

Impact of Indira Gandhi Nahar Pariyojana on Land Use and Land Cover: A Nine-Fold Classification Analysis of Bikaner District, Rajasthan

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Abstract

Land use and land cover (LULC) change is a critical indicator of environmental transformation, particularly in hot arid regions where fragile ecosystems are highly sensitive to human interventions. This study examines long-term land use and land cover dynamics in Bikaner district of western Rajasthan, with a specific focus on category-wise changes over seven time periods ranging from 1978-81 to 2019-22. Using the nine-fold land use classification system employed in Indian land revenue records, the study examines spatial and temporal variations across the four tahsils - Bikaner, Lunkaransar, Kolayat, and Nokha - to evaluate the impact of canal irrigation, particularly the Indira Gandhi Nahar Pariyojana (IGNP), on land-use patterns. The results reveal significant irrigation-led transformations in the land-use structure of the district. A substantial decline in culturable wasteland and barren land is observed across all tahsils, accompanied by a marked expansion of net sown area, particularly in Bikaner, Lunkaransar, and Kolayat tahsils that directly benefit from canal irrigation. Forest cover, although limited due to arid climatic constraints, shows a gradual increase, reflecting afforestation efforts and improved moisture availability. Land put to non-agricultural uses has expanded steadily, indicating growing infrastructural development and urbanization, especially in Lunkaransar tahsil. Conversely, permanent pastures and grazing lands have generally declined, highlighting increasing pressure on pastoral resources. Nokha tahsil, despite having the highest proportion of net sown area, exhibits relatively stagnant agricultural growth due to limited canal access. The time-period average analysis underscores pronounced intra-district contrasts in LULC patterns, emphasizing uneven irrigation reach and differential development trajectories. Overall, the study highlights the transformative role of canal irrigation in optimizing land use and enhancing agricultural expansion in an arid environment, while underscoring the need for balanced, tahsil-specific land management strategies to ensure ecological sustainability and inclusive regional development.

1. Introduction:

A detailed and systematic classification of land use is fundamental for understanding the utilization, transformation, and management of land resources, particularly in environmentally fragile arid and semi-arid regions. The nine-fold land use classification system, encompassing categories such as net sown area, fallow land, culturable wasteland, permanent pastures, forests, land put to non-agricultural uses,

barren and culturable waste land, and water bodies, provides a comprehensive framework to examine the structural dynamics of land utilization. In arid districts like Bikaner, where ecological constraints are severe and irrigation-led development has significantly altered traditional land-use patterns, such category-wise analysis becomes essential for assessing sustainability and planning future land management strategies.

Several studies have highlighted the transformative role of irrigation and technological interventions in reshaping land use in arid and semi-arid regions of India. Srivastava et al. (1991), in their assessment of the Tawa command area of Madhya Pradesh, observed significant post-irrigation shifts in cropping patterns accompanied by forest decline, expansion of fallow land, and diversification towards commercial crops such as soybean, cotton, and oilseeds. Similarly, Ram and Chauhan (2008) documented profound land-use changes in Jaisalmer district between 1980 and 2006, marked by a dramatic expansion of irrigated area, reduction of wastelands, increased plantation activity, and rapid growth of permanent pastures, mining areas, settlements, and water bodies. However, this transformation also led to substantial loss of natural grasslands, notably the decline of *Lasiurus sindicus* (Sewan) grasslands, reflecting ecological trade-offs associated with irrigation expansion.

In western Rajasthan, the introduction and expansion of the Indira Gandhi Nahar Pariyojana (IGNP) have been the most significant drivers of land-use change. Narain et al. (2000) reported that the introduction of canal irrigation significantly reduced wind erosion in sandy interdunal plains through land stabilization under crops and the expansion of double cropping practices. Compared to the pre-canal period of the 1950s, the net sown area increased considerably, while the area sown more than once recorded an extraordinary rise, largely attributable to the IGNP network in districts such as Ganganagar, Bikaner, and Jaisalmer. The availability of canal water, supplemented by groundwater irrigation, facilitated the conversion of long fallow lands, grazing areas, and even rocky and gravelly wastelands into irrigated croplands.

Historically, Bikaner district was characterized by rainfed agriculture, extensive grazing lands, sandy wastelands, and scattered rural settlements, shaped by low and erratic rainfall, frequent droughts, and reliance on pastoral livelihoods. The commissioning of the Bikaner (Gang) Canal in 1927 and the subsequent expansion of the IGNP marked a decisive shift in the region's land-use structure by introducing perennial Himalayan water into the desert ecosystem. This transformation was further accelerated during the mid-1970s under the influence of the Green Revolution, which brought improved irrigation infrastructure, high-yielding varieties, chemical fertilizers, mechanization, rural electrification, and enhanced market connectivity. As a result, net sown area and cropping intensity increased sharply, while fallow lands, permanent pastures, and sandy wastelands declined. Advanced land-levelling techniques and deep ploughing enabled even marginal lands with thin sediment cover to be brought under cultivation (Kar, 2014).

Despite the developmental benefits of canal irrigation, the transformation of land use has also generated serious environmental concerns. Waterlogging, soil salinization, depletion of native vegetation, and reduction of grazing resources have emerged as critical issues in several canal command areas. Simultaneously, the expansion of non-agricultural land uses, including settlements, transport networks, canals, and public utilities, has further altered the land-use composition at local levels. Although previous studies have documented regional-scale land-use changes in western Rajasthan, there remains a significant gap in understanding category-wise land-use dynamics at the tahsil level. A nine-fold land-use analysis at this scale allows for a more nuanced assessment of how individual land categories have

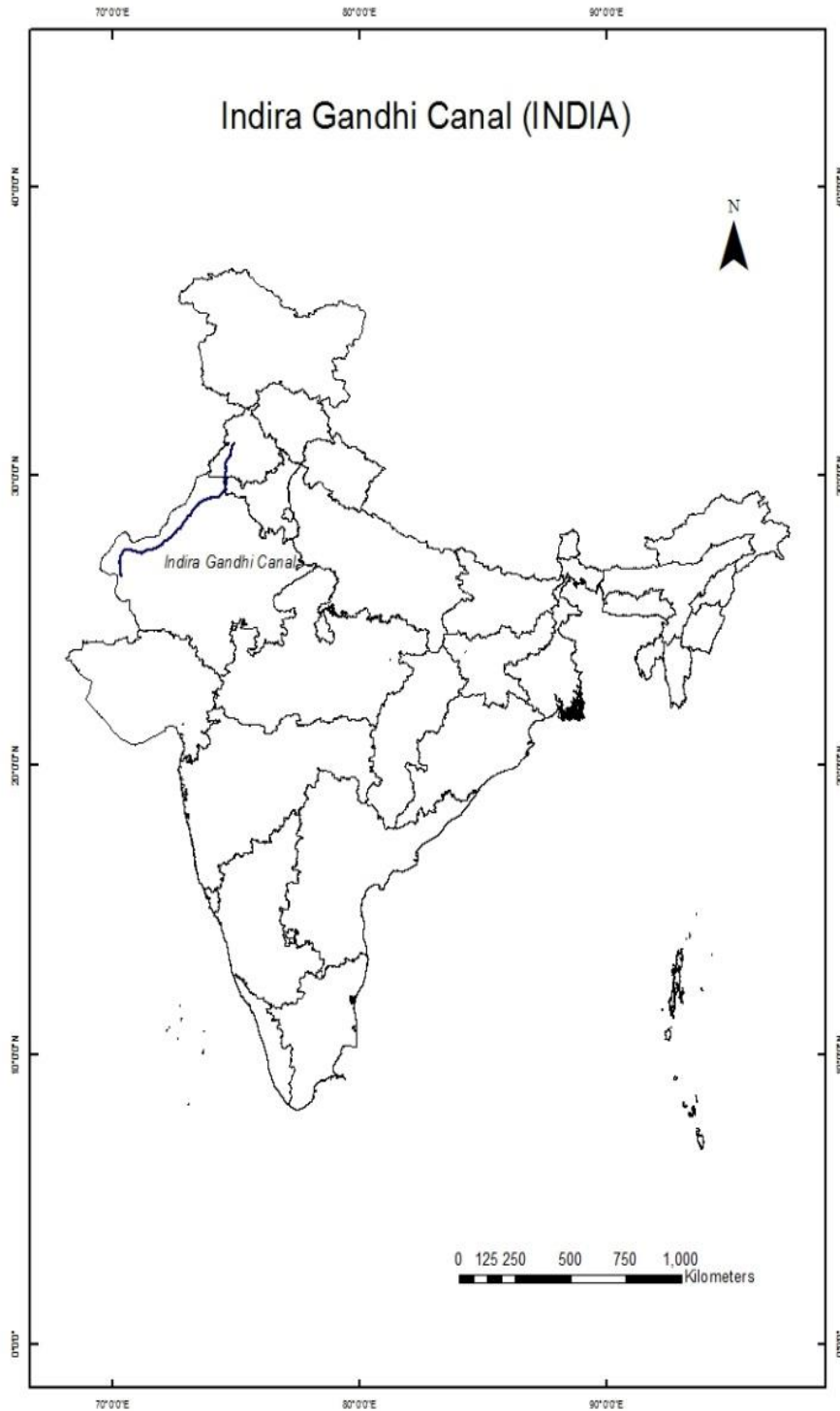
expanded or contracted under varying degrees of irrigation access and development pressure. Against this backdrop, the present study undertakes a tahsil-wise analysis of nine land-use categories in Bikaner district to evaluate structural changes in land utilization and to assess their implications for environmental sustainability and land-use planning in a hot arid desert environment.

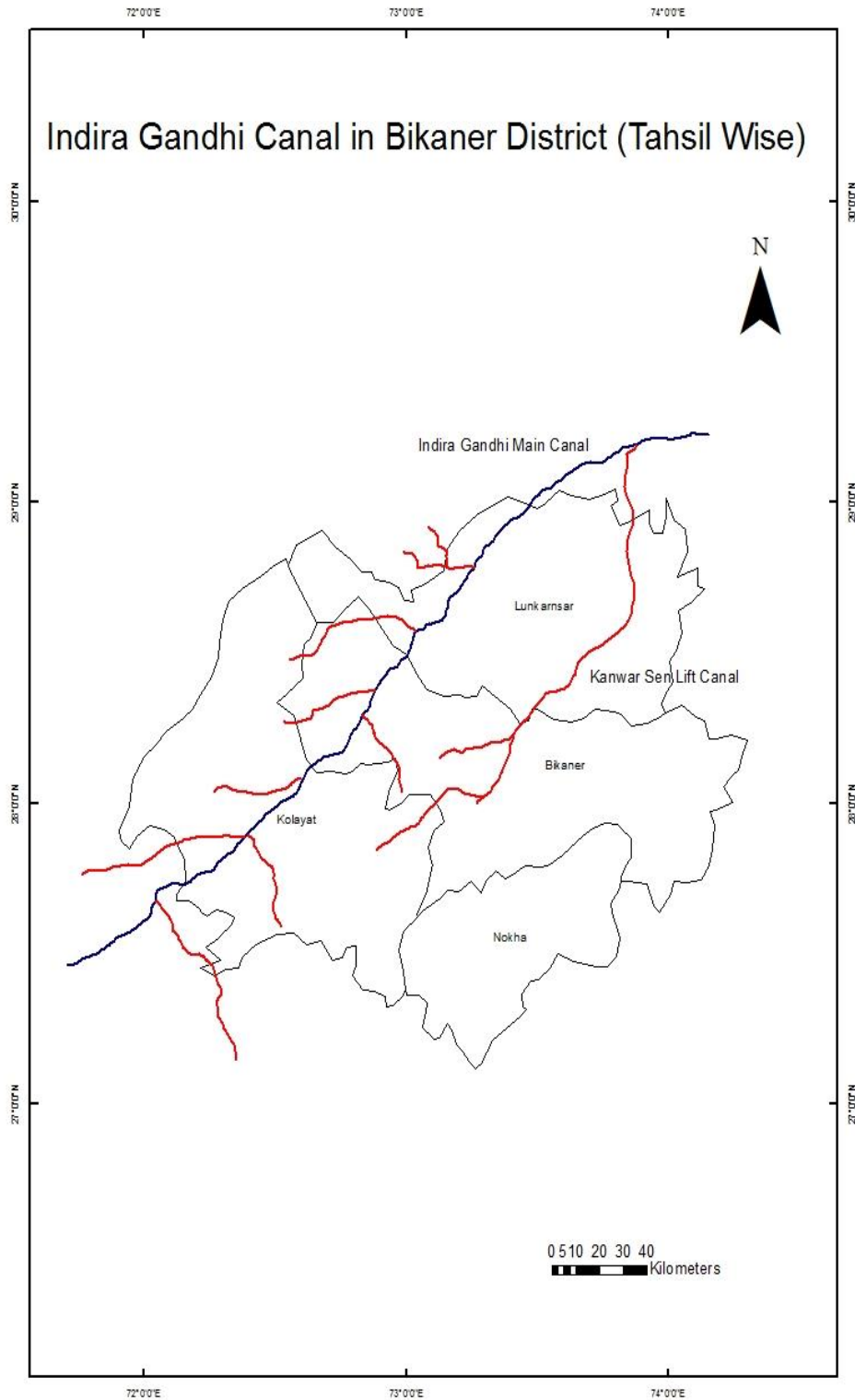
2. Study Area:

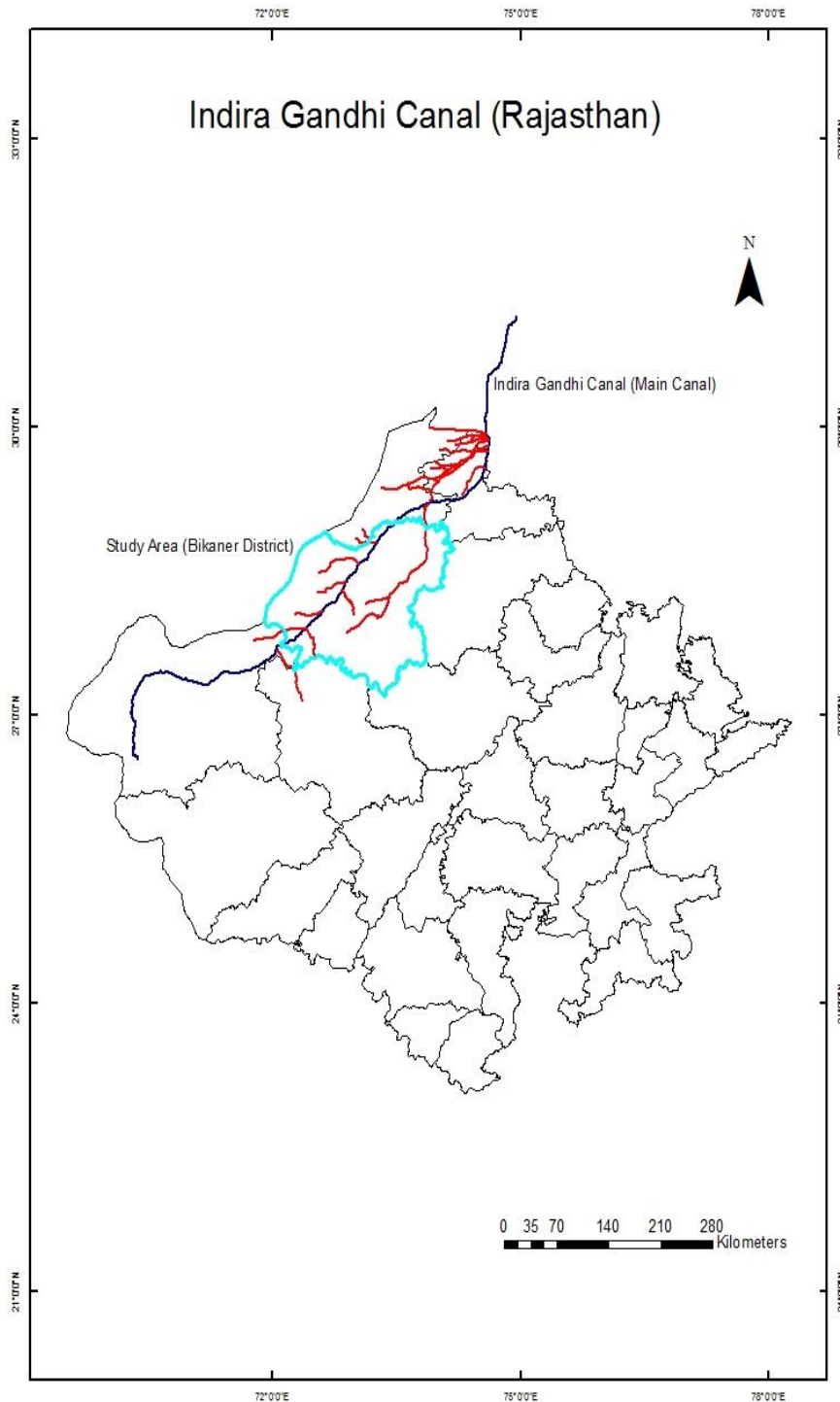
Bikaner district is situated in the north-western part of Rajasthan and covers an area of approximately 27,232 sq. km., geographically, it extends between 27°11' and 29°03' North latitudes and 71°54' and 74°12' East longitudes. The district shares an international boundary with Pakistan to the west, while Sri Ganganagar lies to the north, Churu to the east, and Nagaur, Jodhpur, and Jaisalmer districts to the south. Located within the Thar Desert, Bikaner forms an integral part of India's arid agro-ecological region and is characterized by low and erratic rainfall, sandy terrain, and fragile environmental conditions.

At the inception of the Indira Gandhi Nahar Pariyojana (IGNP), Bikaner district comprised four tahsils - Bikaner, Lunkaransar, Kolayat, and Nokha. However, significant administrative reorganization occurred between 1991 and 2001. During this period, Pugal and Khajuwala tahsils were carved out from Bikaner tahsil, while Chattergarh tahsil was formed through the reallocation of villages from both Bikaner and Lunkaransar tahsils. Further expansion took place on 1 April 2001 with the transfer of Sri Dungegarh tahsil from Churu district. Consequently, the district consisted of eight tahsils at the time of the present study.

Bikaner is a major beneficiary of canal irrigation under the IGNP. The main canal enters the district north of Bhansar village, traverses its central parts, and exits near Goglialo village in the south. Additionally, parts of Bikaner and Lunkaransar tahsils receive irrigation through the Kanwar Sain Lift Canal. Introduced in 1971-72, canal irrigation marked a decisive shift in the district's land-use patterns and agricultural practices. The present study analyses land use and land cover dynamics on a tahsil-wise basis using statistical and spatial data to capture intra-district variations. The spatial extent and administrative divisions of the study area are illustrated in Maps no. 1, 2, and 3.







Maps no. 1, 2 & 3: Indira Gandhi Canal and its distributaries at three scales: India, Rajasthan, and Bikaner district (the study area)

3. Materials and Methods:

The present study investigates the impact of the Indira Gandhi Nahar Pariyojana (IGNP) on land use and land cover (LULC) dynamics in Bikaner district, western Rajasthan, with particular emphasis on tahsil-wise variations across nine-fold land-use categories. The methodological framework is designed to systematically identify, quantify, and compare long-term changes in major land-use classes following the introduction and expansion of canal irrigation. Emphasis is placed on capturing structural transformations in land use driven by irrigation development, demographic pressure, and agrarian change within a hot arid environment. The study is primarily based on secondary data obtained from official government sources. Tahsil-wise land-use statistics for the period 1978-2022 were compiled from land revenue records published in the District Statistical Outline, Bikaner. Conceptual and classification guidelines for land-use categories were adopted from the Land Use - Land Cover Project Manual of the National Remote Sensing Centre (NRSC). Supplementary spatial reference information was derived from Survey of India and NATMO sources, including physical, administrative, and agro-climatic maps of the district. Historical and institutional perspectives on the development of canal irrigation were drawn from the Handbook on the History of the Indira Gandhi Nahar Project issued by the Command Area Development Authority, Government of Rajasthan.

To maintain temporal consistency and analytical comparability, the analysis is confined to the four original tahsils - Bikaner, Lunkaransar, Nokha, and Kolayat - that existed at the time of canal introduction. The study period is divided into seven phases, each represented by a three-year average (1978-81, 1985-88, 1992-95, 1999-02, 2006-09, 2013-16, and 2019-22) to minimize annual fluctuations and reporting inconsistencies. Land-use analysis follows the standard nine-fold classification used in Indian land revenue records. The analysis follows the standard nine-fold land use classification system widely employed in Indian land revenue records. These categories together constitute the reporting area, which may differ marginally from the geographical area as measured by the Survey of India due to variations in reporting practices and administrative definitions. The land use categories analysed in the study include forests; land put to non-agricultural uses; barren and wastelands; permanent pastures and grazing lands; land under miscellaneous tree crops and groves (excluding net sown area); culturable wasteland; current fallow; fallow land other than current fallow; and net sown area. Nine fold classification data were analysed using descriptive statistical techniques to assess absolute and relative changes, identify temporal trends, and examine spatial variations in irrigation-induced land-use transformation across the district.

4. Results and discussion:

A. Land Use and Land Cover changes over time (Category-wise): This section presents a category-wise analysis of land use and land cover changes across the nine land-use classes in the four tahsils of Bikaner district over the study period. The intra-tahsil approach enables a detailed assessment of temporal variations and spatial differences in individual land-use categories, thereby facilitating a clearer understanding of the impact of canal irrigation on land-use dynamics. By examining changes across successive time phases, the analysis highlights the extent to which irrigation-led development has reshaped agricultural, ecological, and non-agricultural land-use patterns within the district.

I. Forest Cover: Bikaner district, located in the western part of Rajasthan, historically exhibits a very low proportion of forest cover due to its harsh arid climatic conditions. The region is characterized by high temperatures, low and highly erratic rainfall, persistent anti-cyclonic conditions, low humidity, and

frequent wind activity, all of which severely constrain natural vegetation growth. Consequently, prior to the introduction of canal irrigation, forest cover in the district was minimal across all tahsils. The introduction of the Indira Gandhi Nahar Pariyojana (IGNP) marked a significant shift in land-use dynamics, including gradual improvement in forest cover over time. Enhanced water availability, coupled with targeted interventions such as afforestation programmes, dune stabilization measures, and initiatives aimed at controlling land degradation, contributed to this positive trend. An increase in forest area is observed across all four tahsils during the study period, with notable spatial variation.

Bikaner tahsil recorded the most pronounced improvement in forest cover, reflecting its relatively greater access to canal irrigation and plantation initiatives (Figure 1). Lunkaransar and Kolayat tahsils also registered moderate increases in forest area over the years. In contrast, Nokha tahsil experienced only a marginal rise in forest cover, primarily due to the limited spatial outreach of the IGNP within the tahsil. In absolute terms, Bikaner tahsil consistently accounted for the largest share of forest area in the district. Forest cover in this tahsil increased substantially from 26,470 hectares during 1978-81 to 75,497 hectares in 2019-22 (Table 1). It was followed by Lunkaransar, Kolayat, and Nokha tahsils, highlighting the differentiated impact of canal irrigation and associated land management interventions on forest expansion across the district.

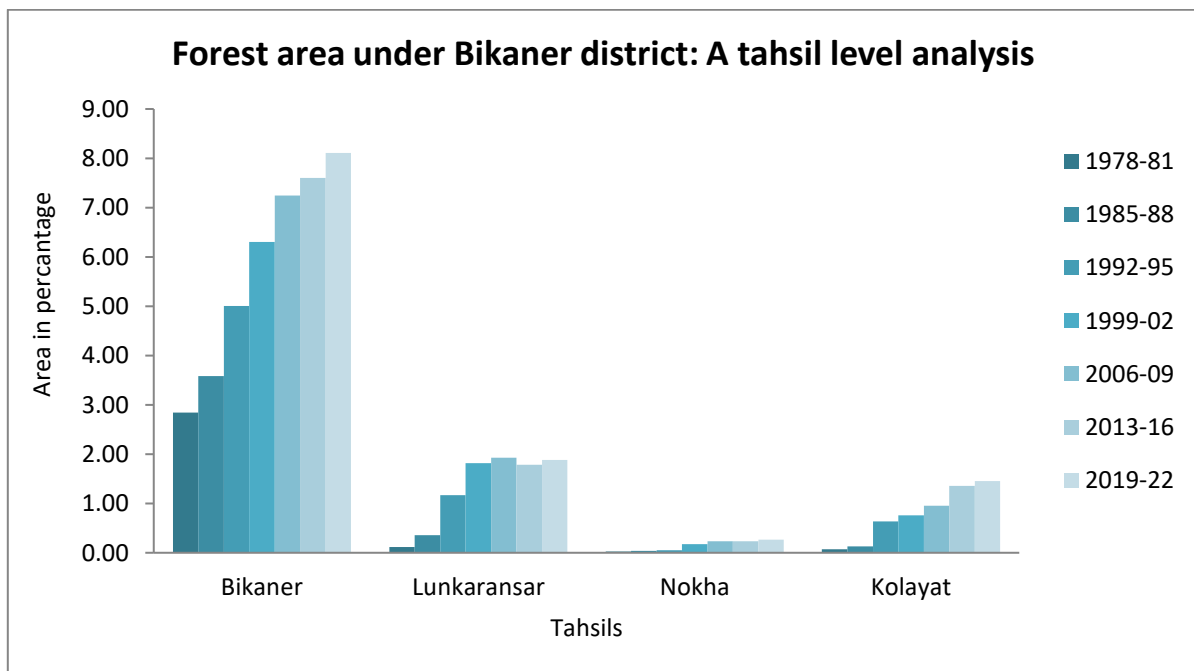


Figure no. 1: Forest area under Bikaner district (tahsil wise analysis)

(Source: District statistical outline, Bikaner district)

Table no. 1: Forest area under Bikaner district (tahsil wise analysis)

(Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	26470	752	105	572
1985-88	33327	2264	137	1026
1992-95	46548	7444	186	5046
1999-02	58668	11590	652	6029
2006-09	67383	12306	894	7586

2013-16	70744	11381	896	10780
2019-22	75497	12008	1012	11571

(Source: District statistical outline, Bikaner district)

II. Land Put to Non-Agricultural Uses: This category includes land occupied by built-up areas, settlements, transportation networks, canal infrastructure, and other non-agricultural activities. In Bikaner district, land put to non-agricultural uses has shown a consistent increase across all tahsils during the study period, reflecting the broader process of irrigation-led development and infrastructural expansion. Among the four tahsils, Lunkaransar recorded the most pronounced growth in non-agricultural land use over time (Figure 2). This substantial increase can be attributed to the expansion of settlement areas, development of canal command-related infrastructure, and the presence of defence-related establishments. In contrast, Bikaner, Kolayat, and Nokha tahsils exhibited a relatively slower but steady rise in this category, indicating gradual urbanization and infrastructural development.

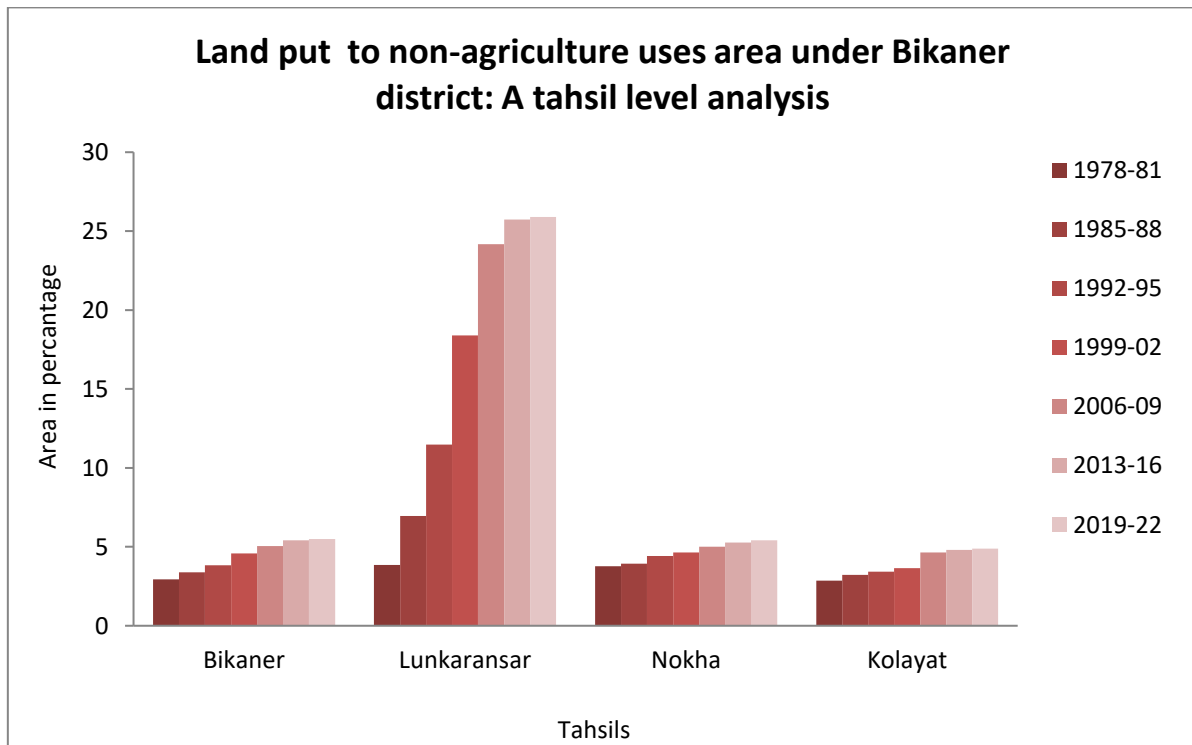


Figure no. 2: Land put to non agriculture uses area in Bikaner district (tahsil wise analysis)
 (Source: District statistical outline, Bikaner district)

In absolute terms, Lunkaransar consistently accounted for the largest area under non-agricultural uses among the four tahsils. The area under this category in Lunkaransar increased markedly from 24,532 hectares during 1978-81 to 165,197 hectares in 2019-22 (Table 2). It was followed by Bikaner, Kolayat, and Nokha tahsils, respectively. The observed trends highlight the spatially uneven impact of canal irrigation and associated development activities on non-agricultural land expansion within Bikaner district.

**Table no. 2: Land put to non agriculture uses area in Bikaner district (tahsil wise analysis)
(Area in hectares)**

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	27264	24532	14290	22648
1985-88	31441	44378	14936	25595
1992-95	35734	73091	16758	27161
1999-02	42651	117172	17577	29060
2006-09	47010	154167	18991	36946
2013-16	50351	164149	20018	38105
2019-22	51161	165197	20512	38791

(Source: District statistical outline, Bikaner district)

III. Barren and Wasteland: Barren and wasteland constituted a significant component of the land-use structure in parts of Bikaner district, particularly in Kolayat tahsil, which historically recorded the highest proportion under this category. Over the study period, however, a clear declining trend is observed across all four tahsils, indicating progressive land reclamation and conversion to other land-use categories. In Kolayat tahsil, the proportion of barren and wasteland peaked during 1999-02, accounting for about 4.35 per cent of the reporting area (34,570 hectares) (Figure 3), after which a steady decline is evident. Similar downward trends are observed in the remaining tahsils, with the most pronounced reduction recorded in Bikaner tahsil. The decline in this category can be attributed to various reclamation measures, including irrigation expansion, land levelling, soil improvement practices, and the diversion of reclaimed land to agricultural and plantation uses.

Nokha tahsil consistently recorded a very marginal extent of barren and wasteland, declining to as low as 20 hectares by 2019-22 (Table 3), reflecting limited availability of such land and effective utilization of existing land resources. In absolute terms for 2019-22, Kolayat tahsil continued to account for the largest area under barren and wasteland (15,104 hectares), followed by Bikaner and Lunkaransar, while Nokha recorded the least. The observed reduction across tahsils highlights the role of canal irrigation and land development initiatives in reducing unproductive land and reshaping the land-use structure of the district.

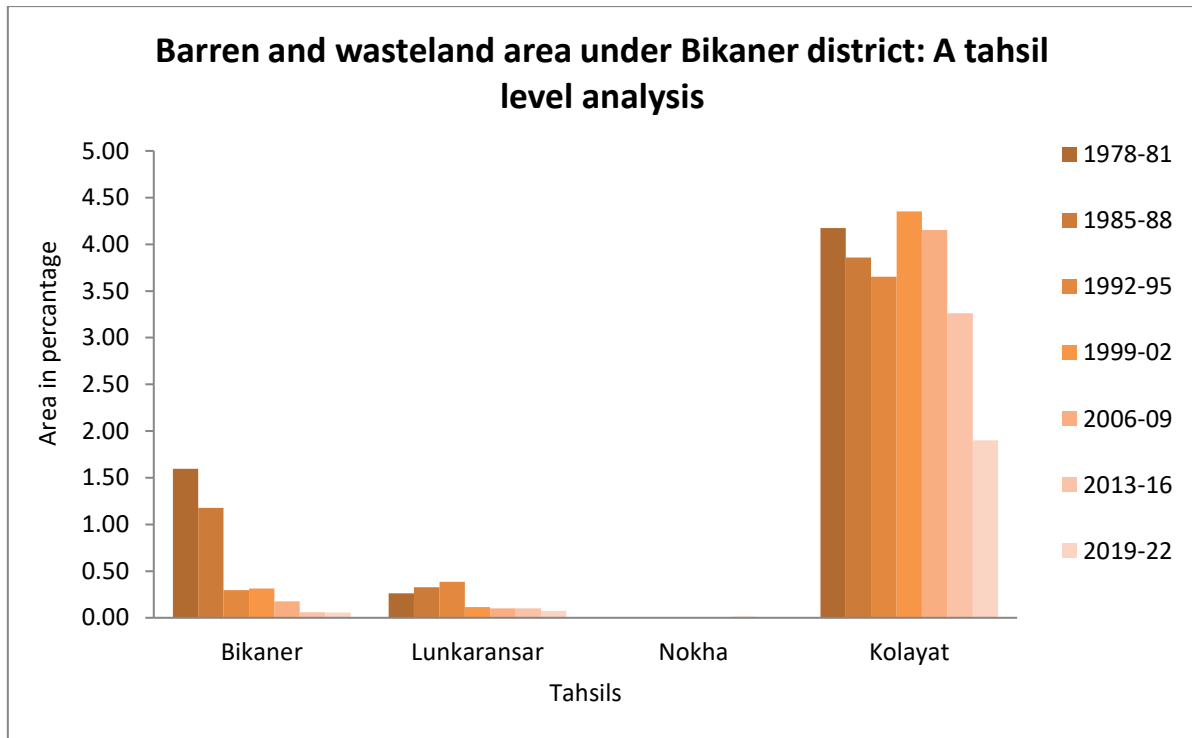


Figure no. 3: Barren and wasteland area in Bikaner district (tahsil wise analysis)
(Source: District statistical outline, Bikaner district)

Table no. 3: Barren and wasteland area in Bikaner district (tahsil wise analysis)
(Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	14843	1675	33	33177
1985-88	10957	2087	6	30646
1992-95	2771	2448	14	29039
1999-02	2917	732	14	34570
2006-09	1639	636	23	32995
2013-16	570	639	41	25918
2019-22	531	459	20	15104

(Source: District statistical outline, Bikaner district)

IV. Area under Permanent Pastures and Grazing Lands:

Permanent pastures and grazing lands have historically played a crucial role in supporting pastoral livelihoods in the arid environment of Bikaner district. However, the extent of this land-use category has undergone notable temporal variations across the tahsils during the study period, largely influenced by irrigation expansion and changing land-use priorities. In the initial phase, Lunkaransar tahsil recorded the highest area under permanent pastures and grazing lands, amounting to 22,377 hectares during 1978-81 (Table 4). Subsequently, a declining trend is observed over successive periods, although a marginal recovery is evident in the more recent phases (Figure 4). Bikaner and Kolayat tahsils exhibited relatively lower pasture areas in the early years, followed by increases reaching peak levels during 1992-95 and 2006-09, respectively. Thereafter, both tahsils experienced a decline, reflecting the gradual conversion of grazing lands to agricultural and other land uses.

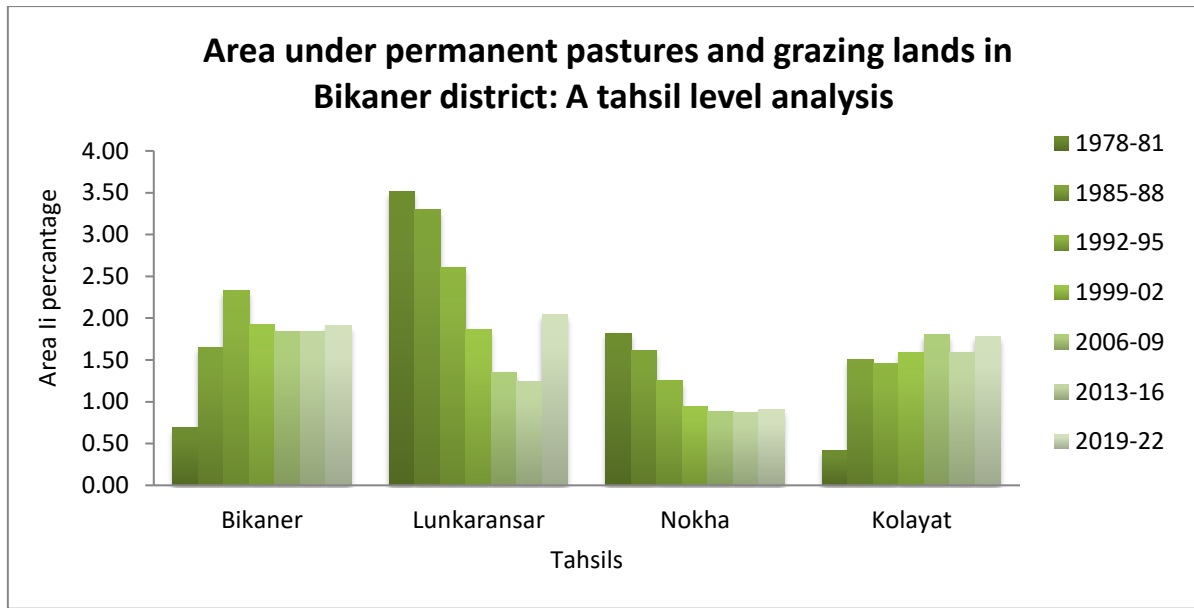


Figure no. 4: Area under permanent pastures and grazing lands in Bikaner district (tahsil wise analysis)

(Source: District statistical outline, Bikaner district)

Table no. 4 Area under permanent pastures and grazing lands in Bikaner district (tahsil wise analysis)

(Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	6417	22377	6910	3304
1985-88	15362	21044	6129	11947
1992-95	21649	16637	4752	11595
1999-02	17864	11848	3589	12669
2006-09	17071	8619	3338	14297
2013-16	17172	7931	3300	12667
2019-22	17822	13013	3432	14124

(Source: District statistical outline, Bikaner district)

In contrast, Nokha tahsil shows a consistent reduction in permanent pastures and grazing lands throughout the study period, indicating sustained pressure on traditional grazing resources. In absolute terms, during 2019-22, Bikaner tahsil accounted for the largest area under this category (17,822 hectares), followed by Kolayat (14,124 hectares) and Lunkaransar (13,013 hectares), while Nokha recorded the lowest extent (3,432 hectares). Overall, the observed trends underscore the declining availability of grazing lands in the district, highlighting the trade-offs between irrigation-led agricultural expansion and the sustainability of pastoral land-use systems.

V. Area under Miscellaneous Tree Crops and Groves:

The area under miscellaneous tree crops and groves constitutes a very small and insignificant component of the overall land-use structure of Bikaner district. Throughout the study period, this category remained negligible across most tahsils, reflecting the limited suitability of arid climatic conditions for tree-based land uses and the preference for agricultural or other economically viable land-use options. Among the

four tahsils, Bikaner consistently recorded the highest area under this category, although its share remained marginal. The maximum extent was observed during 1992-95, when miscellaneous tree crops and groves accounted for about 0.05 per cent of the reporting area, equivalent to 423 hectares (Figure 5; Table 5). Kolayat and Lunkaransar tahsils exhibited only negligible areas under this category throughout the study period, while Nokha tahsil recorded no area under miscellaneous tree crops and groves in absolute terms across all years.

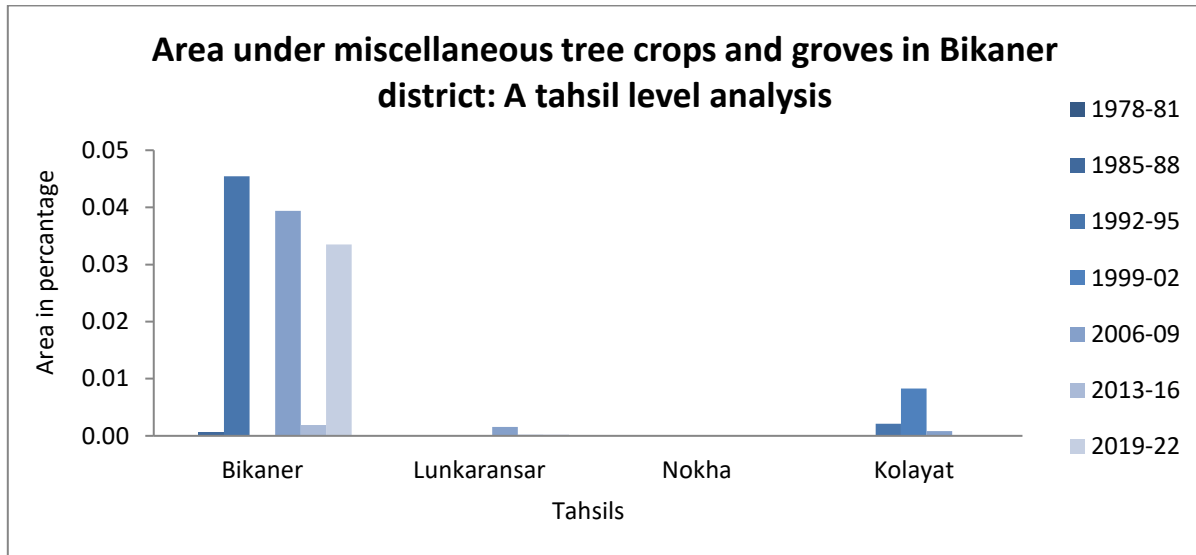


Figure no. 5: Area under miscellaneous tree crop and grooves in Bikaner district (tahsil wise analysis)

Table no. 5: Area under miscellaneous tree crop and grooves in Bikaner district (tahsil wise analysis) (Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	0	0	0	0
1985-88	6	0	0	0
1992-95	423	0	0	17
1999-02	0	0	0	66
2006-09	366	10	0	7
2013-16	18	1	0	0
2019-22	312	22	0	0

(Source: District statistical outline, Bikaner district)

In the most recent period (2019-22), Bikaner tahsil continued to dominate this category with 312 hectares, followed distantly by Lunkaransar with only 22 hectares, whereas Kolayat and Nokha tahsils recorded zero area. The limited and fluctuating extent of miscellaneous tree crops and groves suggests that such land uses are highly sensitive to economic choices, irrigation availability, and land-use priorities of the local population. In many cases, these lands appear to have been converted to agricultural or other land-use categories in response to changing livelihood strategies and development pressures.

VI. Culturable Wasteland:

Culturable wasteland has historically constituted one of the most extensive land-use categories in Bikaner district, reflecting the arid climatic conditions and limited agricultural suitability of large tracts of land prior to irrigation development. During the initial phase of the study (1978-81), a substantial proportion of land in Bikaner and Kolayat tahsils - nearly 60 per cent - was classified as culturable wasteland, while Lunkaransar accounted for about 44 per cent and Nokha for only 16 per cent of their respective reporting areas (Figure 6). Over the subsequent decades, a pronounced decline in culturable wasteland is evident across all four tahsils, indicating extensive land reclamation and conversion to other land-use categories. Lunkaransar experienced the most significant reduction, with an approximate decline of 80 per cent, followed by Nokha (70 per cent), Bikaner (62 per cent), and Kolayat (36 per cent). These changes largely reflect the expansion of canal and groundwater irrigation, improved land development practices, and the increasing incorporation of marginal lands into agricultural use.

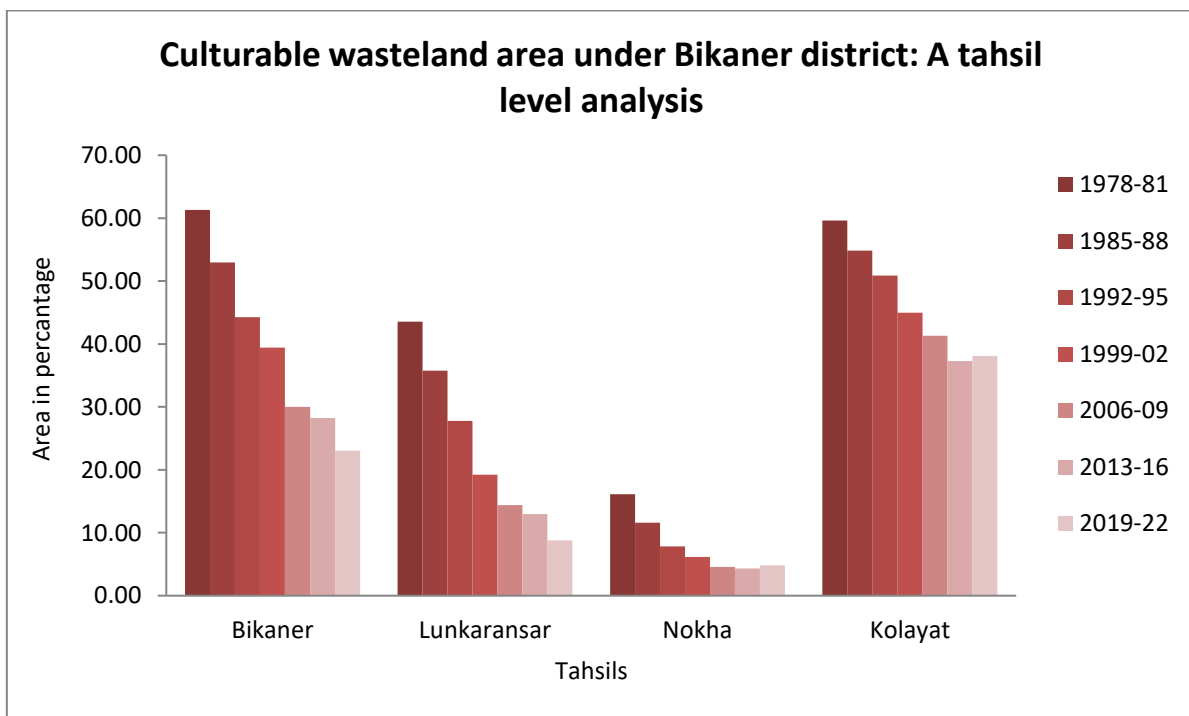


Figure no. 6: Culturable wasteland in Bikaner district (tahsil wise analysis)
 (Source: District statistical outline, Bikaner district)

Despite the overall declining trend, culturable wasteland continued to occupy a dominant position in Kolayat tahsil throughout the study period. In absolute terms during 2019-22, Kolayat recorded the largest area under culturable wasteland (302,746 hectares), followed by Bikaner (214,725 hectares), Lunkaransar (55,986 hectares), and Nokha (18,323 hectares) (Table 6). The persistence of large areas of culturable wasteland, particularly in Kolayat, underscores spatial variations in irrigation access and land development intensity within the district, highlighting the uneven impact of irrigation-led transformation on land-use structure.

Table no. 6: Culturable wasteland in Bikaner district (tahsil wise analysis)
(Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	570525	277464	61250	473784
1985-88	492746	228234	43956	435426
1992-95	411698	176988	29778	404340
1999-02	367155	122734	23318	357350
2006-09	279290	91864	17291	328015
2013-16	263012	82841	16468	296352
2019-22	214725	55986	18323	302746

(Source: District statistical outline, Bikaner district)

VII. Current Fallow and Fallow Other Than Current Fallow:

The combined category of current fallow and fallow land other than current fallow represents agricultural land that has remained uncultivated for periods ranging from one to five years. This category serves as an important indicator of land-use flexibility and reflects short- to medium-term responses to variations in water availability, cropping decisions, and agrarian conditions. During the initial phase of the study, Nokha tahsil recorded the highest proportion of fallow land, followed by Lunkaransar, Bikaner, and Kolayat (Figure 7). Over the study period, this category exhibited considerable temporal fluctuations across all tahsils, influenced by factors such as the reliability of canal irrigation, shifts in cropping patterns, and changing land-use priorities. Despite overall agricultural expansion, fallow land continued to occupy a notable share of the reporting area.

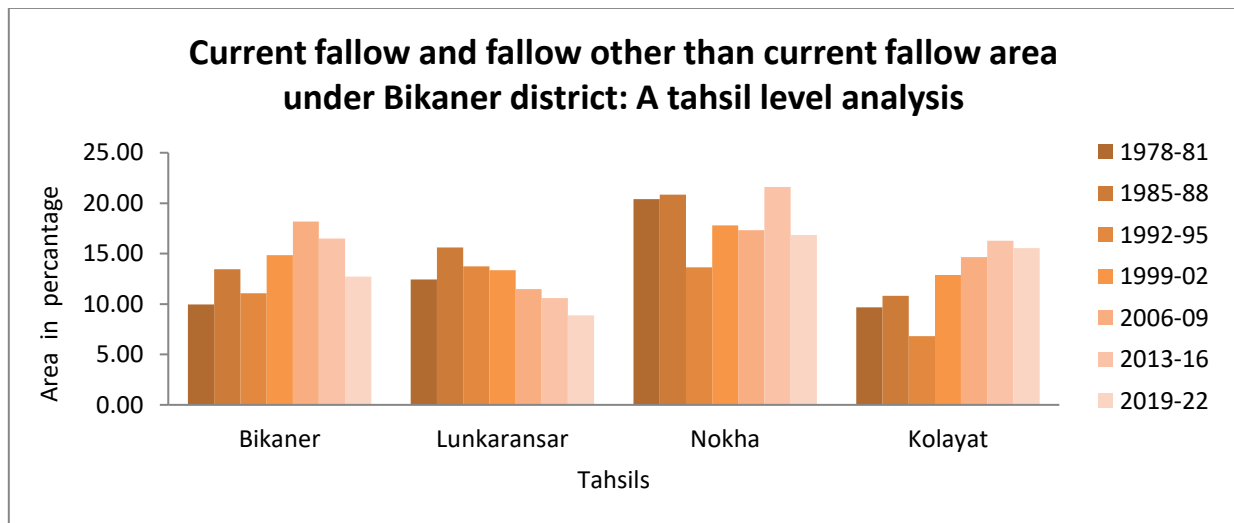


Figure no. 7: Current fallow and fallow other than current in Bikaner district (tahsil wise analysis)

(Source: District statistical outline, Bikaner district)

In the most recent period (2019-22), Nokha tahsil registered the highest proportion of fallow land at 16.85 per cent, followed by Kolayat (15.54 per cent), Bikaner (12.71 per cent), and Lunkaransar (8.89 per cent). In absolute terms, Kolayat accounted for the largest area under fallow land (123,414 hectares), followed by Bikaner (118,318 hectares), Nokha (63,953 hectares), and Lunkaransar (56,676 hectares) (Table 7). The persistence of substantial fallow areas indicates the continued influence of irrigation

constraints, soil conditions, and farm-level decision-making. However, these lands also represent a potential reserve for future agricultural expansion. With improved and reliable availability of canal water, along with supportive agronomic and institutional factors, a significant proportion of fallow land may be brought back under cultivation, thereby enhancing agricultural productivity in Bikaner district.

Table no. 7: Current fallow and fallow other than current in Bikaner district (tahsil wise analysis) (Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	92549	79269	77360	76815
1985-88	125204	99498	79019	85905
1992-95	102828	87475	51673	54165
1999-02	138115	85042	67407	102450
2006-09	169187	73272	65616	116444
2013-16	153683	67595	82025	129360
2019-22	118318	56676	63953	123414

(Source: District statistical outline, Bikaner district)

VIII. Net Area Sown:

Net area sown expanded steadily across all four tahsils of Bikaner district during the study period, underscoring the central role of irrigation-led agricultural transformation in the arid landscape. Among the tahsils, Nokha consistently recorded the highest proportion of net sown land, exceeding 57 per cent throughout the period. The share peaked at 72.80 per cent during 1992-95 and remained marginally lower at 71.74 per cent in 2019-22 (Figure 8). However, despite its high proportional dominance, Nokha exhibited relatively limited growth in net sown area over time. In contrast, Bikaner tahsil experienced the most pronounced expansion, with net sown area increasing by 2.35 times - from 20.68 per cent in 1978-81 to 48.60 per cent in 2019-22. This substantial growth is closely linked to the expansion and stabilization of canal irrigation under the Indira Gandhi Nahar Pariyojana (IGNP). Kolayat and Lunkaransar also recorded notable increases of 1.57 and 1.45 times, respectively, while Nokha registered the lowest growth rate (1.24 times), reflecting spatial disparities in irrigation access and land development intensity.

When net sown area is considered together with current fallow and fallow land other than current fallow, the dominance of agriculture becomes even more evident. By 2019-22, nearly 90 per cent of Nokha's reporting area was under agricultural use, followed by Lunkaransar and Bikaner (61 per cent each) and Kolayat (52 per cent). In the initial phase (1978-81), Nokha was the only tahsil with more than half of its land under these categories (78 per cent), in comparison, Lunkaransar, Kolayat and Bikaner had 49%, 33%, and 31% of their land under these categories, respectively. In absolute terms, Bikaner tahsil recorded the largest net sown area in 2019-22 (452,388 hectares), followed by Lunkaransar (334,390 hectares), Kolayat (288,526 hectares), and Nokha (272,254 hectares) (Table 8). These contrasting patterns reveal that while Nokha remains highly agriculture-dependent, its limited access to canal irrigation has constrained further expansion and diversification. Conversely, the tahsils benefiting directly from the IGNP demonstrate greater dynamism in agricultural growth. This clearly highlights the transformative influence of canal irrigation in optimizing land use, enhancing agricultural productivity, and reshaping the agrarian economy of Bikaner district, while underscoring the need for improved irrigation infrastructure in canal-deficient areas such as Nokha.

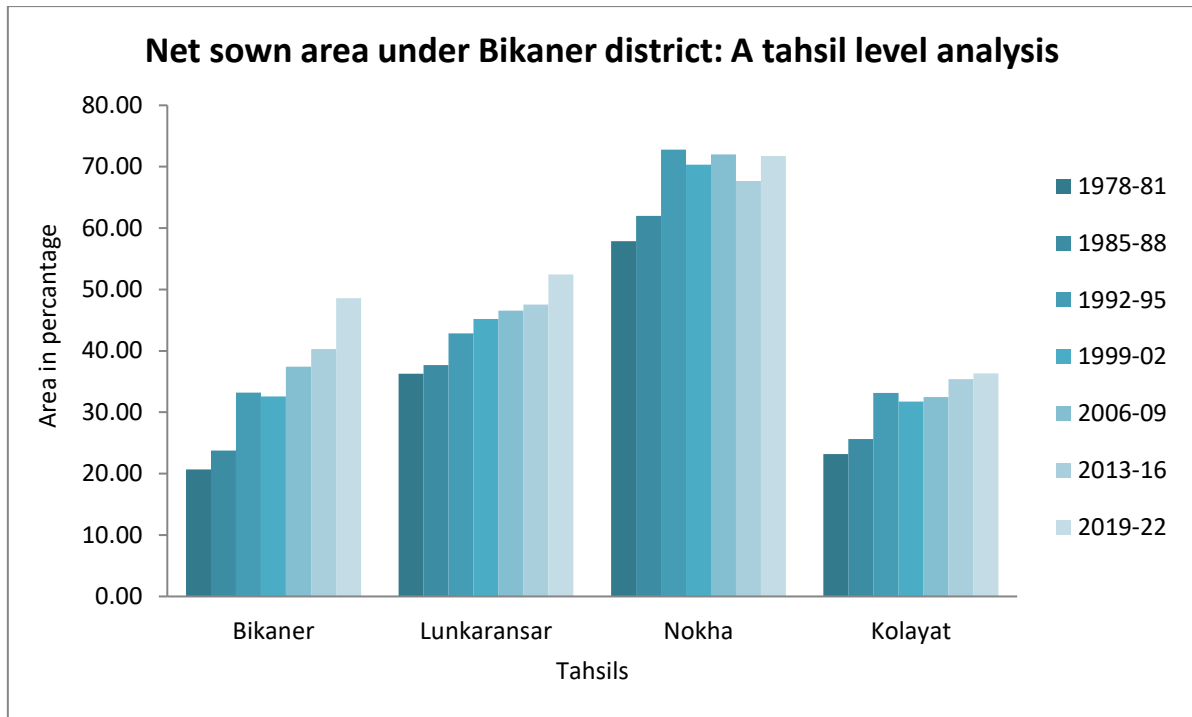


Figure no. 8: Net sown area in Bikaner district (tahsil wise analysis)

(Source: District statistical outline, Bikaner district)

Table no. 8: Net sown area in Bikaner district (tahsil wise analysis)

(Area in hectares)

Years/ Tahsil	Bikaner	Lunkaransar	Nokha	Kolayat
1978-81	192455	231281	219480	184479
1985-88	220891	240344	235121	203463
1992-95	308703	273027	276121	263290
1999-02	303214	288218	266512	252411
2006-09	348284	296723	272857	258124
2013-16	375219	303199	256822	281032
2019-22	452388	334390	272254	288526

(Source: District statistical outline, Bikaner district)

B. Time-Period Average of Land Use and Land Cover Categories: The average land use and land cover (LULC) pattern in Bikaner district exhibits marked spatial variation across tahsils, reflecting differences in physical conditions, irrigation access, and development trajectories. To capture the dominant land-use characteristics, averages were computed for seven time periods spanning 1978-81 to 2019-22. This approach enables identification of the prevailing land-use structure in each tahsil by minimizing short-term fluctuations and emphasizing long-term trends. Table 9 and Figure 9 present the tahsil-wise average distribution of LULC categories in percentage terms. The analysis reveals distinct land-use dominance across the tahsils. Bikaner tahsil recorded the highest average proportion of forest cover as well as land under miscellaneous tree crops and groves, reflecting relatively better plantation activity and afforestation efforts. Lunkaransar tahsil exhibited higher average shares of land put to non-agricultural uses and permanent pastures and grazing lands, indicating greater infrastructural development alongside the persistence of pastoral land use.

**Table no. 9: Average of land use and land categories in Bikaner district (tahsil wise analysis)
(Value in percentage)**

Tahsil/LU LC Categories	Forests	Land put to non agricultural uses	Barren & wasteland	Area under permanent pastures & grazing lands	Area under miscellaneous tree crops & groves	Culturable waste land	Current fallow	Fallow other than current fallow	Net area sown
Bikaner	5.81	4.39	0.53	1.74	0.02	39.91	5.66	8.15	33.79
Lunkaransar	1.29	16.64	0.19	2.27	0.00	23.22	5.71	6.58	44.10
Nokha	0.15	4.64	0.01	1.18	0.00	7.92	7.77	10.57	67.76
Kolayat	0.77	3.93	3.62	1.45	0.00	46.72	4.78	7.60	31.13

(Source: District statistical outline, Bikaner district)

Nokha tahsil showed a comparatively high average proportion of net sown area, along with substantial shares of current fallow and fallow land other than current fallow, underscoring its strong agricultural orientation despite limited irrigation expansion. In contrast, Kolayat tahsil accounted for the largest average share of culturable wasteland and barren and waste land throughout the period. Located in the western part of the district, Kolayat thus requires focused attention for land reclamation and sustainable land development interventions. In terms of minimum shares, Nokha consistently recorded the lowest average proportions of forest cover, barren and wasteland, permanent pastures, miscellaneous tree crops and groves, and culturable wasteland. Lunkaransar had the lowest average share of fallow land other than current fallow, while Kolayat recorded the minimum proportions of land put to non-agricultural uses, current fallow, and net sown area. Overall, the time-period average analysis highlights pronounced intra-district contrasts in land-use structure and emphasizes the need for tahsil-specific land management and planning strategies.

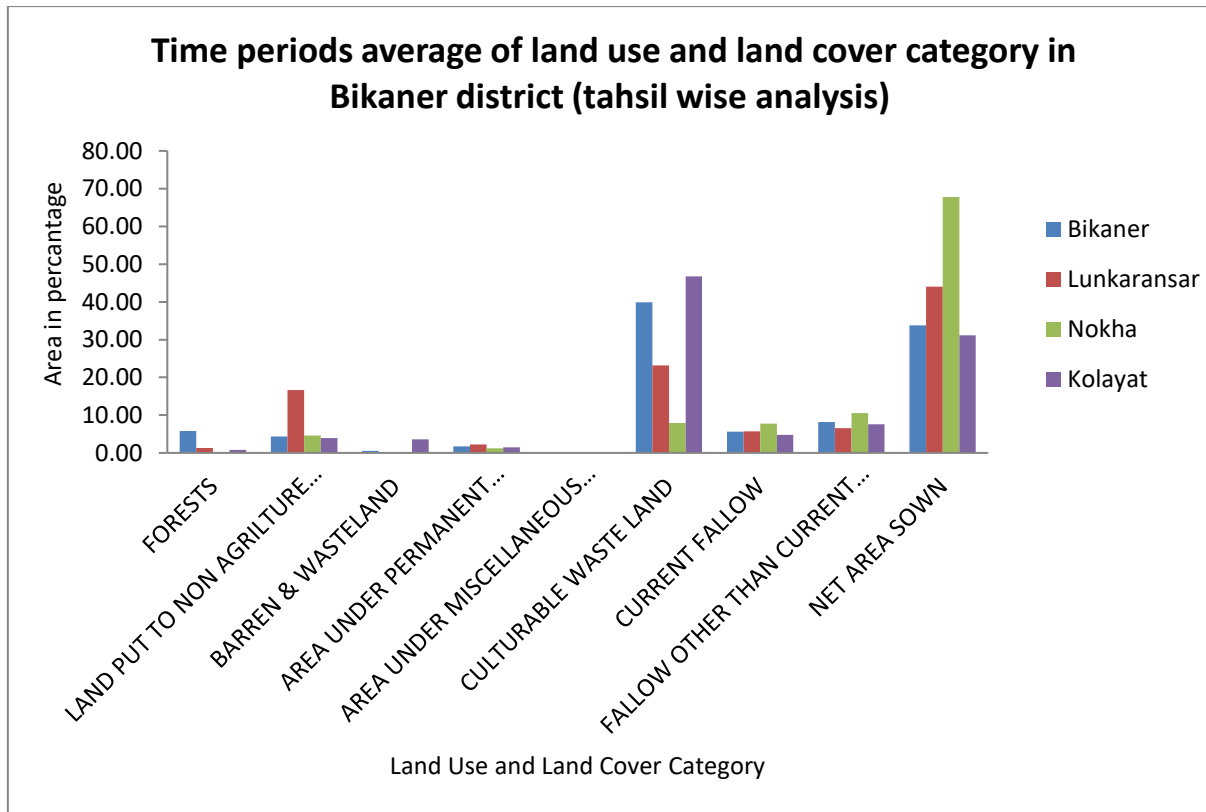


Figure no. 9: Time periods average of land use and land cover categories in Bikaner district (tahsil wise analysis)

(Source: District statistical outline, Bikaner district)

5. Conclusion:

The present study provides a comprehensive analysis of land use and land cover (LULC) changes in Bikaner district over more than four decades (1978-81 to 2019-22), with a specific focus on category-wise and tahsil-wise transformations under the influence of canal irrigation, particularly the Indira Gandhi Nahar Pariyojana (IGNP). The findings clearly demonstrate that irrigation-led development has been the most decisive factor reshaping the agrarian, ecological, and infrastructural landscape of this hot arid region, though its impacts have been spatially uneven across the four tahsils - Bikaner, Lunkaransar, Kolayat, and Nokha. Historically constrained by extreme aridity, erratic rainfall, and limited natural vegetation, Bikaner district exhibited a land-use structure dominated by culturable wasteland, barren land, and extensive fallow areas prior to canal intervention. Over time, however, the expansion of canal irrigation, along with land reclamation measures and development initiatives, has brought about substantial shifts. One of the most significant positive changes observed is the steady increase in forest cover across all tahsils, particularly in Bikaner tahsil, where afforestation programmes, dune stabilization efforts, and improved moisture availability have supported gradual ecological recovery. Although forest cover remains limited in absolute terms, its growth reflects an important ecological dimension of irrigation-led transformation in an otherwise fragile desert environment.

Land put to non-agricultural uses has increased consistently across the district, indicating rising urbanization, infrastructural development, and economic diversification. Lunkaransar tahsil stands out in this regard, recording the most pronounced expansion due to canal command infrastructure, settlement growth, and defence-related activities. This trend highlights how irrigation not only stimulates

agriculture but also catalyzes broader socio-economic and spatial transformations. In contrast, the slower yet steady increase in other tahsils suggests differentiated development trajectories shaped by locational advantages and functional roles within the district. A notable outcome of the study is the marked decline in barren and wasteland as well as culturable wasteland categories. These reductions underscore the effectiveness of irrigation expansion, land levelling, and soil improvement practices in converting previously unproductive land into cultivable or alternative uses. Nevertheless, the persistence of large tracts of culturable wasteland in Kolayat tahsil points to continued spatial disparities in irrigation access and development intensity. This emphasizes the need for targeted reclamation strategies and context-specific interventions in the western parts of the district.

The analysis also reveals important trade-offs associated with irrigation-led agricultural expansion. Permanent pastures and grazing lands, which are vital for sustaining pastoral livelihoods in arid environments, have generally declined across the tahsils. While some temporal recovery is visible in Lunkaransar and Bikaner, the overall reduction reflects increasing pressure on common grazing resources as land is diverted towards agriculture and other uses. This trend raises concerns regarding the long-term sustainability of pastoral systems and calls for balanced land-use planning that accommodates both agriculture and livestock-based livelihoods. Miscellaneous tree crops and groves have remained negligible throughout the study period, indicating limited adoption of tree-based land-use systems in the district. Their marginal presence suggests that economic considerations, water availability, and climatic constraints continue to favour field crops and other land uses over agro-forestry or orchard-based systems, except in very limited pockets.

Agricultural expansion, as reflected by the growth in net sown area, constitutes the most transformative change in Bikaner district. All tahsils recorded an increase in net sown area, with Bikaner tahsil experiencing the most dramatic growth due to direct access to canal irrigation. Nokha tahsil, despite maintaining the highest proportional share of net sown area, showed relatively stagnant growth, highlighting the limitations imposed by inadequate canal coverage. The combined analysis of net sown and fallow lands further underscores agriculture's dominance in Nokha, while also revealing unrealized potential in other tahsils where fallow land could be brought under cultivation with improved water availability. The time-period average analysis reinforces these findings by revealing distinct and persistent land-use patterns across tahsils. Bikaner emerges as relatively better balanced in terms of agricultural, ecological, and plantation-related land uses; Lunkaransar reflects infrastructural growth alongside pastoral land use; Nokha remains strongly agriculture-oriented but irrigation-deficient; and Kolayat continues to be characterized by extensive wastelands requiring focused developmental attention.

Overall, the study conclusively demonstrates that canal irrigation has been a powerful driver of land-use change in Bikaner district, enhancing agricultural productivity, reducing wastelands, and reshaping local economies. At the same time, it brings to light the uneven spatial outcomes of this transformation and the emerging challenges related to ecological sustainability and pastoral livelihoods. The findings underscore the necessity of tahsil-specific land management strategies, expansion of irrigation infrastructure in deficit areas such as Nokha and Kolayat, and integrated planning approaches that balance agricultural growth with environmental conservation and social equity.

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