jodhpur, India
[2]Regional Remote Sensing Centre East, NRSC, ISRO, Kolkata, India
*Corresponding Author's email: sagar.swce@gmail.com

Abstract

Land and water resources, considered vital natural resources for any region, are gradually becoming scarce because of improper management and over-exploitation. Optimal utilization and conservation through proper planning are essential for maintaining the sustainability of such resources. Therefore, an attempt has been made to generate a Land Resources Development Plan (LRDP) and Water Resources Development Plan (WRDP) for the Dausa District of Rajasthan using geospatial data. LRDP and WRDP identify the most suitable measures that can be taken to conserve land and water resources in any particular region. The present study used geospatial data such as land use/land cover (LULC), slope, land capability class (LCC), groundwater potential, soil texture, soil depth, land degradation, geomorphology and drainage orders to generate LRDP and WRDP. LRDP was generated using an Analytical Hierarchical Process (AHP) by assigning weights to input layers and subsequent integration. Based on the suitability of each product, a binary "Yes" or "No" condition has been given to each input layer class to develop WRDP. The area is assigned to a particular WRDP product if the "Yes" condition for each input layer is satisfied. It was observed that intensive agriculture (62.16%), horticulture (9.92%), afforestation (8.88%) and silvipasture (6.59%) are the major LRDP suitable for the study area, followed by other classes like grazing/pasture lands, recreational/industrial, agroforestry, aquaculture, reclamation of wasteland and agro horticulture. Similarly, earthen contour bunds (57.89%) and percolation tanks (23.61%) were found to be the most appropriate WRDP for the study area, followed by other classes like gabion structures, contour trenches, loose boulder check dams, farm ponds and minor irrigation tanks. The LRDP and WRDP will facilitate the decision-makers in taking up site-specific sustainable natural resource management practices more comprehensively. The current study emphasizes the application of digital cartography and geospatial technologies for sustainable ecosystems and resource management in the Dausa District of Rajasthan.

Keywords: LRDP; WRDP; AHP; Dausa district; geospatial data; natural resources management

Introduction

The land serves as our home and is utilized by us for all daily activities necessary for survival. Land, a finite resource, is under pressure from urbanization, population growth, industrialization, and infrastructure development and requires responsible stewardship (UNCCD, 2022). The extent of land resources, especially soil and water, is progressively decreasing. Using these resources sustainably and efficiently is crucial, especially amid the rising population pressure. The soil eco-environment is suffering extensive harm due to the overuse of natural resources. As land is used for multiple purposes, trade-offs favor one use over another, which leads to land degradation (FAO & ITPS, 2015). Approximately 187.7 million hectares, or 57.1% of India's total geographical area, are affected by different types of soil degradation caused by wind, water, chemicals, and physical forces (Sehgal & Abrol, 1994). It has a significant impact on long-term productivity. In India, it is estimated that 5.33 million tonnes of topsoil are lost each year due to various forms of degradation, which equals 5.37 to 8.4 million tonnes of plant nutrients (Dhruvanarayana & Babu, 1983).

Land conservation is a key focus area for maintaining the land efficiently. Additionally, soil and water conservation are prioritized for the physical enhancement of land (Dalal-Clayton et al., 2013). Wastelands must be used for multiple purposes to prevent them from being left fallow (Fazal, 2000). Alternate land use practices such as agro-horticulture, agro-forestry, etc., significantly influence watershed development. It reduces runoff from watersheds, increases crop productivity and diversification, and increases the land used for cultivation. It also raises the average annual family income (Wani et al., 2009; Sharma et al., 2001).

To ensure equitable access and minimize environmental impact, accelerating development planning at the local community level (grassroots) is essential (World Bank, 1993). Uncontrolled and lack of planned development in rural and peri-urban areas poses significant social, environmental, and health risks (IPCC, 2021). In India, Gram Panchayat (GP) is the primary planning unit in the bottom-up model of decentralized developmental planning. Land resource development planning in rural areas is a subject matter of local authorities from Panchayati Raj Institutions (PRIs). Due to their limited GIS expertise, performing sustainable land use planning by optimizing spatial data is challenging for local planners. They mainly rely upon conventional methods, which are often laborious, costly, and time-consuming (Paul et al., 2017). While native and traditional technologies and knowledge have to be protected, there is also a need for new technologies and know-how to be developed and adjusted to local conditions.

With advancements in geospatial technology, high-resolution satellite data and sophisticated processing techniques have revolutionized as a powerful tool for mapping and monitoring natural resources at various scales, enabling ongoing development planning and periodic resource assessments. In order to avoid haphazard development, endeavors are being made to orient space technology towards providing technical assistance in preparing scientifically justified sustainable development plans such as Land Resources Development Plan (LRDP) and Water Resources Development Plan (WRDP) for any area. Many studies show that developing countries' non-conventional land use planning techniques use remote sensing and GIS technologies (Cools et al., 2003). Chowdary et al. (2009) also used remote sensing and GIS to prepare an integrated water resource development plan for sustainable management of the Mayurakshi watershed, India. One needs to evaluate various criteria to choose the best alternative land use. A spatial optimization problem needs support tools when planners make decisions. Geographic Information Systems (GIS) is one such tool. Shankar Ram et al. (2022) gave multi-criteria-based land and water resource development planning using geospatial technologies for Chharba Gram Panchayat of the Dehradun district, Uttarakhand, India. Moreover, with web-based enablement, geospatial technologies have the potential to provide input for the development of an online platform for spatial land use planning.

Generally, LRDP Suggests alternate land use planning after assessing the land's potential for improving social and economic conditions. WRDP includes identifying suitable areas where certain types of water resource activity are recommended for implementation. The primary purpose of these activities is to improve the groundwater condition by storing and allowing water to percolate into the ground by holding the water in water harvesting structures as much as possible. Developmental planning using spatial inputs generated at very high resolution using geospatial technologies is necessary for the management and judicious utilization of land, water, vegetation, and other resources in a sustainable way. A comprehensive LRDP and WRDP plan, utilizing the advantages of geospatial technology and carefully addressing the environmental, topographic, and climatic parameters, may provide practical and feasible solutions toward sustainable and resilient rural development and livelihood. Therefore, the present study aims at utilizing several thematic layers, viz., land use/land cover, soil texture, soil depth, slope, groundwater prospects, land capability classification, land degradation, drainage orders, and geomorphology, towards developing adequate land and water resource development plan for Dausa district, Rajasthan.

Materials and Methods

Study Area:

The study was carried out in Dausa district of Rajasthan (Fig. 1). It is situated in the northeastern region of Rajasthan, widely known as Dhundhar. The geographical area of Dausa district is 3418 $km^{2,}$ and it lies between 26.33º and 27.33º E Latitude and 76.16º & 77.16º N Longitude. Dausa district comes under the agro-climatic zone IIIA, known as the semi-arid eastern plain. This agro-climatic zone has annual rainfall in the range of 500-700 mm. It has sandy surfaces with buried pediments, scattered hills, and extensive areas covered by alluvium. A thick mantle of soil-blown sand alluvium covers a large part of the district. The climate of the district is dry. The minimum and maximum temperatures recorded in the district vary from 5 ºC to 47 ºC. The average annual rainfall of the district is 604 mm. The district has only seasonal flow and no perennial rivers exists. The major rivers flowing in the district are Morel and Banganga. Among them, Banganga is the main river. It originated in the Aravali hills, near Arnasar and Bairath in Jaipur District. The river is approximately 240 km in length. The right bank tributaries of the Banganga River include Gumti Nalla and Suri River, and the left bank tributaries include the Sanwan and Palasan Rivers. The district headquarters of the Dausa lies on the bank of the River Banganga.

Data Used:

Land Use/Land Cover (LULC): The LULC data (10k) mapped from 2.5 m multi-temporal satellite data (LISS-IV + Cartosat pan merged) for the year 2018–2019 of NRSC, ISRO, Hyderabad prepared under the project “Space Based Information Support for Decentralized Planning (SISDP) - Phase II” were used (https://bhuvanpanchayat.nrsc.gov.in/). The classification scheme adopted in this project comprised of 41 classes, which extensively covered all the essential features across India. The LULC of the Dausa district of Rajasthan and its area statistics is presented in Fig. 2 and Table 1. It was observed that agricultural land is the most dominant, covering 72.46% of the area. Wastelands account for 9.63%, followed by forest land (8.96%), built-up areas (6.55%), water bodies (2.28%) and others (0.12%).

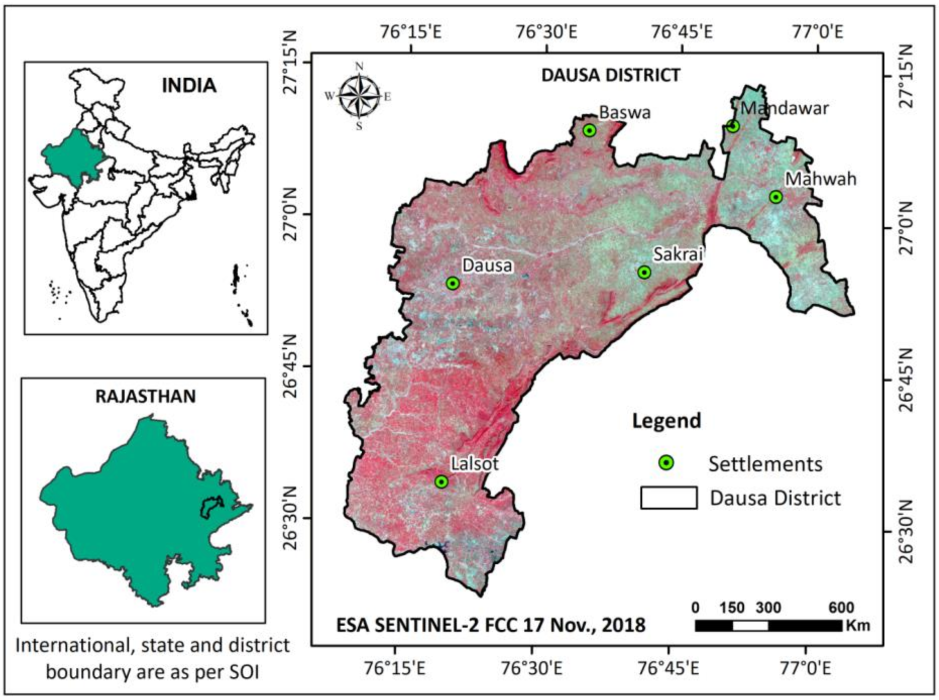

Fig. 1 Study area location: Dausa District of Rajasthan.

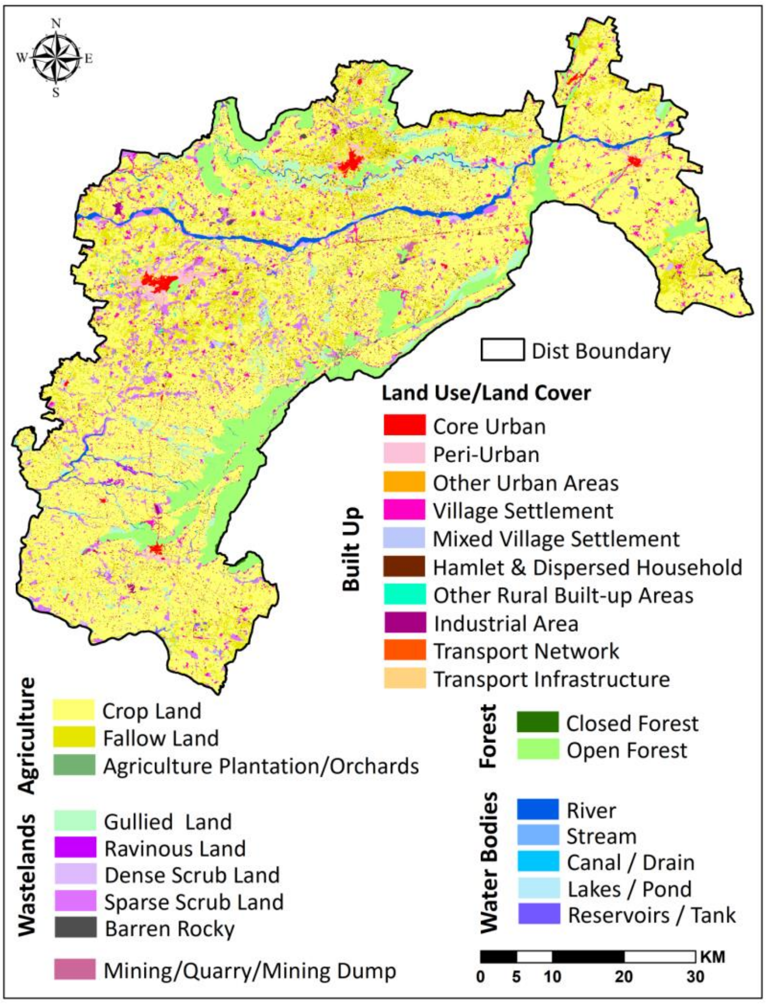

Fig. 2 LULC of Dausa District of Rajasthan.

Table 1 Area Statistics of Land Use/ Land Cover for Dausa District of Rajasthan.

Level-I	Level-II	Level-III	Area (km^2)	Area (%)
Built up	Built up urban	Core urban	16.97	0.50
		Peri-urban	27.60	0.81
		Other urban areas	1.13	0.03
	Built up rural	Village settlement	76.58	2.24
		Mixed village settlement	0.07	0.00
		Hamlet & dispersed household	83.64	2.45
		Other rural built-up areas	2.08	0.06
	Industrial area	Industrial area	6.41	0.19
	Transportation	Transport network	8.81	0.26
		Transport infrastructure	0.50	0.01
Agriculture land	Crop lands	Crop land	2116.22	61.92
	Fallow lands	Fallow land	358.03	10.48
	Agriculture plantation	Agriculture plantation	2.00	0.06
Forest	Forest	Closed forest	1.90	0.06
		Open forest	304.50	8.90
Wastelands	Gullied and ravinous land	Gullied land	114.14	3.34
		Ravinous land	2.30	0.07
	Scrub land	Dense scrub land	34.44	1.01
		Sparse scrub land	174.37	5.10
	Barren land	Barren rocky	3.73	0.11
Water bodies	River/stream	River	55.05	1.61
		Stream	5.89	0.17
	Canal/drain	Canal/drain	3.38	0.10
	Lakes/pond	Lakes/pond	9.21	0.27
	Reservoirs/tank	Reservoirs/tank	4.56	0.13
Others	Mining/quarry	Mining/quarry/mining dump	4.26	0.12
		Total area	**3417.77**	**100**

Soil Related Datasets: The soil-related datasets used in the study i.e., soil texture, soil depth, land capability class (LCC) and land degradation, are presented in Fig. 3. Soil texture and land capability classification data were obtained from the Natural Resource Information System (NRIS) project – SAC, ISRO Ahmadabad (Dasgupta et al., 2000). In this project, soil resources of Rajasthan State were mapped on 1:50,000 scale by a collaborating agency, namely the State Remote Sensing Application Centre, Government of Rajasthan, Jodhpur, using IRSP6 LISS-III data and field soil sample analysis results (SRSAC, 2010). Soil depth data were obtained from soil maps (250k) prepared by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), India (Bhattacharyya et al., 2009). Land degradation data (50 k) were obtained from the Natural Resource Census Project of NRSC, ISRO, Hyderabad mapped from multi-temporal Resourcesat-2 LISS-III data for the year 2015 – 2016 (NRSC, 2019). Sandy, sandy loam and loamy are the most common soil textures in the study area. The soil depth map shows that most of the study area has deep and moderately deep soils. Similarly, the primary land capability classes observed in the study area are class II, class III and class VI. It shows that the majority of the land is suitable for cultivation. Water erosion (sheet, gullies and shallow ravines) was the main land degradation category in the study area. At the same time, some patches of saline, sodic, and saline-sodic soils were also observed.

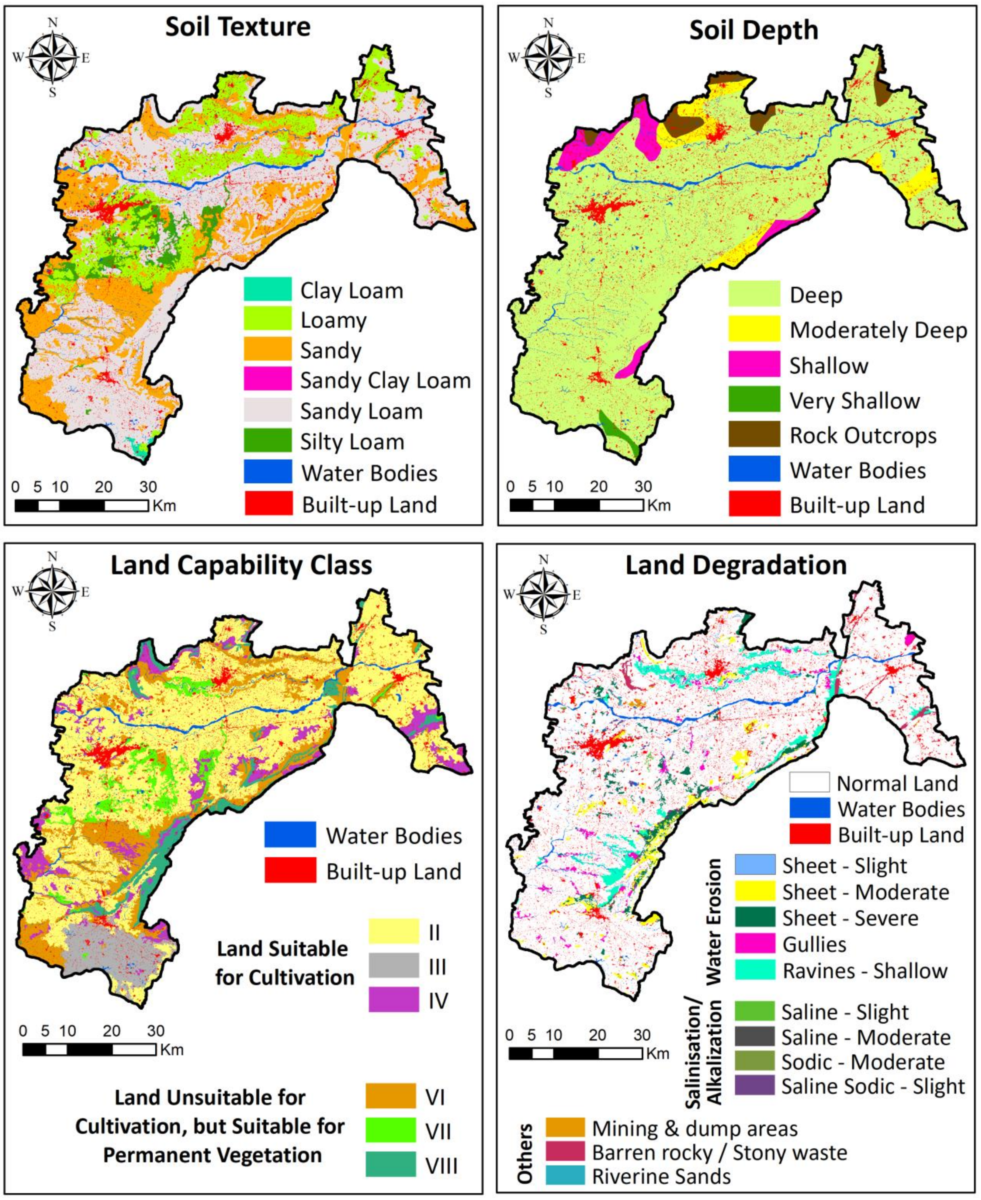

Fig. 3 Soil Related Datasets of Dausa District of Rajasthan.

Geological Datasets: The geological datasets used in the study i.e. geomorphology, ground water prospects, slope and drainage orders are presented in Fig. 4. Geomorphology data (50 k) were obtained from the National Geomorphology and Lineament Mapping (NGLM) Project of NRSC, ISRO, Hyderabad, mapped from multi-temporal Resourcesat-1 LISS-III data for the year 2005–2006 (https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php). Ground water prospects data (50 k) were obtained from the Rajiv Gandhi National Drinking Water Mission Project of NRSC, ISRO, Hyderabad (NRSC, 2015). Slope data was obtained from NRSC, ISRO, Hyderabad. It was prepared under SISDP – Phase I project of NRSC using Cartosat 30m DEM (https://bhuvanpanchayat. nrsc.gov.in/). Drainage orders prepared on a 1:50,000 scale under the India-WRIS project of NRSC, ISRO, Hyderabad, were used in the study (https://indiawris.gov.in/). Pediplain is the main geomorphological feature present in the study area, with some patches of structural hills, alluvial plain and flood plain. The ground water prospects map shows that most of the study area falls under the good and moderate categories. Similarly, most of the area has a nearly flat (0-1 %) to very gentle (1-3 %) slope. The drainage of orders 1 to 6 are present in the study area.

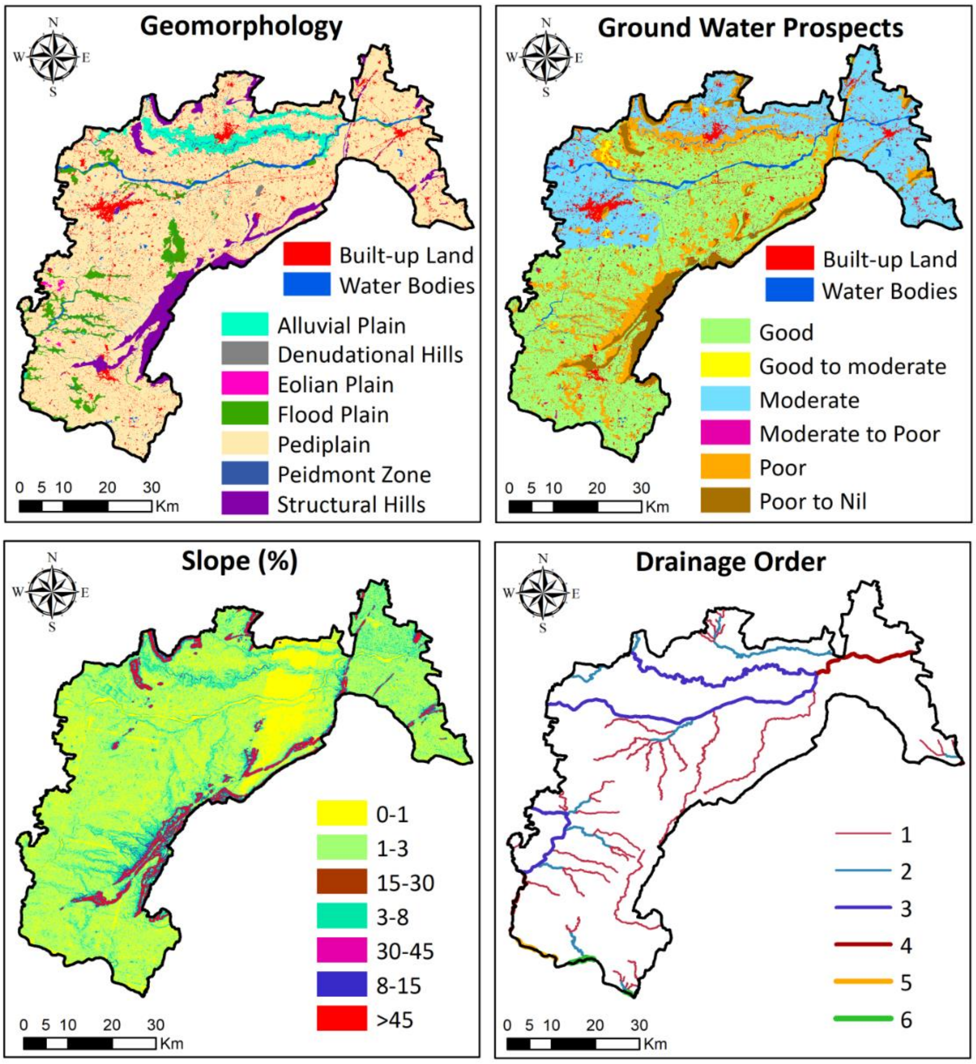

Fig. 4 Geological Datasets of Dausa District of Rajasthan.

Methodology:

Land Resources Development Plan (LRDP): LRDP is crucial in ensuring the long-term sustainability of land resources and promoting comprehensive development. It provides a framework for informed decision-making and guides the allocation of resources for sustainable land management practices within a specific geographic area. It includes a variety of considerations such as land use planning, agricultural development, natural resource conservation, environmental protection etc. LRDP is typically developed at the regional or local level but can also be applied nationally (ILRI, 2005; UNESCAP, 2010; FAO, 2011). LRDP aims to balance economic development, social equity, and environmental sustainability.

In the present study, eleven LRDP products, namely intensive agriculture, agro-horticulture, agro-forestry, horticulture, silvipasture, grazing/pasture land, production forestry, afforestation, reclamation of wasteland, aquaculture and recreational/industrial, were evaluated for Dausa district of Rajasthan. A detailed description of each LRDP product is provided in the comprehensive document prepared by NRSC, ISRO, Hyderabad under the project “Space Based Information Support for Decentralized Planning (SISDP) - Phase II” (NRSC, 2021). This document can be downloaded from the Bhuvan Panchayat portal of NRSC, ISRO, Hyderabad (https://bhuvanpanchayat.nrsc.gov.in/). The methodology flow chart for generation LRDP is presented in Fig. 5. Seven thematic layers, namely land use/land cover, land capability class, ground water prospectus, slope, soil texture, land degradation and soil depth, were used as input to generate suitable LRDP. Each input layer class has been assigned normalized weights in the range of 1 to 10 based on its importance with respect to each LRDP product (NRSC, 2021). However, there are certain classes, such as built-up lands and rivers/drains/canals, for which LRDP products could not be assigned. A ‘Nil’ value has been assigned to these classes and are excluded for further processing. Each input layer has been reclassified according to the normalized/priority weights by generating seven layers of each of the 11 products (77 layers). Relative weights (ranging from 0 to 1) were also assigned to each input layer for each LRDP product using the Analytical Hierarchy Process (AHP) (NRSC, 2021). Then, each product's weighted sum (i.e., normalized weight multiplied by relative input layer weight) was generated. It gives the favorability layers for each of the LRDP products. The LRDP product layer was generated by selecting the highest favorability by overlaying each product's favorability layers. The final LRDP was generated by updating the built-up lands and water bodies' masks.

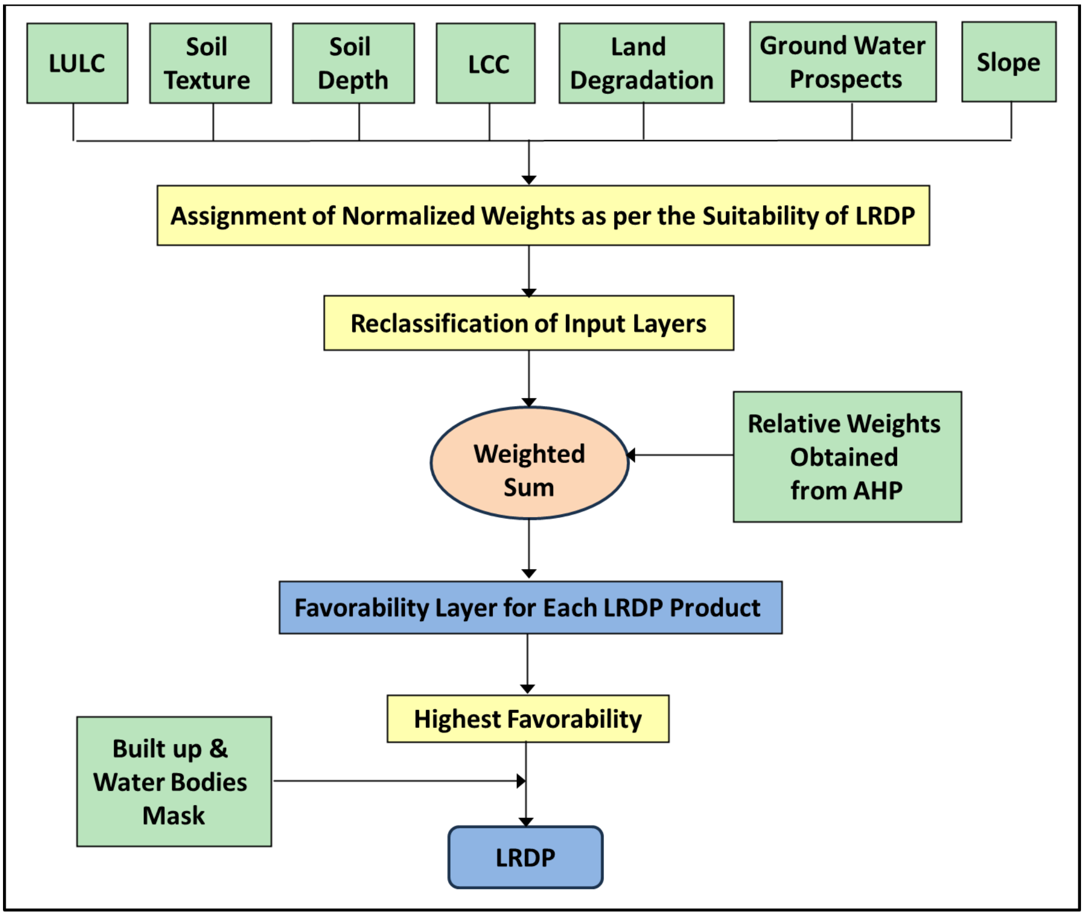

Fig. 5 Methodology Flowchart for Generation of LRDP.

Water Resources Development Plan (WRDP): WRDP shows comprehensive strategies to manage and utilize water resources sustainably, ensuring water security. It covers many considerations, including water demand forecasting, water supply development, water use efficiency, water quality management, and flood control. WRDP is typically developed at the regional or national level but can also be applied locally (UNESCO, 2009; World Bank, 2004; IWMI, 2005). WRDP aims to balance water availability, water demand, and environmental sustainability.

In the present study, five area-based WRDP products (contour trenches, earthen contour bunds, percolation tank, farm ponds and khadins) and five location-based WRDP products (loose boulders check dam/gully plugs, gabion structures, earthen dams (nala bunds), minor irrigation tanks and subsurface dykes), were evaluated for Dausa district of Rajasthan. A detailed description of each WRDP product is provided in the comprehensive document prepared by NRSC, ISRO, Hyderabad under the project "Space Based Information Support for Decentralized Planning (SISDP) - Phase II" (NRSC, 2021). The methodology flow chart for generation WRDP is presented in Fig. 6. Five thematic layers, land use/land cover, soil texture, geomorphology, slope, and drainage orders, were used as input to generate suitable WRDP. For area-based WRDP products, all thematic layers except drainage orders were used as inputs. Each input layer class has been assigned a binary "Yes" or "No" condition based on the suitability of each area-based WRDP product (NRSC, 2021). The area is assigned to a particular area-based WRDP product if the "Yes" condition for each input layer is satisfied. That means AND operation is performed over the layers to obtain suitable WRDP products. The percolation tank is given higher priority because of the similarity in prevailing conditions for the suitability of any area under a percolation tank and farm ponds (NRSC, 2021). For location-based WRDP products, all five thematic layers were used as inputs. Location-based WRDP products are generated for stream/drainage buffer areas only. For that, a 50 m buffer for drainage orders 1 to 3 and 75 m for drainage orders 4 to 6 were created. Similarly to area-based products, each input layer class has been assigned a binary "Yes" or "No" condition based on the suitability of each location-based WRDP product (NRSC, 2021). The area is assigned to a particular location-based WRDP product if the "Yes" condition for each input layer is satisfied. The outputs of the location-based WRDP product were updated over the area-based WRDP product for the generation of WRDP. The final WRDP was generated by updating the built-up lands and water bodies' masks.

Results and Discussions

Land Resources Development Plan (LRDP): The LRDP for the Dausa district of Rajasthan and its area statistics are presented in Fig. 7 and Table 2. Out of a total of eleven LRDP products evaluated, ten were found suitable. Among the suggested LRDP products, intensive agriculture is the primary activity, encompassing a vast 2124.50 km^2 (62.16%) of the total district area. It aligns with the existing LULC data, which reveals a potential to expand agricultural land by 8.28 km^2 compared to the current 2116.22 km^2. This expansion denotes further opportunities for increased food production and rural economic growth. The LRDP also highlights the tremendous potential for horticultural development alongside conventional agriculture. With 339.10 km^2 area suggested for horticulture activities and 4.50 km^2 suggested for agro-horticulture, the plan demonstrated how to diversify and enrich the agricultural landscape in Dausa district. This diversification can yield numerous benefits, including increased farmer income, improved nutritional security, and enhanced environmental sustainability. Furthermore, the LRDP identifies 303.21 km^2 area as suitable for afforestation initiatives, especially in open forest areas. This proactive approach towards increasing forest cover by 8.88% holds immense promise for environmental conservation, biodiversity enhancement, and climate change mitigation. Aquaculture also finds its place in the LRDP, with a small area of 13.60 km^{2,} which is 0.4% of the total district area. It will open doors for establishing fish farms, promoting sustainable aquaculture practices, and diversifying the local economy. The LRDP visualizes a brighter future for industry and leisure activities in Dausa district, with approximately 21.65 km^2 area suggested for recreational/industrial development. As per the existing LULC data, an industrial area already developed is about 6.41 km^2. It denotes a high potential to improve about 15.24 km^2 under industrial development. This allocation indicates the potential for attracting investments, creating new jobs, and fostering economic diversification in the Dausa district. LRDP also suggested considerable area for silvipasture (6.59%) and grazing/pasture land (2.11%).

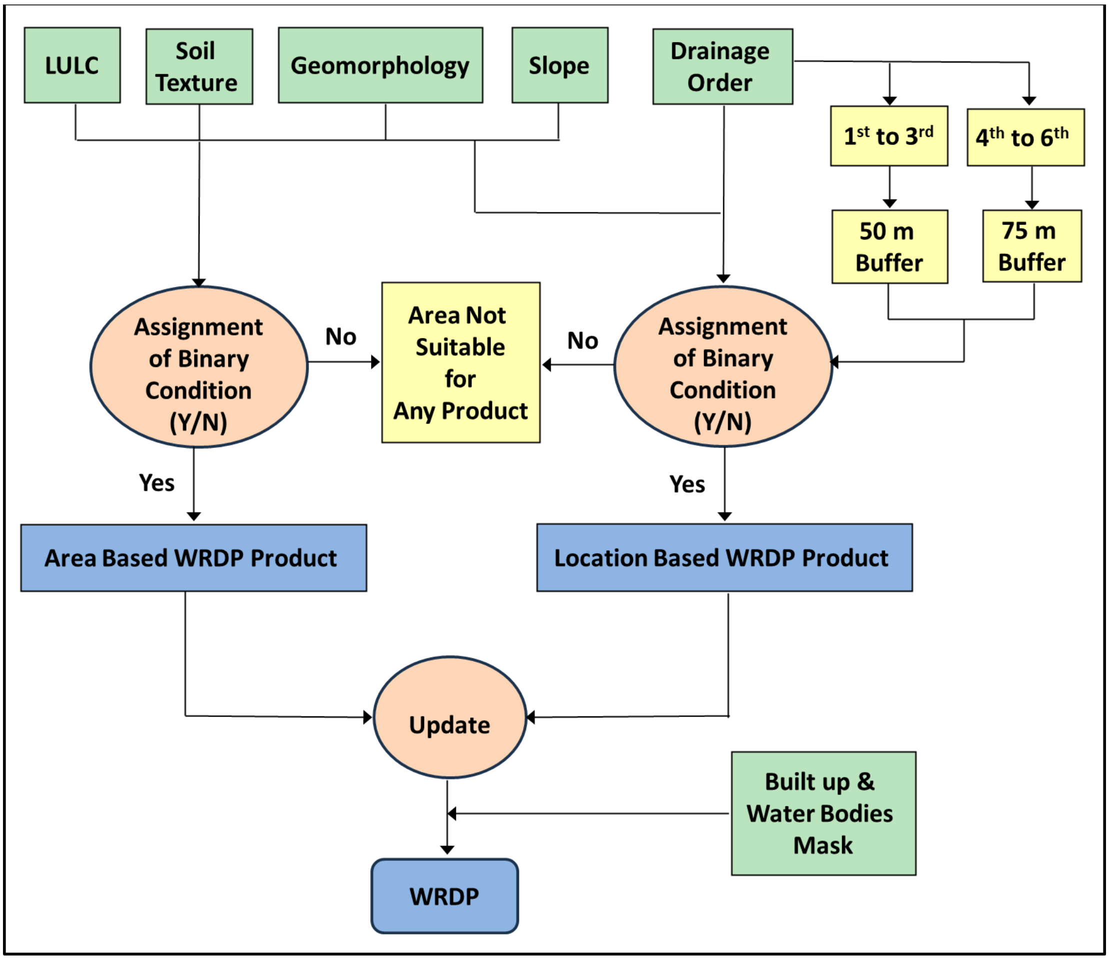

Fig. 6 Methodology Flowchart for Generation of WRDP.

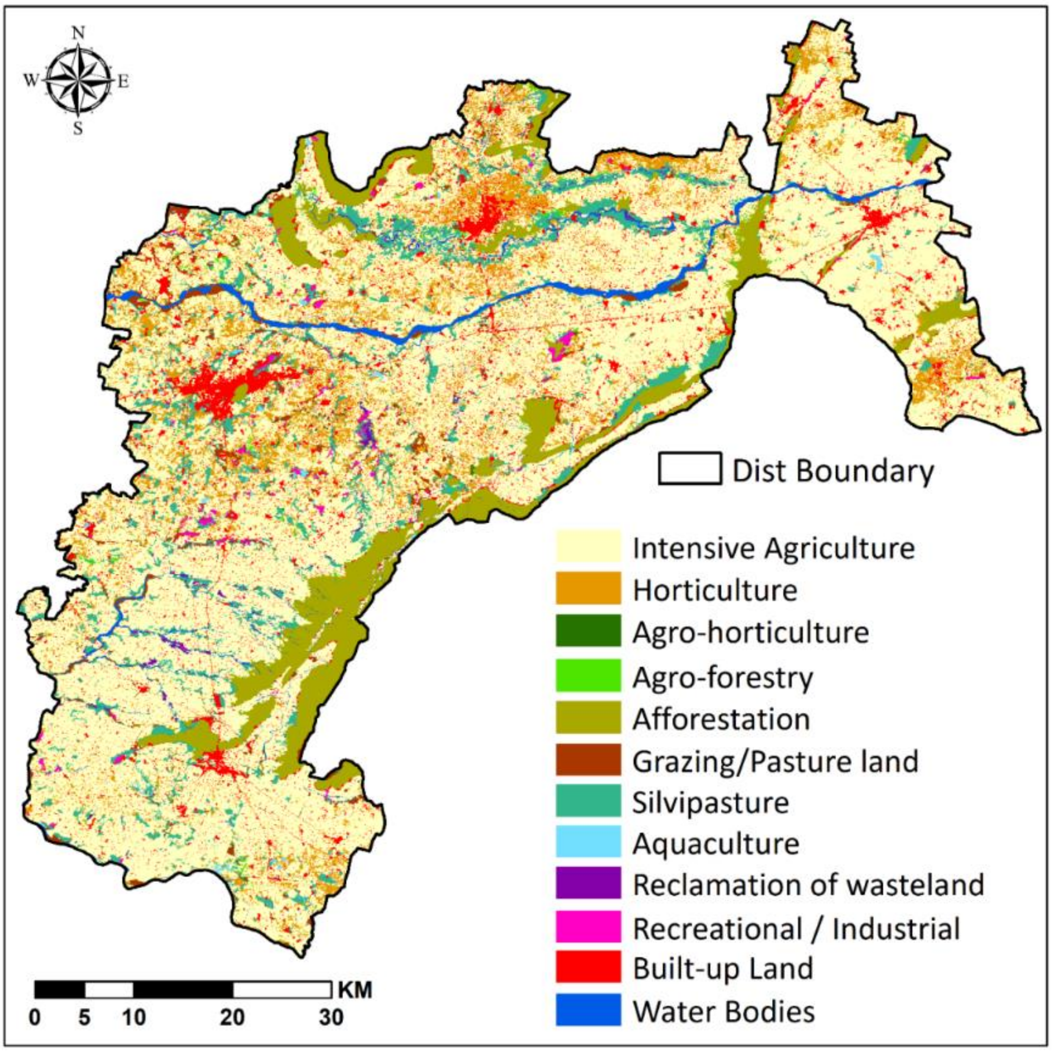

Fig. 7 LRDP for Dausa District of Rajasthan**.**

Table 2 Area Statistics of LRDP for Dausa District of Rajasthan.

LRDP Class	**Area (km²)**	**Area (%)**
Intensive agriculture	2124.5	62.16
Agro-horticulture	4.50	0.13
Agro-forestry	18.22	0.53
Horticulture	339.10	9.92
Silvipasture	225.20	6.59
Grazing/pasture land	71.53	2.09
Afforestation	303.21	8.88
Reclamation of wasteland	8.15	0.24
Aquaculture	13.60	0.40
Recreational or industrial	21.65	0.63
Built-up lands	223.79	6.55
Water bodies	64.32	1.88
Total area	**3417.77**	**100**

Water Resources Development Plan (WRDP): The WRDP for the Dausa district of Rajasthan and its area statistics are presented in Fig. 8 and Table 3. The plan prioritizes areas with different water management structures based on suitability and potential impact. Among the suggested WRDP products, earthen contour bunds and percolation tanks emerge as the most prominent intervention, covering 57.89% and 23.61% of the total area, respectively. These structures can effectively capture rainwater runoff and promote groundwater recharge, making them ideal for maximizing water availability in hilly or undulating terrains. Among the other WRDP suggested, about 1.54% of the total area is occupied by contour trenches, farm ponds, gabion structures, loose boulder check dams/gully plugs, and minor irrigation tanks. Farm ponds offer individual farmers a readily accessible water source for irrigation and other agricultural needs, boosting their productive capacity and resilience. Gabion structures and loose boulder check dams/gully plugs help to control soil erosion and mitigate gully formation. These structures are significant in the areas vulnerable to water-induced land degradation. Contour trenches and minor irrigation tanks are micro-level interventions that will help to optimize water use efficiency and minimize water losses on agricultural lands. Additionally, 8.53% of the total area was found to be unsuitable for any WRDP activity. These areas may require further investigation or may not be deemed high-priority for current interventions

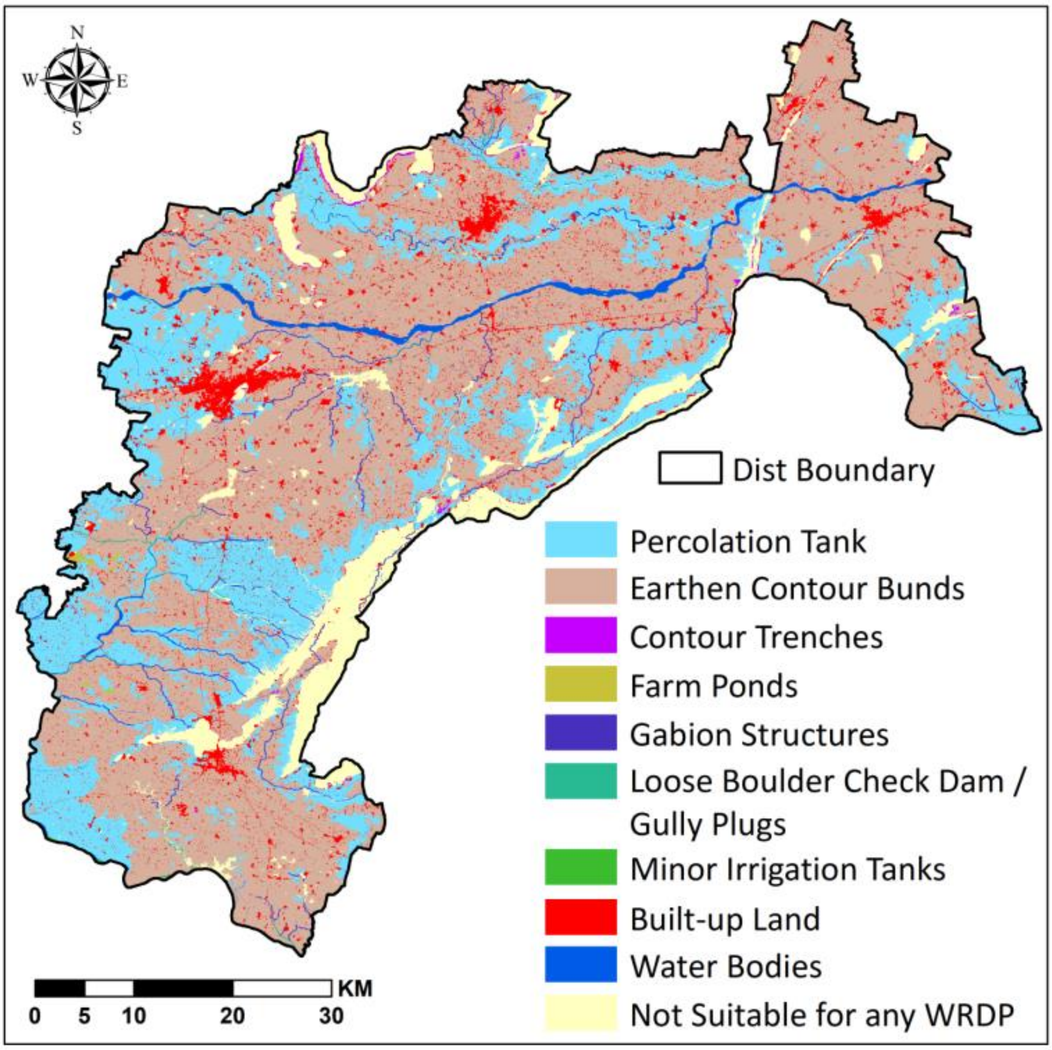

Fig. 8 WRDP for Dausa District of Rajasthan.

Table 3 Area Statistics of WRDP for Dausa District of Rajasthan.

WRDP Class	Area (km^2)	Area (%)
Contour trenches	13.52	0.4
Earthen contour bunds	1978.32	57.89
Percolation tanks	806.98	23.61
Farm ponds	2.78	0.08
Loose boulders check dams/gully plugs	8.72	0.26
Gabion structures	26.68	0.78
Minor irrigation tanks	0.95	0.02
Built-up lands	223.79	6.55
Water bodies	64.32	1.88
Area not suitable for any WRDP	291.71	8.53
Total area	**3417.77**	**100**

Conclusions

Land degradation and water scarcity are the major problems in the arid and semi-arid regions. Therefore, land use planning and effective water resource management are crucial for sustainable development. The present study demonstrates the generation of LRDP and WRDP for the Dausa district of Rajasthan using geospatial techniques and utilizing thematic layers generated using remote sensing and other ancillary data. Due to the presence of suitable ground water potential along with existing agricultural land, 0-3% slope with land capability class II and pediplain geomorphology, for the significant parts of the Dausa district, intensive agriculture is suggested as the most suitable LRDP and earthen contour bund and percolation tank are suggested as the most suitable WRDP.

The suggested LRDP provides a promising picture of the district's future by strategically utilizing its resources and addressing its specific needs. By prioritizing agricultural expansion, embracing horticultural opportunities, promoting afforestation, and exploring promising sectors like aquaculture and recreation/industry, the LRDP presents a roadmap for sustainable growth and development in the years to come. The WRDP's strength lies in its multifaceted approach. By employing a range of interventions to specific land characteristics and needs, it strives to create a resilient water infrastructure that caters to both large-scale and individual requirements. From empowering farmers with farm ponds to safeguarding the land with gabion structures, the WRDP captures a hopeful picture for the district's water future, promising enhanced water security and sustainable community development. The proposed LRDP and WRDP will act as cost-effective methods for planners to combat land degradation and water-related issues in the study area. An integrated land and water resources management/development approach with watershed as a unit is suggested for further research/planning.

Acknowledgments

The authors acknowledge the Director, NRSC, ISRO, Hyderabad, and the CGM RCs, NRSC, ISRO, Hyderabad, for their keen interest, encouragement, and support in the present study. We are grateful to Dr. A. K. Bera, General Manager, RRSC-W, NRSC, ISRO, Jodhpur, for valuable suggestions and support for the work. We are thankful to all the organizations that have provided different datasets used in the present study. Sincere thanks are also to all the SISDP project team members of NRSC, ISRO, Hyderabad for their suggestions and recommendations. All the employees of the RRSC-W, Jodhpur, deserve our gratitude for their help throughout this endeavor.

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Citation

Salunkhe, S.S., Roy, S., Pathak, S., Paliwal, R. (2024). Geospatial Approach for Land and Water Resource Development Planning for Dausa District of Rajasthan. In: Dandabathula, G., Bera, A.K., Rao, S.S., Srivastav, S.K. (Eds.), Proceedings of the 43rd INCA International Conference, Jodhpur, 06–08 November 2023, pp. 598–612, ISBN 978-93-341-2277-0.